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THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

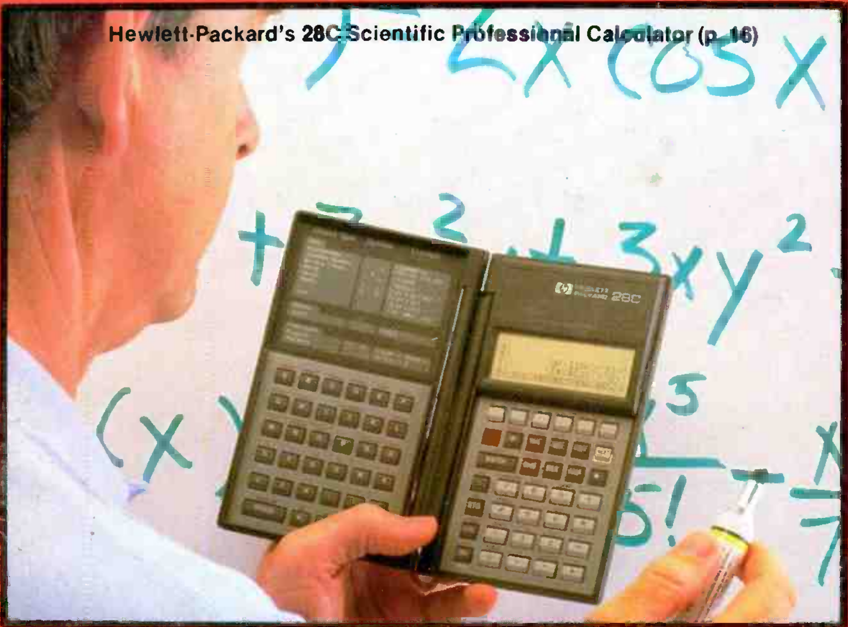
- H-P's Newest Scientific Calculator: "A Pocket Powerhouse with Symbolic Math"
- Quick LED Display Circuit Design

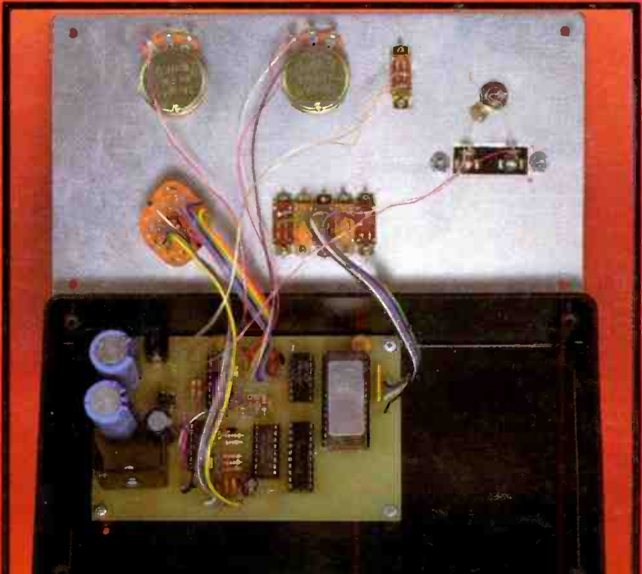
Proportional Temperature Controller (p. 52)

Full Construction Plans:

- Programmable Audio Generator Produces 32 Different Waveforms
- Proportional Controller Maintains Precise Temperatures
- Human-Sounding Speech From ASCII-Type Synthesizer

Hewlett-Packard's 28C Scientific Professional Calculator (p. 16)





Programmable Waveform Generator (p. 42)

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BSR's Endangered Colossus

Prepare for bone jarring bass and dramatically clear highs from these newly developed 15" 3-way 5 speaker systems that nearly missed their chance to charm an audiophile's ear. BSR moved its dbx and ADC divisions into one facility and these speakers almost became orphans. So now, they're yours at a close-out price.

By Drew Kaplan

It's a shame. But, it's also a great opportunity to get a pair of 15" audiophile loudspeakers with the newest in stereo imaging at a market-breaking price.

Imagine a precisely matched mirror image pair of top-of-the-line BSR speakers that can effortlessly recreate the cataclysmic impact of a full orchestral crescendo at full volume and yet offer flawlessly subtle sound detail to 21,500hz.

You'll thrill to thunderous bass all the way down to 26hz. Incredibly rich, full, vibrant sound at low volume will explode with life as you increase the volume.

But before we examine the front speaker complement, the twin overlapping crossovers and **the top mounted sonic placement and ambiance speakers**, let's see why they were almost orphaned.

You see, BSR, the half billion dollar electronics giant, is the parent company of two of the best names in up-scale audio, dbx and ADC.

Last year dbx developed a new multi-thousand dollar speaker system called the Soundfield One which lets you sit virtually anywhere in your room and have full stereo imaging and terrific sound.

BSR decided to consolidate ADC and dbx into one building (still 2 companies) and put all its speaker efforts into dbx.

POOR JACK

Well, while dbx's engineers were off designing their multi-thousand dollar masterpieces, BSR's Senior Acoustical Engineer (he had been Fisher's Chief Engineer for 10 years during its top end component stereo days), was designing BSR's radically new speaker line.

The revolutionary top of the line 15" stereo imaging pair pictured above will let you enjoy superb stereo imaging without sitting directly in front of your speakers.

But unfortunately, in the consolidation move, BSR's speakers went by the wayside, and so did Jack.

Enter DAK. After a few fearful negotiations and considering the engineering costs BSR had already expended, they agreed to make the speakers just for DAK.

Because there's virtually no BSR overhead left on these speakers, and the R&D was all but complete, we've gotten these speakers for virtually the component costs plus a little BSR labor.

And don't worry about Jack. BSR had him finish the engineering (they really are great people) and they'll pay him a royalty on each speaker we sell. Besides, by the time you read this, Jack is sure to be snapped up as the Chief Engineer at another esoteric audio company.

WHAT'S STEREO IMAGING?

Stereo imagery is the logical separation and interaction between channels. It's the successful creation of a panoramic wall or stage of music rather than the confined, easily located 2 speaker sound.

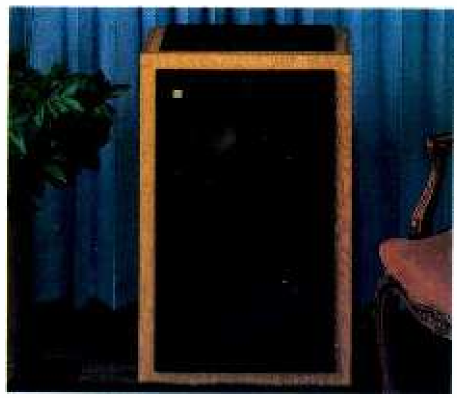
IT'S WHAT'S INSIDE THAT COUNTS

Imagine the full thunder of a kettle drum, or the pluck of a string bass being explosively recreated in your living room. BSR's 15" sub-bass acoustic suspension driver will revolutionize your concept of low clean bass.

Its magnetic structure weighs a thundering 48 ounces. But that's not all. The magnetic field is developed by the rare earth metal Strontium for state of the art massive but flawlessly controlled bass.

A 38mm voice coil with a 200° centigrade temperature capacity, will handle the most demanding digital or analog recordings. And, a new super rigid cabinet design virtually eliminates coloration due to uncontrolled cabinet resonance.

At low volume, the bass will fill in and envelop you. At high volume, your room, your walls and your neighbors will shake. (Not for apartment dwellers please.)



MATCHED PAIRS

The mid-range and high end of BSR's speakers are truly unique. Front mounted 8" polypropylene mid-range drivers provide rich sound while top mounted 5" polypropylene mid-range drivers provide an open, lifelike ambiance.

Front mounted exponential horn tweeters provide awesome brilliance to 21,500 hz, while top mounted tweeters enhance separation because they are mounted to the outside edge of each speaker.

So, this system has a specific left and a specific right speaker. You'll find wide, but interactive separation that will vastly widen your ideal listening area.

The imagery will give the illusion of musicians actually playing in front of you. Your music will take on a three dimensional quality. You'll enjoy superb stereo imagery regardless of each speaker's specific placement in your room.

MORE SPECIFICS

The exponential horn tweeters, both in front and on the top of these systems, employ 25mm rigid phenol diaphragms for stability and accurate response.

Polyamid-imid binders and ferro-fluid coolant allow for a 300% increase in heat dissipation so you can drive the voice coils up to 200° centigrade.

Now, the mid-range. Both the 8" front firing and the 5" top firing polypropylene drivers reproduce the mid-range frequencies like no ordinary speakers.

It's amazing that so many speaker manufacturers simply slap in 5" paper mid-ranges to reproduce what's really the major portion of the sound spectrum.

BSR's 8" and 5" polypropylene mid-ranges are rigid, exacting drivers that deliver incredibly pure uncolored sound. They have matched 25mm voice coils, also protected by ferro-fluid and polyamid-imid to 200° centigrade. They are driven by powerful barium ferrite magnetic fields.

NOT QUITE FINISHED YET

To prevent phase shift and cancellation, two totally separate crossover networks are employed in these speakers.

All frequencies below 800 hz are directed to the 15" woofer. The front system routes frequencies above 800hz to the 8" mid-range to take full advantage of its superb reproduction capabilities. Frequencies above 3400hz are routed to the horn tweeter.

The top mounted system routes only frequencies above 1200hz to the 5" polypropylene ambiance mid-range driver, and frequencies above 3400hz are routed to the top sonic placement tweeter.

There are level controls for both the top and front mounted speakers so that you can voice the speakers to match your musical taste and environment.

Note: Only the top tweeters are mounted at the the edges. The front mounted tweeters are conventionally mounted for acoustical symmetry.

Each speaker is fuse protected for up to 200 watts peak, 150 watts continuous power. You can operate these super efficient speakers with as little as 20 watts.

AND OH WHAT A PRETTY FACE

The speaker systems are 30" tall, 19¼" wide and 10½" deep. Their lovely oak wood-grain appearance is enhanced by the dark removable grill cloths that beautifully contrast with the rich wood-grain tones. They're a statement of audio elegance when placed in any room. They're backed by BSR's 2 year limited warranty.

A COLOSSAL DREAM COMES TRUE RISK FREE

You'll hear depth of sound at low levels that was previously unobtainable. And yes, when you crank up the volume, your music will explode with realism and drama.

Try these speakers in your own system. Then compare them at any Hi-Fi Store with any pair of speakers up to $1000. If they don't beat all the competition hands down, simply return them to DAK in their original boxes within 30 days for a courteous refund.

To order your matched pair of BSR top-of-the-line 15" 3-way 5 speaker systems with unique stereo imaging risk free with your credit card, call toll free or send your check for DAK's market-breaking price of just **$299** for the **MATCHED PAIR** plus **$34** for Postage and Handling. Order No. 4868. CA res add tax.

It's a dream system for an audiophile. Sonically pure, thunderously powerful, these BSR speakers will make your future listening years an on-going fabulous, if not earthshaking experience.

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MODERN ELECTRONICS

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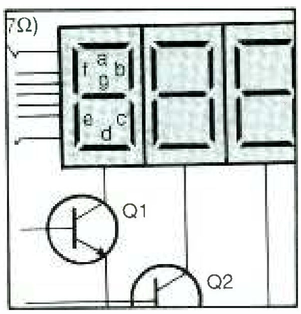

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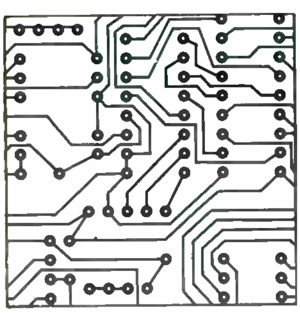

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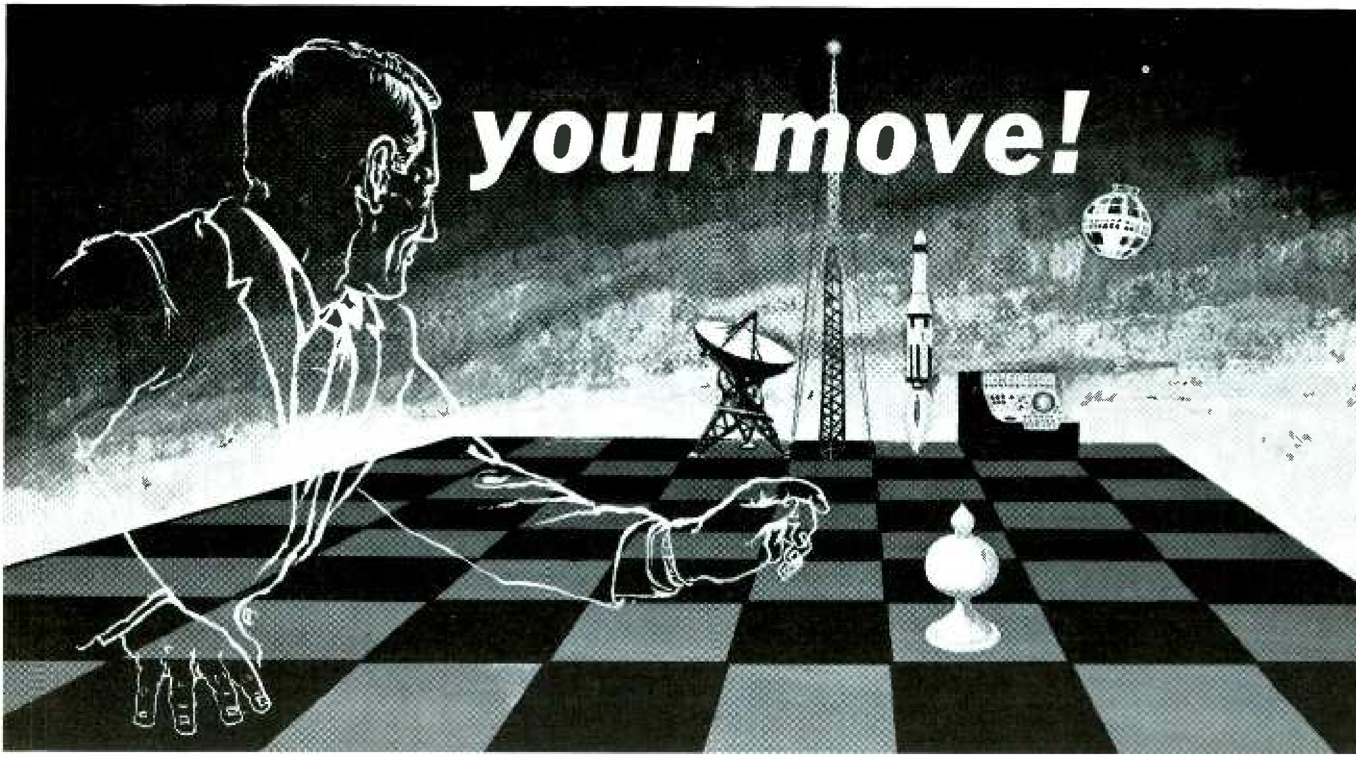

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EDITORIAL

The High End

I got into a discussion last week with two "High-End Audio" aficionados. They're likely in their late Fifties, so I was surprised by their enthusiasm. My silent reasoning was that high-frequency hearing ability diminishes with age, and so I thought was the extraordinary dedication to absolute audio reproduction perfection. Apparently I was wrong.

Neither gentleman owns a compact-disc player, considered to be the acme of disc-playing equipment and accompanying program material today. It took many years before they embraced stereophonic sound, too, they admitted, so they evidently sail a steady course.

Audio component brands that cropped up—basic turntables such as Oracle's Mark II ($2,350) and MRM Audio ($1,995); tonearm's such as Dennesen's Albt-1 ($1,450) and Mitch Cotter's ($1,750); phono cartridges such as Kiseki's Lapis Lazuli ($3,500) and Miyaba's Ivory ($1,695); and Mark Levinson's $6,400 basic power amplifier, among models out of the mainstream of audio components—will give you some idea of what "high end" means. Spurred on by their viewpoints (compact-discs don't give you a sense of realism as compared to analog LPs and super turntable/tonearm/cartridge combinations; few solid-state amplifiers can match the top vacuum-tube models that are being sold in increasing numbers in the high-end world), I decided to spend some serious time with stereo equipment in my home. That is, not just leaning back and enjoying the music, but listening carefully for deficiencies on compact-discs, LPs, varying program material, test records for both LPs and compact disks, solid-state equipment, vacuum-tube equipment, *et al.*

The results, which have to be personalized, of course, were revealing. Unfortunately, I don't have any records that are duplicated on compact disc. Therefore, I could not make any precise comparison judgments between the same programs. Nevertheless, I have some 25 compact discs (as compared to about 200 LPs), so there were enough of a CD sampling to give a a sense of fairness. Half of the digital CDs originated with analog recordings, while about 5 percent or so of the analog LPs were digitally mastered. The same 100 watts/channel amplifier and sealed-enclosure four-loudspeaker (including a passive woofer) floor-standing systems were used for all source equipment.

After many hours, my conclusion was that the notions of this high-end duo were not at all flaky. Compact discs/players were not superior in all aspects; they just seem to be so at first blush. As an example, not one of the compact discs came anywhere near matching LPs in reproducing high-frequency overtones, such as those from drum cymbals or strings. Consequently, a cymbal's shimmering sound is stifled; the lush sounds of violins aren't present. They simply don't sound as realistic as those produced from good LP records! Furthermore, whereas some LPs issued the feeling of depth, none of the compact discs did. They were purely two-dimensional.

Compact discs, on the other hand, were pristine-sounding source materials in two senses. Firstly, pops and ticks or even scratches are not present to distract you, whereas these problems are rampant with LPs (our high-end people counter these problems with Nitty Gritty motorized record cleaners whose price starts at about $240, pop and tick electronic eliminators, etc.). Secondly, intermodulation distortion levels are apparently so low that they don't even count as a measurement specification. Each instrument can be heard with the utmost clarity, easily beating out LPs here. (They're even more distinctly heard on CDs than under live-concert conditions, though, so realism due to this factor is questionable.) Furthermore, a CD's dynamic range is clearly greater than an LP's. And clean bass reproduction is superior (at least on my equipment, which is not at the level of high-end equipment, but rather at the point of diminishing returns where you'd have to spend small fortunes for each minute improvement).

If you're into hard-rock recordings, CD is certainly the way to go owing to its wide dynamic range. For any other program material, though, LPs can hold

(Continued on page 92)

LETTERS

Parts Procurement

• I have been reading your magazine since I was switched by the demise of *Computers & Electronics* and have seen other letters discussing the problems I am having. I'm referring to the March 1987 article of "An Audio/Video Distribution Amplifier." I have called local dealers and all the 800 numbers that I could find, but to no avail. I have not found any dealers that stock the transistors or the op amps mentioned.

This has happened to me before and it would be nice if more articles were edited for inclusion of parts availability and/or parts suppliers. I realize that this article did have some parts supply information, but the ones mentioned were not included.

Bruce Gustafson
Arlington, VA

This is indeed a long-standing problem. The solution, after checking out local electronic-parts dealers, is to contact mail-order suppliers. You've tried both sources, you say, to no avail. I suggest trying harder, as follows: In the same issue as the article, advertisers like Digi-Key listed the 5532 op amp for $2.65 and Micromart listed both voltage regulators for $1.85 as part of a seven-device package. You should arm yourself with parts catalogs offered free by suppliers. Mouser's catalog has the RCA CA3100 op amp listed for $2.65, the 2N3053 for 46¢ and the 2N4037 for 71¢. Your local Radio Shack store has the voltage regulators in its catalog for $1.19 each, and so on. Sure, it's not as easy as one would hope to gather up parts, but it's not usually terribly difficult either. Furthermore, the catalogs revealed a host of other interesting products. Try 'em (for free). You'll like them.—Ed.

Battery Memory

• Brent Gloege's article, "Battery Basics" (June 1987) provides an excellent review of battery characteristics. I have not seen anything as good elsewhere.

He leaves me a little confused, however, when he says (page 24), "Lead batteries are more complex," and goes on to describe a relationship between depth of discharge and number of recharge cycles possible. Then in the next column, says, "Lead cells have no memory and do not care . . . ." It sounds as though he is talking about two different kinds of lead-based storage devices. But, if so, what kinds?

Charles H. Chandler, P.E.
Malden, MA

It was an oblique reference to a Ni-Cd's "memory," not different types of lead cells.—Ed.

The Metric World

• Your June 1987 "Electronics Notebook" included metric units for length in Fig. 1. The symbol for micrometre is μm, not the μ used in the article. The μ (Greek mu) is a prefix meaning 0.000001, not a unit of length.

Also, "micron" was used several times for this length, which is incorrect jargon. I'm glad to see you use metric units in your article, however, such as Celsius temperatures. Please continue to do so whenever possible.

Larry Stempnik
U.S. Metric Association, Inc.
Warren, MI

MODERN ELECTRONICS NEWS

LISTENING TO BOOKS. The big sales movers--compact discs, video cassette recorders, et al--get the most publicity, of course. But there are lower-selling products attracting many people that are interesting. One here consists of growing libraries of books on audio cassettes. Noted actors and even the original authors often "read" the books, which many listeners can appreciate with portable cassette tape players and light-weight headphones while traveling to and fro on public transportation. Saves getting bleary eyes, too. Listen For Pleasure (Niagara Falls, NY), as an example, has a huge library that includes best-seller "A Perfect Spy," written by John le Carre and also read by the author. Many book-stores carry such books on cassettes.

PARALLEL PROCESSING PREDICTIONS. Parallel processing architecture in computers will be used in 48% of high-performance machines in a few years, forecasts Gene Selven, publisher, Electronic Trends Publications, Saratoga, CA. He says that a new category of computers, such as mini-supercomputers will emerge to represent more than a $1B market by 1990.

VIDEO SPECIAL EFFECTS. With camcorder sales booming, video recordists will be looking to enhance their recordings. To meet this need, Ambico (Norwood, NJ) has introduced a line of camera lens attachments, including kits for special effects, such as color filters; a "Fogalizer" that produces a clear center and softly diffused background; starbursts, multi-images, rainbows, etc. Additionally, the company introduced telephoto and wide-angle lens adapters. Just like the good old 35mm-camera days.

GE BUSINESS SHIFTS. General Electric Co. has been making business news ever since it merged with RCA. Now it gave up control of its worldwide consumer electronics business, with this part of the company--that is, GE/RCA consumer electronics--going to a giant French company, Thomson. This leaves Zenith as the largest consumer electronics manufacturer in the U.S....In another shift, in name, at least, GE/RCA Solid State became just plain GE Solid State. The division will continue to sell GE, RCA and Intersil semiconductor brands, retaining these trade names (for now).

PRIVATIZING CUSTOM CALL SIGNS. In response to the FCC's proposal to issue custom call signs in the Amateur Radio Service, Forest Industries Telecommunications (FIT) filed comments asking to be named the "Special Call Sign Coordinator" for the Amateur (Ham) Radio Service. The Commission invited applications for the SCSC job because it doesn't have the resources to handle the large demands for special call signs, such as a name, initials, code-sending rhythm, re-issuance of an expired or deleted call sign, etc. FIT would charge $25 for this service with an added $5 for a wall certificate. Renewal would be $10. Three requested call signs would be accepted, with FIT assigning one of them. If none are available, a $10 credit would be issued.

SATELLITE DESCRAMBLING AUTHORIZATIONS DOUBLE. For the first half of 1987, consumer authorizations for descrambling encrypted satellite TV programming rose 100% to the 200,000 mark, announced General Instrument's VideoCipher Division. More than 20 STV program operations now use VideoCipher technology.

DO YOU REALLY GET THE BEST BUY FROM THEM?

Let's face it: There will always be some outfit that can undercut a published price. They do it by having no overhead, and no responsibility to you, the consumer.

"So, you want that Jerrold 450 combo? The one that **Pacific Cable Co., Inc.**, is offering for $199.00? Well, that's a good price, but here's what I'll do..." What may happen is that you may save a couple of bucks at the time. But suppose there's a problem (and it happens to the best of them,) and you call that "Dealer"... This could be what you'll hear:

"No, Steve isn't here. He moved out, the bum! And he owes me $437.00 on the phone bill! No, I don't know about any guarantees on your Gerald, who's that? Listen, if you see that creep..." etc.

At **Pacific Cable Co.**, you've got an established company who will be here for you, time after time. We may be tough competitors, but we've got a soft spot for our clients! Try us, and be treated right—and we'll prove it by giving a one-year warranty on everything we sell.

Check our prices on Scientific Atlanta Units!

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Panasonic Wireless Converter (our best buy)	88.00	69.00	*Minicode (N-12) with Vari Sync	99.00	62.00
400 or 450 Converter (manual fine tune)	88.00	69.00	*Minicode VariSync with Auto On-Off	145.00	105.00
*Jerrold 400 Combo	169.00	119.00	Econocode (minicode substitute)	79.00	52.00
Jerrold 400 Hand Remote Control	29.00	18.00	Econocode with VariSync	89.00	56.00
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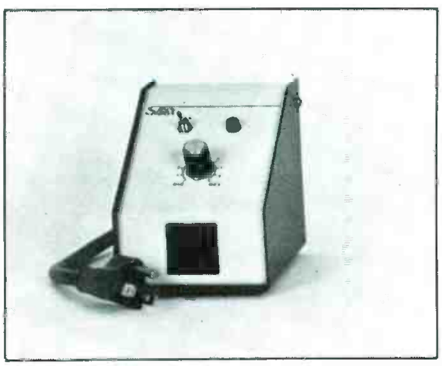
For more information on products described, please circle the appropriate number on the Free Information Card bound into this issue or write to the manufacturer.

Soldering Iron Temperature Controller

New from Sibex (Clearwater, FL) is the Model S-4 control unit that is designed to convert any soldering iron rated at up to 100 watts into an adjustable-temperature soldering station. The controller works with any 117-volt ac soldering iron or pencil. It features solid-state circuitry to produce spike-free adjustable dc



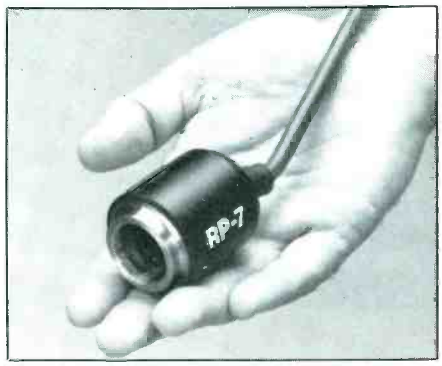
voltage to power the iron or pencil and minimize the possibility of damaging critical components. $48.94 (not including soldering iron or pencil).

CIRCLE 73 ON FREE INFORMATION CARD

Subminiature Color TV Camera

A subminiature solid-state color TV camera whose head is small enough to fit in the palm of a hand and weighs less than 4 ozs. has been announced by M.P. Video, Inc. (Hopkinton, MA). Designed for use in rugged environments for inspection, robotics, process control, medical and industrial microscopy, the Model RP-7 camera has advanced imaging technology for excellent picture quality under virtually any lighting condition without burn-in or blooming. An RGB analog output permits direct computer interface without the need for an NTSC decoder.

Features include: ⅔-inch CCD image sensor with 510 × 492 picture elements and 330 lines of resolution; automatic white balance switch; on/off automatic gain switch; color-bar signal generator; automatic iris; manual color balance control; and RGB, NTSC and PAL formats. The

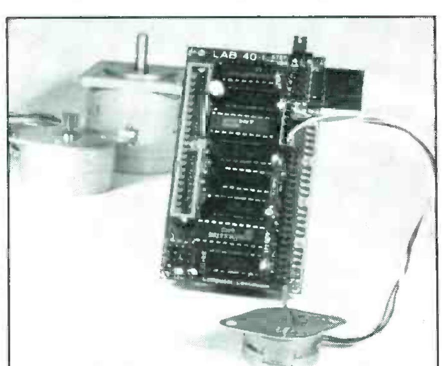


camera is designed to operate up to 30 feet from the main electronics (a choice of cable lengths are available). The camera head measures 1.67 inches in diameter and 1.71 inches long and accepts a standard C-mount lens.

CIRCLE 74 ON FREE INFORMATION CARD

PC Stepper-Motor Driver

Up to four stepper motors can be driven by a personal computer equipped with Computer Continuum's (Daly City, CA) Local Applications Bus (LAB-40) bus board and new stepper motor board. Each motor can be rated at 1.5 amperes and 15 volts per phase. The new Stepper Driver Module is programmable to drive motors in full-step, half-step, four-phase or two-phase power se-



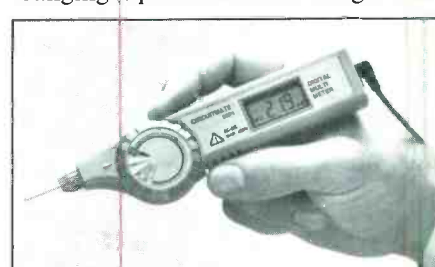
quences and supports brake and free-wheel operations individually for each motor. The Module receives step and direction commands from the host computer, and an input port for limit switches is provided.

Software included with the board empowers the user to generate complicated combinations of motor moves in response to external stimuli. $95 for Stepper Driver Module ($150 for LAB 40 host adapter for IBM PC or Apple II).

CIRCLE 75 ON FREE INFORMATION CARD

Pocket Digital Multimeter

Beckman Industrial's new Model DM71 Circuitmate digital multimeter is a handheld pen-type instrument with a 3½-digit display and a 0.7-percent accuracy (dc, 2 mV range) auto-ranging system. It has a rotary dial that is claimed to be simpler to use than button-operated pen-type DMMs. A data-hold function enables manual "freezing" of the display, and continuity and diode-test functions are included. Full auto-ranging is provided on 15 ranges that



measure up to 450 volts dc and ac and to 20 megohms of resistance, using a dual-slope integrating analog-to-digital conversion technique.

Features include: an audible continuity tester, buzzer that sounds when changing functions, built-in scabbard for the ground probe and display of the function in use. The instrument is supplied with battery (for up to 90 hours of useful life), test leads, operators manual and rigid shirt-pocket carrying case. A padded vinyl carrying case is available as an option. $49.95.

CIRCLE 41 ON FREE INFORMATION CARD

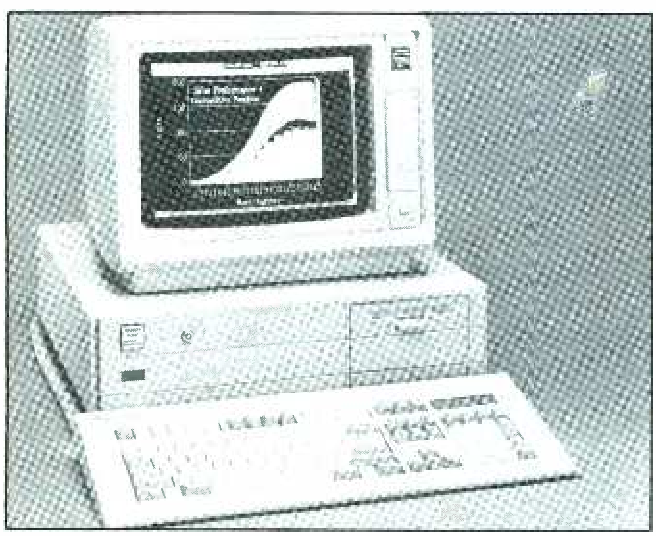
New Tandy Computers

Celebrating its tenth year in the personal computer business, Radio Shack unveiled four new and two upgraded PC-compatible Tandy computers, while retaining earlier models in its line. Its new top-of-line model, the Tandy 4000, employs the powerful 80386 microprocessor, a 32-bit data-path CPU that operates at a 16-MHz clock speed that is said to achieve a speed index exceeding 17 using Norton Utilities' test, as compared to an IBM PC XT's index of 1.0. The basic machine is pegged at $2,599, and comes with 1 megabyte RAM and a 3½" floppy disk drive that stores 1.4 Mb, serial and parallel ports, a real-time clock, and a 101-key enhanced keyboard. The 4000 is designed to run with MS-DOS 3.3, OS/2 and Unix 5.3 operating systems, and is reported to support VGA, EGA, and CGA color graphics as well as monochrome. Expansion facilities include two additional drive slots for hard disk, floppy disk or disk cartridge use, six AT expansion slots, two XT-style slots (one of which is used in the basic machine), and a 32-bit dedicated memory slot for future expansion. Memory expansion capabilities extend to 16 megabytes, and an 80287 math coprocessor socket is provided to speed up numeric-intensive applications.

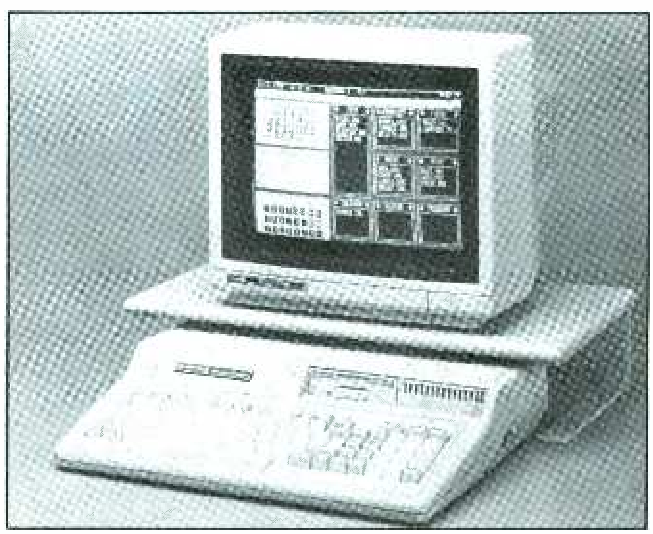
Two new Tandy 1000 personal computer models augment existing 1000 models. The $699 Tandy HX, designed for home, classroom and first-time PC users, features "instant-on" operation with the assistance of an electrically erasable programmable read only memory (EEPROM) device that stores the system configuration and user-specified start-up mode with more than 20 configuration selections. With it, users can bypass operating system prompts on start-up and go directly to an application of their choice. The MS-DOS 2.11 operating system is stored in ROM for the first time in a desktop computer, loading it automatically without ever touching an MS-DOS diskette. The model comes with a 3½" 720K floppy drive and 256K RAM that's expandable to 640K. Using an Intel 8088-2 microprocessor, clock speed of 7.16 or 4.77 MHz is software selectable. It's CGA compatible and optional RGBI or composite video monitors can be plugged in. It comes with Radio Shack's new Personal DeskMate 2 software, which is an integrated, graphics-oriented productivity package, the core of which is stored in a ROM to create faster operation. Serial and parallel ports are standard.

Another new 1000 model, the Tandy 1000 TX, at $1,199, features an 80286 microprocessor, with 8/4-MHz clock speeds. It, too, has a built-in 3½" 720K floppy drive, with provisions for adding another drive, 3½" or 5¼", internally. Throughput is claimed to be six times faster than a standard PC XT. The 1000TX comes equipped with 640K RAM that's expandable to 768K for video memory purposes. External connections include serial and parallel ports, dual joysticks, composite video, RGBI color monitor, a headphone jack with volume control, and line level audio output. There are five internal expansion slots with a 10" non-standard-PC length and an 80287 math coprocessor socket. MS-DOS 3.2 and GW-BASIC software are included.

The final new Radio Shack computer model is a dual-disk (3½", 720K) MS-DOS laptop computer, the Tandy 1400 LT, priced at $1,599.



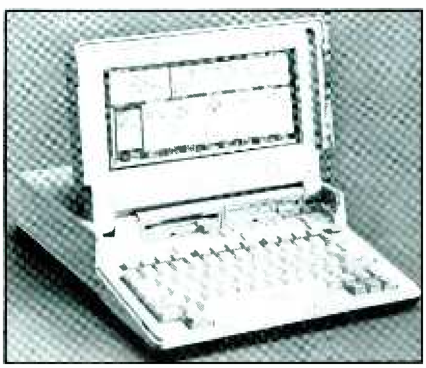
The Tandy 4000 computer, with a 16-MHz 80386 processor, is Radio Shack's new top-of-line model.



Radio Shack's Tandy 1000 HX PC-compatible has MS-DOS operating system incorporated into a ROM.

New Tandy Computers Continued . . .

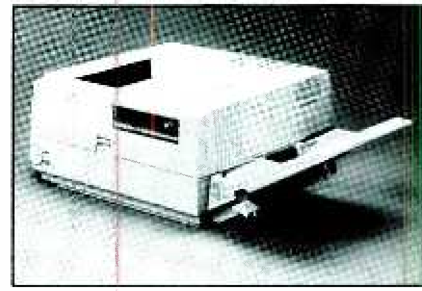
It uses an NEC V-20 microprocessor, which is an 8088 equivalent, and has a switchable clock speed of 7.16/4.77 MHz. The model employs a backlit, 80-character by 25-line adjustable display with LCD "super-twist" technology. Resolution is said to be 640 × 200 plus eight shades of gray. The 1400 LT comes with 640K MS-DOS addressable RAM and an additional 128K that can be used as a RAM disk or print spooler. External connections include serial and parallel ports, RGBI color monitor and composite video output, external disk drive, and an enhanced keyboard that has 101 keys instead of the laptop's 76-key one. Other features are a battery-powered clock/calendar and a speaker. The laptop comes with MS-DOS 3.2 operating system and GW-BASIC. An internal 1200-baud Hayes-compatible modem is optional ($199.95), as are an 8087 math coprocessor ($250) and soft carrying case ($39.95). The unit is powered by a removable, rechargeable 12-volt battery pack or ac adapter. Battery life is rated at about four hours of continuous use.



The new Tandy 1400 LT PC-compatible laptop has built-in 3.5" 720K floppy disk drives and 768K RAM.

Tandy 3000 models were enhanced, including a speed increase to 12 MHz, bundling of a new Professional DeskMate integrated software product, and a 101-key enhanced keyboard and keylock system for its lowest priced ($1,499) 80286-based 3000 HL.

Leading a number of other new product introductions is the Tandy LP 1000 laser printer. The $2,199 unit features full-page 1.5 Mb memory and on-board controller, producing six pages per minute in Tandy, IBM and HP LaserJet Plus-compatible modes, with 300 × 300 dot-per-inch resolution on an 8½" × 11" page. It comes with four type fonts built in that can be selected from the front panel or software. Optional fonts can be downloaded, with up to 16 different ones used on a single page, though resolution will be less than 300 dpi in this case. A paper tray holds 150 sheets of 20# bond maximum weight. Letter, legal, and half-letter sizes are accommodated. The LP 1000 is equipped with a standard parallel printer interface (cable is optional) and a video interface for connection to an external page description device or an alternate controller.



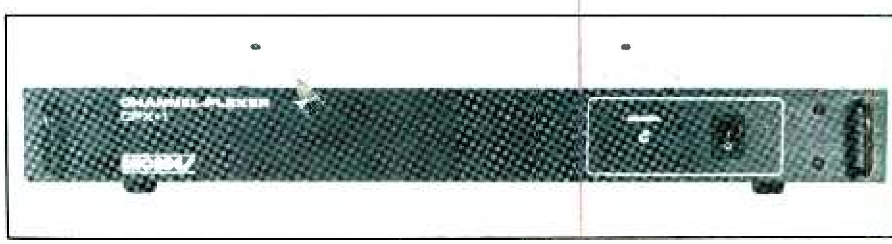
The Tandy 1000 laser printer complements Radio Shack's new, more powerful computers to make a complete desktop publishing system.

CIRCLE 77 ON FREE INFORMATION CARD

Video Distribution System

Rhoades' new Model CPX-1 "Channel-Plexer" allows every TV receiver and videocassette recorder in your home to tune to a different channel or video source simultaneously, without requiring central location switching. Channel-Plexer changes the channel 3 or 4 outputs from such sources as a cable TV converter, satellite TV tuner, VCR or video-disc player to unused uhf channel frequencies and adds them to existing broadcast TV and cable channels for distribution via a single cable run to all TV receivers and VCRs in your house.

Because Channel-Plexer is not a traditional video switcher, it completely eliminates the need for r-f switching. The central distribution amplifier feeds all sources simultaneously to all TV receivers and VCRs connected to the line. Hence, all you have to do to change channels at any TV receiver or VCR is to operate the unit's tuner. You can even program your VCR to change channels and sources to record broadcast, pay cable, and satellite channels unattended.

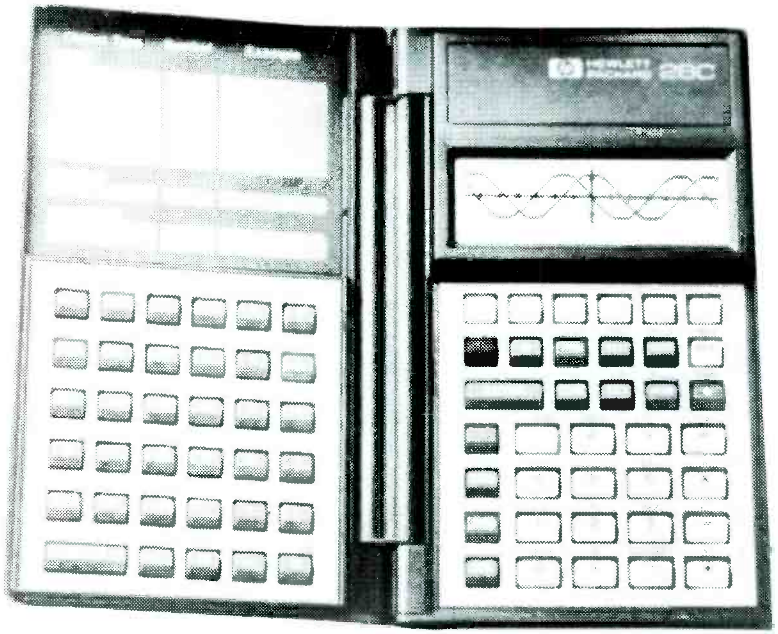


Since the CPX-1 converts all input channels to different frequencies that are then amplified, interference and attenuation problems associated with traditional video switchers are eliminated. Because all signals appear on the cable that feeds the individual TV receivers and VCRs, only the one output cable is required, which greatly simplifies installation of the system. $229.95.

CIRCLE 78 ON FREE INFORMATION CARD

(Continued on page 86)

The UnExpected HP-28C PLUS...



A

A.

The HP–28C lists for $235. It will be the world's standard for years to come. You're sure to get one sooner or later. Why not now? I have them in stock, and I'll give you a discount savings of $55 now.

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B.

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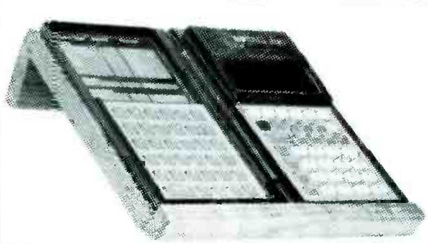
B



D

C.

HP STEP–BY–STEP BOOKLETS for the HP–28C

Let experts help you set up your calculations so you can work with them most easily. These professional references include practical routines and tips for getting the most from the Built–in Menus as well as setting up Personal Menus for your specific profession. Order the ones that fit your work:

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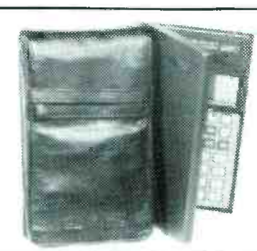
Stock #18–811 [Bocote Desk Wedge]..................$29.95

C

E



F

F.

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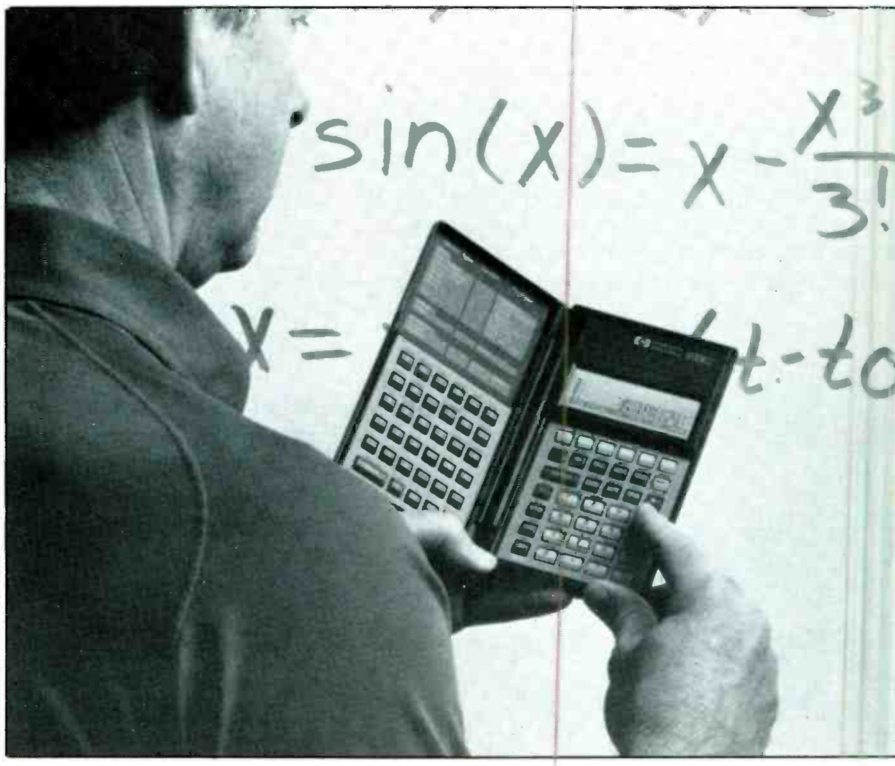
A Pocket Powerhouse

The author examines Hewlett-Packard's latest scientific professional calculator, the 28C, which introduces symbolic mathematics and an enhanced operating system that allows mixing direct entry of algebraic expressions with RPN logic

By David A. Nordquest



The first personal number-cruncher was Hewlett-Packard's HP-35 scientific calculator that sold for $395 15 years ago. Although analysts doubted that sales would be great, nearly a third of a million were snapped up by scientists, businessmen, teachers, and students within three years. Their enthusiasm for the HP-35—and for the limited freedom from data processing centers it provided—might have alerted H-P to the potential of the personal computer one of their employees, Steve Wozniak (Apple Computer founder), began to promote. The 35's success did lead the company to follow up with a succession of more powerful handheld calculators. The latest of these devices is the HP-28C, an extraordinary scientific programmable calculator that introduces working with symbols as well as numbers. Its suggested retail price is only $235 with batteries, or about 40 percent less than the original HP-35 in 1972 that added trig, log and exponential functions and RPN logic to popular "four-bangers."

Features of the 28C nicely illustrate the direction in which scientific calculators are evolving. Particularly important are its 32 × 137-pixel graphics display, its capacity to do symbolic math (as well as complex and computer math), its extensive use of menus, and its flexibility in handling a wide variety of objects, from data to programs. The 28C's power is made possible by 128K of ROM, the same amount used in more advanced models of IBM's new PS/2 PC line. Built-in RAM is 2K bytes, with 1.7K available for working memory (the remainder is used by the operating system).

Description

Fitting all this power into a pocket-size device was no easy task, but, at $3\frac{11}{15}'' \times 6\frac{3}{16}'' \times \frac{11}{16}''$ closed and $7\frac{3}{8}'' \times 6\frac{3}{16}'' \times \frac{9}{16}''$ spread open, the 28C qualifies as a large pocket scientific. With its size and 8-ounce weight, it is more suited for the jacket or coat than for the shirt. Three 1.5-volt N-cell alkaline batteries power the unit, with a reported nine-month life average.

The 28C is protected by a hard-shell, grayish-brown plastic case that opens to reveal a keyboard half in the lower case shell and half in the upper. The display and 37 of the most-used keys, including numerals, frequently used functions and commands, and menu keys are on the right. On the left side are 35 keys, including an alphabetically organized alphabet (with upper- and lower-case letters) and a number of other function and menu-selection keys. Almost all of the 28C's scientific functions require either use of the shift key or selection from a previously-chosen menu.

Given the enormous power of the 28C, a somewhat complex keyboard was inevitable. H-P has avoided the excesses of the multi-function keys on some scientifics and mocked in an old ZX-81 cartoon relating to Sinclair's ZX-81 computer: "Amazing! He's put a hundred functions on a single key!" Thanks in large part to its judicious use of menus, the 28C's keyboard is uncluttered and unintimidating. However, it does take time to master. The ability to enter commands either by the appropriate key or by typing helps, as does a built-in catalog of commands. Scanning at a rapid pace, the 28C takes about 70 seconds to run through its entire command list. This scanning can be stopped to view notes on command usage or to fetch a command for use in a calculation.

Generally speaking, calculator keyboards have gotten softer over the years. The 28C bucks this trend. It is firm. I compared its keyboard with those of several other calculators and found its keys to be among the least yielding. They were slightly firmer than a well-used HP-21C's and were much firmer than a Casio FX-4000P's, which was fairly typical of today's soft keys. This firmness might very well slow data entry, but it does provide the positive feedback needed to ensure accurate entry. Because the usual sloped-front H-P keys match the angle at which keys would normally be pressed, the edge-pressing and sliding common with some models are minimized. Their slope also compensates for the action of the keys, which pivot from the front, rather than traveling straight down. When listened to with a stethoscope, the 28C key clicks have a metallic sound, suggesting that the mechanisms are spring metal levers or "crickets." Unlike most calculator keys, the 28C's are wobble-free. In general, the keyboard tends to facilitate accurate entry and has a feel of high quality.

A graph was plotted on a 28C calculator and printed on H-P's $135 printer, as shown. Printing directions can be sent with up to a foot and a half separation between the 28C and the printer with no cord connection, providing a user with a hard copy record of his calculations.

When immediate operations involving intensive microprocessor activity are involved, keyboard entry can easily outstrip the operations. However, the 28C has a keyboard buffer that allows typing ahead by several characters or commands.

The 28C's text and graphics display is one of its most important features. The display window measures $\frac{7}{8}'' \times 2\frac{11}{16}''$, and the main display area, in which characters and graphs appear, measures $\frac{5}{8}'' \times 2\frac{7}{8}''$. In that area, four lines of up to 23 characters each, or three lines of characters and one of menu labels are displayed, which each character formed on a 5 $\times$ 7-pixel matrix. Characters measure just slightly more than $\frac{1}{8}''$ high, which is considerably smaller than on most scientifics. However, the characters are better formed than most and are easy to read in all but dim light. Pressing the "On" key and either "+" or "−" simultaneously will adjust the LCD's contrast over a wide range. The area above the main display is used for seven annunciators, which indicate the current status of the calculator in regard to such matters as shift mode, units of angular measurements in use, and battery condition.

The 28C's relatively large display helps make it more user-friendly than previous H-P models. The display is especially welcome, given the 28C's RPN-based operating system. The four lines of the display allow the contents of three or four stack levels (depending on whether a menu is being displayed) to be viewed si-

HP-28C FEATURES AT A GLANCE

- *Symbolic Algebra & Calculus*—Operations performed without assigning numerical values to a variable, which can be substituted at will.
- *Equation Solver*—Entered and stored in the user's own terms and solved for any unknown variable in any order.
- *Matrices & Vectors*—Thirty commands with easy entry, editing and manipulation.
- *Plotting*—Expressions or statistical data plotted on four-line display with visual estimates, followed by using Equation Solver for accurate solution.
- *Unit Conversion*—Has 120 built-in unit conversions plus any others user defines.
- *Programming*—Has 250 built-in programmable commands and 60 keyboard commands.
- *Menu Labels & Softkeys*—Offers pushbutton access to commands and six softkeys (variable function) take on meaning defined by on-screen menus.
- *Operating Logic*—Enhanced RPN logic allows work with stack of data objects and is also capable of algebraic-expression entry and evaluation.
- *Catalog Functions*—Commands accessed through softkeys by command name or by scanning and selecting from built-in catalog.
- *Accuracy*—Real precision, 12-mantissa digit; integer precision, 64 bits.
- *Display*—Adjustable-contrast LCD, 32 × 137 pixels, 7 status annunciators, 5 × 7 dot matrix font, 23 characters per line, 4 lines and scrolling capability.
- *Printing*—Built-in capability to work with battery-powered HP 82240A infrared-beam printer.

multaneously, making it possible to watch how operations affect the stack. Although RPN (reverse Polish notation) is an efficient and flexible method of problem-solving, it does require certain mental rearrangements of problems to be used successfully if one has only worked with algebraic entry, which requires keying in "=" and "( )" signs. The 28C's multi-line display makes it easier to visualize these rearrangements. The large display also simplifies editing, provides room for menu key labels and for status annunciators, and makes help messages possible. Interestingly, the 28C employs "Enhanced RPN," which allows the user to also employ algebraic entry or even mix it with RPN logic.

The most striking benefit of the display is its graphics capabilities. Equations and data points can be plotted and trends determined. Graphics can be magnified or reduced and a cursor arrow moved to select points of interest. The coordinates for these points can be displayed, input into equations, or massaged by the 28C's "Solver" feature to provide more precise answers to problems. Roots can be calculated with 12-digit accuracy.

H-P was not the first to offer graphics capabilities in a calculator. Casio's two-year-old FX-7000P features a 96 × 64-pixel display and can also return coordinates for cursor-selected points. However, the relatively inexpensive Casio is not so adept at massaging graphics-derived solutions as the 28C. Since the Casio model sells for only a third of the 28C's price, it is worth considering by those on a budget. But it lacks many of the 28C's new features, including symbolic math, and has no output to a printer, as does the 28C.

The 28C's large display also simplifies the solutions of matrix problems, a 28C capability not widely available from competitive models. For simple matrices, the display allows the matrix to appear as it would

normally be written. Once entered, the matrix can be manipulated by the 28C in a wide variety of ways. Although not displayable without scrolling, matrices of up to about 11 × 11 elements can apparently be squeezed into the 28C.

The most revolutionary feature of the 28C is its ability to solve and manipulate equations using symbolic math. Numerical values need not be assigned. The equations themselves can be solved in a completely general fashion, even for problems that involve calculus. The enormous advantage of this is that the user discovers not just a particular answer, but the structure of all answers. The complexity of equations that can be handled is said to be limited only by the 28C's memory. Though 2K of RAM seems overly restrictive, one should recall that this is used mainly for entering the equation. General instructions for solving most types of problems are already present in the device's very ample 128K of ROM. Data and display contents are retained in memory when the 28C is turned off, by the way, which is a welcome feature since the calculator shuts off automatically when it is inactive for about 10 minutes to conserve battery power.

In most general terms, the 28C operates by evaluating objects placed on the stack. These objects may be data, names or procedures. A number would be an example of a data object, a variable one type of name object, and a program one case of a procedure object. Anything from a number to a program can be stored in a variable, which is handled like a data object in setting up a calculation. Since objects of various types are treated similarly, operating the 28C is made simpler.

The 28C's Reference Manual rightly stresses the uniformity and flexibility its system of objects provides. The possibility of handling complex objects like much simpler ones also allows for great creativity

A basic formula discussed in the text is shown keyed in with the HP-28C scientific professional calculator.

in problem-solving. It is, for example, easy to include programs within other programs.

Hands-On Use

As cited, the 28C uses H-P's familiar RPN user interface. However, its implementation on the 28C includes important new features. The stack is not limited to four variables, as before, but can be expanded to the limits of the 28C's memory. The only disadvantage is that memory can be eaten up rather quickly unless objects are removed from the stack. An advantage of having results preserved on the stack is that a fuller history of calculations is provided than is available from other calculators. A number of commands make inspection and manipulation of the stack quite easy.

Algebraic expressions can be evaluated by themselves, so it is possible to use the 28C as if it had an algebraic operating system. To do this, a delimiter (a single quotation mark) is needed to alert the calculator that it is dealing with such an expression. This feature should make it easier for users of non-RPN calculators to adapt gradually to the more efficient and flexible RPN system.

The power of the 28C's operating system can best be shown with a couple of sample problems. Let us assume, to begin with, that we wish to wind some air-core coils for a transmitter we are building. The formula for coil inductance is:

$$L(\mu H) = \frac{d^2n^2}{18d + 40l}$$

where L is the inductance in microhenries, d is the coil diameter in inches, l is its length, and n is the number of turns of wire required. If we have available plastic tubing of a particular diameter and length to use as a form, we might wish to solve for the number of turns required. If we know the number of turns that would be wound with the available wire, we might need to discover over what length to wind the coil. If we had an old coil and knew the length, diameter, and number of turns, one could calculate the inductance to see if the coil might be usable.

Programming such a function on as fine a scientific calculator as Casio's FX-4000P would be a complicated matter. We would need to enter the formulas for solving for each of the variables, as well as instructions for directing the calculator to the correct one, depending on what our unknown was. Instead of one formula, we would need four, plus rules for choosing the right one. Let us now see how we might solve such a problem on the 28C.

After clearing the stack and selecting the cursor menu, we would simply key in our basic formula. To make the elements easier to remember, we might enter it as:

$$LUH = \frac{DIA^2*NO.T^2}{18*DIA+40*LNGH}$$

If we wished, we could use names of up to 127 characters for the variables, but that would waste memory. At the beginning of the formula we would type a single quote mark to indicate that an algebraic expression would follow—and that commands within the expression should not be

BUILT-IN VS. EXPANDABLE

The HP 28C calculator discussed in the main article does not supplant Hewlett-Packard's vaunted HP-41, of which nearly 1.5-million units are said to have been sold. The former might be compared to an all-in-one personal computer with much of what you would wish to have already built in, but with no expansion bus. In comparison, the HP-41 could be likened to a powerful, minimally equipped modular personal computer with an expansion bus to pick and choose from among a wide variety of plug-ins.

Let's do some direct comparisons between the two professional calculators: The 28C measures 3⅛" × 6½" × ⅞" (closed) and weighs 8 oz. with batteries (three disposable), while the 41's size is 3" × 5" × 1⅜" and weighs 7.2 oz. with batteries (four rechargeable/disposable). Neither, therefore, is a miniature device, though they are portable hand-held types and can be carried in a jacket pocket or in an attache case. H-P's 28C displays 4 lines of 23 characters, whereas the 41 has only 1 line with 12 characters; the 28C's displayed accuracy is 12 digits and 3 exponents, while the 41 clocks in at 8 digits and 2 exponents. Thus, the new 28C reveals more data at one shot, as well as providing greater precision.

The model 41 has about 0.5K more RAM than the 28C, with another 4.2K of volatile memory that can be added with plug-in modules. But the newer 28C has a 128K ROM as compared to the 41CX's 24K or the less powerful version's (41CV) 12K. As you'd expect, then, the HP 28C has very substantially more built-in functions, such as calculus, boolean operators, matrix operations, unit conversions, linear regression, probability analysis, factorial, etc. Many of these features can be added on to an HP-41 in one form or another (application pacs [sic], Users' Library programs, etc.). Moreover, the 28C has certain math features and functions incorporated within it that add-ons for the 41 cannot duplicate. Among them are a text file editor, bit manipulation, equation solver, and display function plotting, not to mention the ultra-important symbolic functions (polynomial integration, derivatives and symbolic algebra) as well as the capability of using algebraic notation as an addition to RPN logic. Insofar as programming is concerned, the new 28C has more conditional tests and flags, too. Top-of-line HP-41CX, however, has a built-in stopwatch and alarm that the 28C doesn't have.

Examining the foregoing, the 28C is unmistakably a much more powerful stand-alone calculator than the 41 is. Even adding all the feature/function options available to a model 41 calculator, it still can't match the raw calculating power of the 28C, nor can it rival its operating efficiency.

Nonetheless, the 41's expansion facilities go beyond raw calculating and problem-solving. It can be tailored to certain needs, making it exceptionally flexible. For example, it contains four plug-in ports for adding software modules, peripherals, etc. Additionally, there are provisions for an optional card reader, optical bar-code wand, and HP-IL (interface loop) interfacing.

What this means is that HP-41 users can employ a Hewlett-Packard battery-powered ThinkJet printer as well as two printer/plotters, though they're not wireless types. Furthermore, there are provisions for mass storage of data with a portable 3½" disc drive, a digital cassette drive, and a magnetic card reader. And with an HP-IL interface module, you've got a neat system controller for use with a variety of peripherals, instruments and computers. Lastly, Hewlett-Packard offers a wide variety of "application pacs" and thousands of Users' Library programs to give you finger-tip solutions to narrow-field problems. Included here are pacs for circuit analysis, clinical lab and nuclear medicine, machine design, navigation, petroleum fluids, structural analysis, surveying, thermal and transport science, financial decisions, real estate, home management, securities, and even games such as Space War, Craps, etc.

Adding the HP-41 options don't come cheap, of course. But you do have a choice, depending on your needs. There's even a wider choice if you want to give up portability, of course, since there are a handful of software programs for computers that emulate the Hewlett-Packard HP-41's capabilities. One company, Straightforward (15000 Halldale Ave., Gardena, CA 90249; telephone 800-553-3332), for example, has implemented selected HP programs and solution books for IBM or compatible personal computers that promise much greater speed and accuracy than the handheld calculator provides. And you've got built-in computer data storage, stack display and full high-level programming capability. Its "Forty-one-ES" is priced at $115, while an 8087 math coprocessor version is $100. Individual "Button" programs are priced at only $2.50 each, while bundles for specific fields (electrical engineering group, high level math group, etc., are offered at lower per program costs.

As you can see, if you're into serious calculating, there are a lot of ways to skin the cat.

—Art Salsberg

carried out at present. The closing quote would not be needed. ENTER would take care of it.

Next, we would select the Solve menu and invoke SOLVR (solver) with the third menu key. After a moment, the variables in our equation would appear in inverse video across the bottom of the display. We would then key in the value for each variable that we knew and press the menu key under the variable label to assign it that value. We would then key in the unknown we wished to know and press the ISOL or "isolate" menu key. Our answer would be returned. No other calculator could handle such a problem so efficiently.

But let us say that we needed a symbolic solution instead; that we wanted the formula for the number of turns in a coil rather than any numerical result. We would recall or enter our formula for the inductance of coils, select the Solve menu if it were not present, enter "NO.T" on the command line, and press the ISOL menu key. The result the 28C would show would be:

'sl* √(LUH*(18*DIA + 40*LNGH)/DIA^2)'

The sl indicates that the sign of the square root could be positive or negative, that the answer is either +1 or −1 times the square root. Clearly, the power to obtain such symbolic solutions is highly useful and could save much time. When dealing with complex algebraic expressions, somewhat more user participation might sometimes be needed. Terms might need to be collected with the COLCT or "collect" key, for example.

To plot expressions or equations on the 28C, we prepare by clearing the stack, selecting the radians mode if not present, choosing the standard display mode, and selecting the cursor mode. We then invoke the Plot menu, change the plotting parameters if necessary, and key in the expression we wish to plot. We store the expression in EQ, the variable for the current equation, by pressing the SELQ menu key, and then press the DRAW menu key. The calculator plots the expression on a grid, with the horizontal line representing the independent variable and the vertical the dependent.

Once we have our plot, we can alter it in several ways. We might return to the Plot menu and set new variables for the height and width of the graph with the *H and *W menu keys. We could choose a new center by moving the cursor to a point, digitizing it with the INS key, and then entering the value with the CENTER key. Different corners could be set by digitizing the points we wished to be the new corners and then using those numbers to set PMAX and PMIN with the menu keys having those labels. We might also digitize a point to solve a problem or to provide an approximation for refinement by the 28C's SOLVR routine. The graphics powers of the 28C are not only fun to work with, they are also extremely flexible and useful.

Conclusions

Hewlett-Packard bills the 28C as a math tutor, in addition to its other functions. Since working problems, rather than hunting up values or formulas, is the best way to learn math, H-P's sales claim seems to be entirely reasonable. The 28C fairly invites experimentation and will probably lead many users to a better appreciation of the beauties of symbolic math. Its graphics talents will certainly make it easier for students to visualize trends in functions.

Somewhat more conventional, but not altogether common, 28C features include its powers to handle imaginary numbers and computer math. Previously, one needed an HP-15 for built-in complex number powers and an HP-16 for the fullest computer math capabilities. The ability to deal with the square root of −1 is important in solving a number of electronics problems, such as the values of impedances. With the wide variety of personal computers, binary and hex calculations are no longer exotic procedures. Both powers belong on scientific calculators, and the 28C provides them. Also, the 28C incorporates a unit-conversion system with 120 units built in.

The 28C lacks the ability to use BASIC or any other high-level language. H-P's 81B, TI's 94, Sharp's 5500 III, and Casio's PB770 are among the calculator-size devices that do so. Given the 28C's great built-in power, however, I doubt if this lack will be noticed very much.

Except for an infrared printer, the 28C accepts no peripherals. There seem to be two reasons for this. First, silicon is cheap and mechanical storage devices, such as card readers, are expensive. By eliminating them and their interfaces, space is saved, reliability boosted, and costs reduced. Second, H-P probably did not want to kill off their highly successful "cash cow," the HP-41, which, in the absence of 28C peripherals, continues to have its appeal. The 41 family is now several years old and must be dear to the hearts of H-P accountants.

The 28C printer (the same as used for the 18C business calculator) measures 3½" × 7¼" × 2¼" and weighs one pound with a roll of paper, operates on battery or ac power (the latter with an adapter), uses thermal paper, and can handle screen dumps. Printouts are smaller than screen displays, and the width is truncated more than the height. The print quality is sharp and clear.

There are many similarities between the 28C and its sister, the 18C business calculator. The main difference is that the 18C majored in finance, while the 28C was a math major at the university. The 28C is the obvious choice for anyone with non-business calculating needs. Users of the 28C could borrow the 18C printer in offices already using that model.

H-P has provided outstanding documentation for the 28C. A 54-page *Getting Started Manual* and a 406-page *Reference Manual* are included with the calculator. Both are clearly written and contain numerous examples of 28C displays. The *Reference Manual* is organized according to the various menus available on the 28C screen. Every command for each menu is explained and examples of their uses are provided.

(Continued on page 92)

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Quick LED Displays

How to use National Semiconductors' 4-digit counter/driver ICs for creating easy, low-cost numeric displays for your projects

By J. Daniel Gifford

Liquid-crystal displays (LCDs) have supplanted light-emitting-diode (LED) displays in most commercially made products, mainly because of the LCD's low-power requirements and high visibility under typical lighting conditions. However, there is still a lot of mileage to be gotten out of LED displays, which are still a lot cheaper and easier for the hobbyist and experimenter to use.

If you are like most experimenters, you probably groan at the thought of designing and building projects that require multiple-decade displays because of the multiplicity of components needed—counter and decoder/driver chips, resistors and the LED displays themselves. Fortunately, things are not as bleak as they first appear to be now that National Semiconductor is making a series of 4-digit counter/driver ICs designed to drive LED displays. These relatively new chips reduce the component count, in some cases, to just two: the IC and display. Hence, working with this new series of chips is a breeze.

The series itself consists of four separate devices (numbers 74C925 through 72C928), all of which are nearly identical but differ with some important variations. All four chips are also relatively low in cost and readily available from a number of sources traditionally used by hobbyists and experimenters.

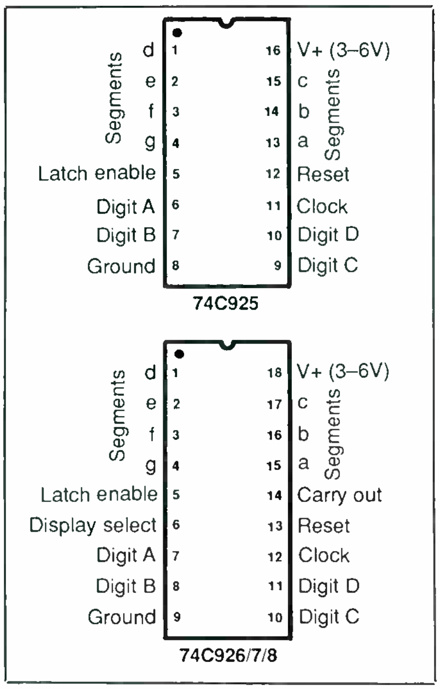

Fig. 1. Pinouts of 16-pin 74C925 and 18-pin 74C926, 74C927 and 74C928. The 74C925 and 74C926 are functionally identical except that the 74C926 lacks carry output and display select input. The 74C927 and 74C928 are identical to the 74C926 except for different counting sequences.

Technical Details

The four chips that make up the National series each contain a 4-digit BCD counter, quad 4-bit latch, BCD to 7-segment decoder and segment and digit drivers. The 74C925 is a 16-pin DIP device, while the other three are 18-pin devices (Fig. 1). With any one of these chips, a minimum of outboard components are needed to provide full four-digit decimal counting. The only external components one might need are four common-cathode numeric LED displays, which can be either discrete-digit or a four-digit array, and four bargain-basement npn transistors.

In spite of the many combined on-chip functions, this series of ICs is exceptionally easy to use. Other than the segment and digit outputs, there are only four inputs and one output per chip. Since these chips are CMOS devices, they draw very little power so that any significant power drawn by a 4-decade counter is confined to the LED display, which can consume as much as 100 mA or more.

CMOS construction makes these chips relatively immune to electrical noise and aids in interfacing with almost any kind of circuit that requires a numeric display. Too, there is nothing critical about power-supply requirements, since they are designed to operate over a range of from 3 to 6 volts dc, making operation from 5 volts the easiest design option.

All four ICs in the series feature digit multiplexing. An internal oscillator in each runs the multiplexing circuitry. Hence, the need for even a single external timing capacitor is eliminated. Individual a through g segment-drive outputs can each source up to 40 mA of current, which is sufficient to assure a bright display when an IC is called upon to drive even large (0.6- to 0.8-inch) LED numeric digits. Segment resistors should, however, be used when these ICs are powered from a 5- to 6-volt source. though they can be dispensed with when less than 5 volts is used to power the chips.

If very large, bright displays that draw greater current than the counter/driver ICs can safely deliver are to be used, high-current drivers like the CD4050B hex buffer can be included between the combined counter/driver IC's outputs and the displays.

Digit driver outputs A through D are limited to a maximum source current of about 1 mA. This is enough current to drive a general-purpose npn transistor like the 2N2222 or 2N3904 that is then used to sink current from the common cathodes of a single LED decade. The four outputs are switched high in succession, with one and only one being high at any given moment in time. Each output has an on time of 22 percent of a single duty cycle, leaving a 3-percent "dead" time during which no decade is on. This dead time keeps the segment signals from traveling to the wrong display and causing "ghosting" (faint lighting of wrong segments). In severe cases, ghosting can cause the display to faintly light all eight segments continuously.

As each driver output is switched high, the segment drivers switch to the corresponding counter stage's outputs. Actually, the outputs of the 7-segment decoder driver remain connected the same way (to the segment output pins). It is the BCD *inputs* to the decoder that are switched from the outputs of one 4-bit latch to the next.

Each latch is connected to the output of one of the four counter stages and all four latches are controlled by the latch-enable (LE) input. When LE is high, the latches are in flow-through mode, and the outputs of the counters are directly passed to the segment decoder. When LE is brought low, the count in the latches at that point—and the display—is frozen until the input is brought high again. The counters continue to count, however, and their output (instead of the count being held in the latches) can be displayed by bringing the display-select (DS) input high.

When DS is low, the value in the latches is displayed, whether static or changing with the counters. When DS is brought high, the value held in the latches is ignored and the counter outputs drive the decoder.

It is in the counter sections where the only differences between the four ICs lie. The 74C926 has four divide-by-10 counters with BCD outputs. The clock input is connected to the least-significant digit's (LSD's) counter stage. The carry output of

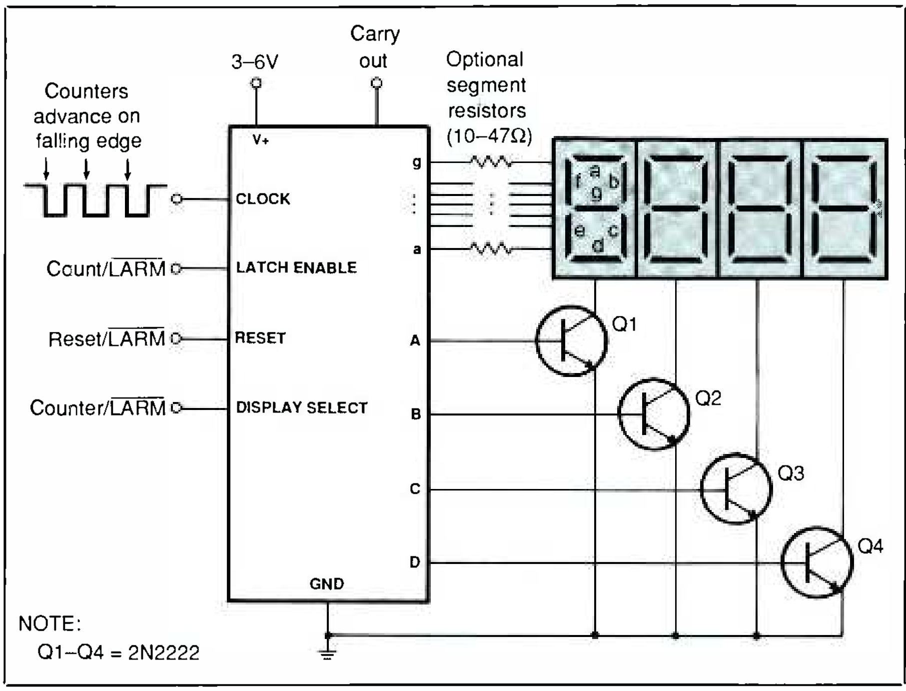

Fig. 2. Basic application circuit for all versions of counter. Segment resistors are optional but should be used whenever power supply delivers 5 volts or more.

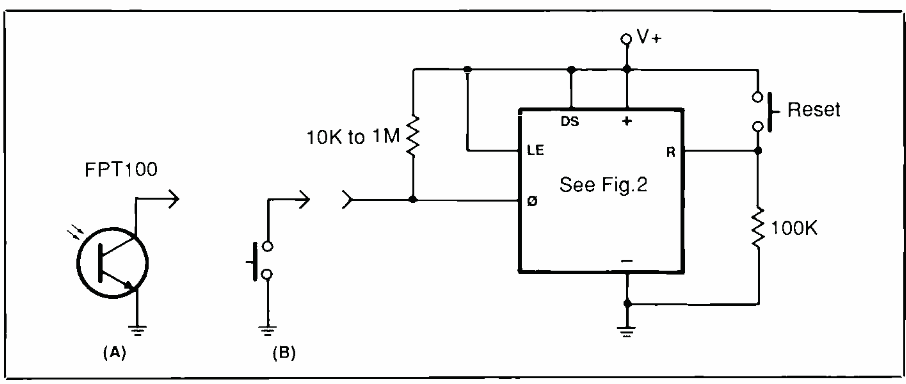

Fig. 3. Basic event counter can use switch (A), phototransistor (B) or any other sensor that can produce a 0-to-5-volt pulse.

the LSD's counter stage drives the second counter stage, the second counter's carry output drives the third counter stage, and the third counter stage's carry output drives the fourth counter stage. With four counter stages, the 74C926 has a count range of 0000 to 9999. When the count increments by 1 past 9999, the count (and display) roll over to 0000 to begin counting upward again. (All count incrementing occurs on the negative edge of the clock pulse input.)

The fourth counter's carry is brought out to the carry out pin. Hence, two or more of these chips can be cascaded for any desired number of display decades. The chip carry output is low until the display reaches 6000, at which point it drops low again when the counter rolls over to 0000.

With a 5-volt power supply, the maximum clock frequency for all four 4-digit counter/drivers in this series is typically 4 MHz (2 MHz guaranteed), which should be fast enough for most counting applications. If a faster count input is needed, a prescaling counter like the 74HC4017 or 74HC4510 can be used ahead of the display counter/driver to divide the input frequency by any factor of 10. These prescaling counters can be cascaded as needed to obtain the desired divide factor to bring the input signal frequency into a range that can be handled by the display counter/driver.

All four counter/drivers in this series share a common reset input, which is kept low for normal operation and is brought high to force all counter stages to zero and the carry output to its low state. Reset also inhibits counting when it is high.

Being a simple decimal counter, the 74C926 is probably the most useful of the four IC devices. Indeed, it is the most widely available. The 74C925 is an almost identical decimal counter, except that it lacks carry output and display-select pins. Because the output of this counter is always connected to the latches, bringing LE low freezes the display. The only real advantage to the 74C925 is that in OEM quantities (10,000 or

IC Availability

The National Semiconductor LED counter/driver integrated circuits referred to in this article are readily available, but not from all sources traditionally used by electronics hobbyists and experimenters. If you would like to experiment with and use these chips, they can be obtained from the following sources:

Source*	Device No.	Cat. No.	Unit Price
Digi-Key	74C925	74C925N-ND	$8.75
P.O. Box 677	74C926	74C926N-ND	$8.75
Thief River Falls, MN 56701	74C927	74C927N-ND	$8.75
Tel.: 800-344-4539	74C928	74C928N-ND	$8.75
Jameco Electronics	74C925	74C925	$4.95
1355 Shoreway Blvd.	74C926	74C926	$4.95
Belmont, CA 94002			
Tel.: 415-592-8097			

*Digi-Key has no minimum, but service charges may apply; Jameco has a $20 minimum.

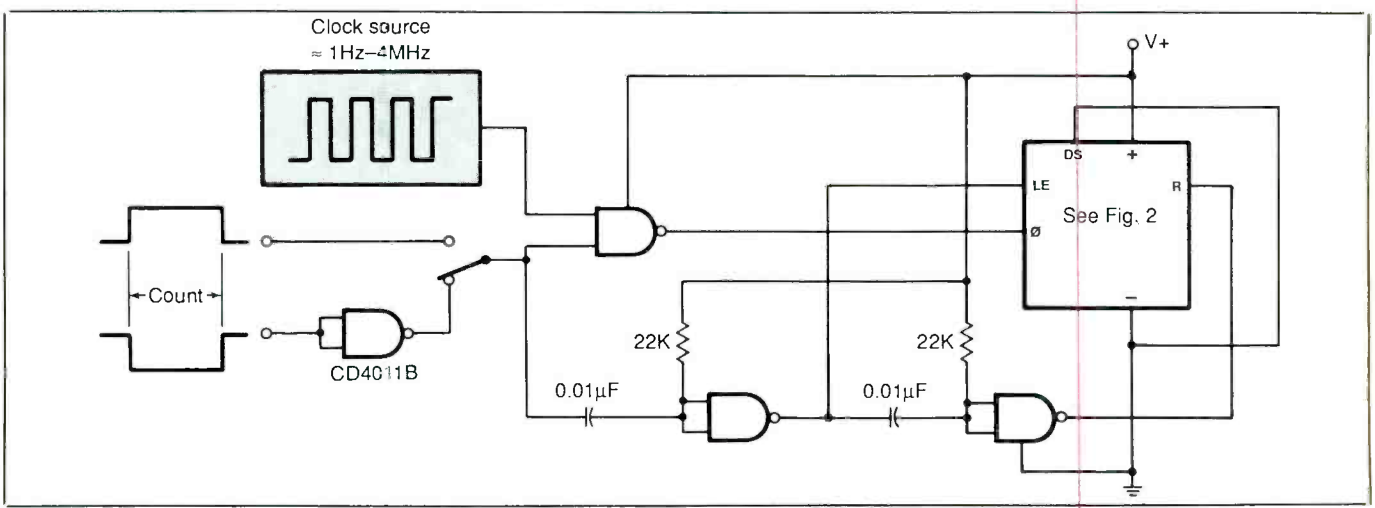

Fig. 4. Basic period-measurement circuit.

more pieces), it is cheaper than the 74C926. In the small quantities an experimenter usually buys, there is no price advantage worth considering.

The 74C927 is identical to the 74C926 in that it is housed in an 18-pin package and has both reset and carry output pins. The difference is that the second most-significant (hundreds) digit has a maximum count of 6 and rolls over to 0 when it is incremented past 5 (the 6 count is the result of 0 being used as a count digit). This yields a maximum count for the four-digit device of 9599, which is useful for timing and clock applications. (If a 10-Hz clock signal is used with the 74C927, the output would display seconds in tenths up to 10 minutes, which would be displayed as 9:59.9.) The carry output pin follows the same logic as that of the 74C926, going high at 6000 and low at 0000.

Except that its most-significant digit divides by 2, giving a maximum count of 1999, the 74C928 is also identical to the 74C926. The carry output latches high when the count reaches 2000. It returns to low only when the counter is reset. The 74C928 is, thus, a 3½-digit counter, with the carry output acting as an overflow indicator. This counter/driver is suitable for many types of panel-meter circuits.

Applications

All of the application circuits we will be discussing use the basic circuit shown in Fig. 2. This is the circuit implied in later figures by a box with internal callouts. Power supply delivery is assumed to be 5 volts dc. If a lower voltage is used, you might have to make some adjustments in the circuits to be shown.

● *Event Counter.* The resettable event counter circuit shown in Fig. 3 is about as simple an application for the National ICs as you can get. A switch (detail A) or a phototransistor (detail B) are two possible input sensors than can be used to count, say, openings of a door or objects passing on a conveyor belt. Any kind of sensing device that produces a 0-to-5-volt pulse can be used in this circuit in place of the switch or phototransistor.

The Fig. 3 circuit uses a manual reset function, and the display-select and latch-enable inputs are wired high to provide for a continuously updating display. As with all these circuits, you can make any modifications you see fit to suit your particular applications.

● *Gated Timer.* Figure 4 shows a very useful circuit that turns the counting function of the basic circuit into a timing function with a digital display and an adjustable timebase. If the project you incorporate the basic circuit into does not generate countable pulses, you can probably arrange it to produce a variable pulse width to drive this circuit or a variable frequency to drive a frequency counter (see below).

An astable multivibrator or clock source, built around the popular 555 timer or a pair of CMOS gates, is used to provide a timebase frequency for this circuit, the frequency of which can be adjusted to suit the project's needs. The output of the timebase is connected to the clock input of the counter circuit via a gate. The other input of the gate is used to turn on and off the counter.

Two different gating circuits are shown. One counts when the input is high, the other when the input is low. On each, when the output returns to the "don't count" state, the LE input is briefly enabled to store the count, and then the reset input is pulsed high to reset the counters to

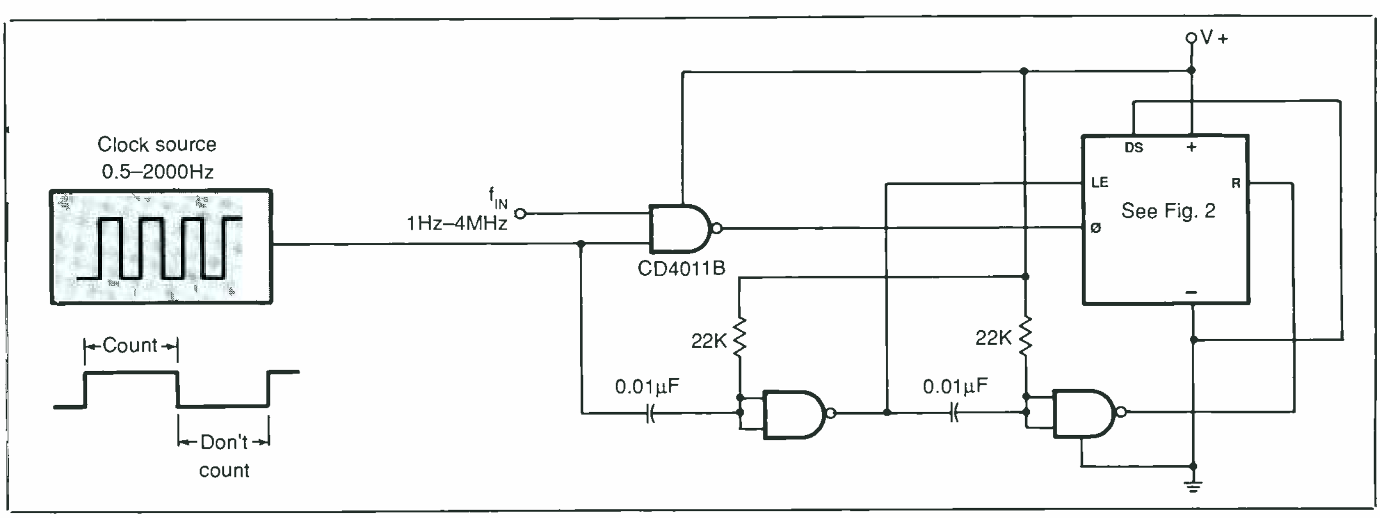

Fig. 5. Basic frequency-counter circuit.

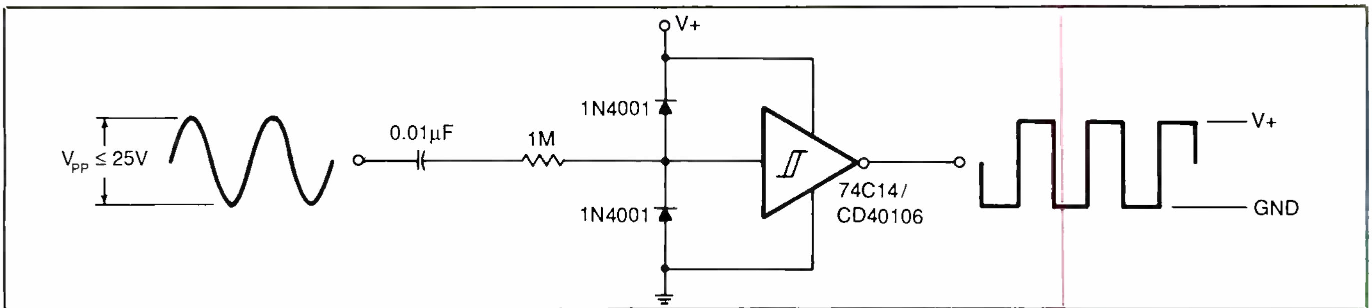

Fig. 6. General-purpose input conditioning circuit for use with Fig. 5 circuit.

await the next counting period. The last count will be displayed until the next counting period is completed.

In general, you will probably want the timebase frequency of the Fig. 4 circuit to be a decade division of 1 second (0.1 second, 0.01 second, and so on), since this will produce a display that tells you how long the high or low pulse was. The timebase frequency can be adjusted to produce other frequencies—to correct for timing factor errors in the main circuit, for example.

- *Frequency Counter*. If your main circuit does not produce countable pulses and cannot be rigged to produce some sort of time-proportional pulses, you might be able to get it to produce a proportionally variable frequency. To produce a readout display from such a frequency, you can use the circuit shown in Fig. 5. If this circuit looks familiar, it is because it is the logical inversion of the Fig. 4 circuit. However, instead of gating on and off a steady frequency with a pulse input, this circuit uses the stable frequency to gate on and off a variable input frequency.

Unless the input frequency is generated by other digital circuitry, it will probably have to be conditioned before it will work properly with the Fig. 5 circuit. Figure 6 illustrates an excellent general-purpose signal conditioner. Because the two diodes clip the input voltage at the ground and V + levels, peak-to-peak inputs of 25 volts or so are safe to apply to the input of the circuit, even though the supply voltage may be as low as 3 volts. Since the main element in this circuit is a Schmitt trigger, the circuit will turn even fairly ragged input signals into clean square waves to drive the counter circuit.

Cascading Counters

In the circuits discussed above, it was assumed that only one counter/driver IC was used. However, with the exception of the 74C925, all of these counters can be cascaded without limit. Although 32 or more decades are possible by cascading, the practical limit is probably more in the range of eight decades, which requires two counter/driver ICs.

Cascading these devices is simply a matter of using the original clock signal—no matter what its source—to drive the clock input of the least-significant digits (units through thousands counter) and then connecting the carry output of that counter to the clock input of the next. In general, the other inputs of each counter (latch enable, display select and reset) should be chained together so that they act simultaneously.

It is difficult to conceive of a circuit in which the lower counter would be anything but a 74C926. The second counter could easily be any of the four counter/drivers in this series—a 75C925 or 74C926 for all-decimal (0 to 9) counting, a 74C928 for 7½-digit counting with an overflow, or even a 74C927 for time counting from 0.00001 second to 10 minutes (with a 100-kHz timebase). If more than two counters are cascaded, all but the highest would be 74C926s.

By choosing the proper counting configuration and correct circuit from those discussed here, you should be able to add a four-or-more-digit LED display to almost any circuit that can benefit from one. **ME**

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List price $299.95/**CE price $148.95/SPECIAL**
8-Band, 60 Channel • No-crystal scanner
Bands: 30-50, 88-108, 118-136, 144-174, 440-512 MHz.
The *Regency* Z60 covers all the public service bands plus aircraft and FM music for a total of eight bands. The Z60 also features an alarm clock and priority control as well as AC/DC operation. Order today.

Regency® Z45-RA

List price $259.95/**CE price $139.95/SPECIAL**
7-Band, 45 Channel • No-crystal scanner
Bands: 30-50, 118-136, 144-174, 440-512 MHz.
The *Regency* Z45 is very similar to the Z60 model listed above however it does not have the commercial FM broadcast band. The Z45, now at a special price from Communications Electronics.

Regency® RH256B-RA

List price $799.95/**CE price $329.95/SPECIAL**
16 Channel • 25 Watt Transceiver • Priority
The *Regency* RH256B is a sixteen-channel VHF land mobile transceiver designed to cover any frequency between 150 to 162 MHz. Since this radio is synthesized, no expensive crystals are needed to store up to 16 frequencies without battery backup. All radios come with CTCSS tone and scanning capabilities. A monitor and night/day switch is also standard. This transceiver even has a priority function. The RH256 makes an ideal radio for any police or fire department volunteer because of its low cost and high performance. A *60 Watt* VHF 150-162 MHz. version called the **RH606B-RA** is available for $459.95. A UHF 15 watt, 10 channel version of this radio called the **RU150B-RA** is also available and covers 450-482 MHz. but the cost is $439.95.

Bearcat® 50XL-RA

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10-Band, 10 Channel • Handheld scanner
Bands: 29.7-54, 136-174, 406-512 MHz.
The *Uniden Bearcat* 50XL is an economical, handheld scanner with 10 channels covering ten frequency bands. It features a keyboard lock switch to prevent accidental entry and more. Also order the new double-long life rechargeable battery pack part # **BP55** for $29.95, a plug-in wall charger, part # **AD100** for $14.95, a carrying case part # **VC001** for $14.95 and also order optional cigarette lighter cable part # **PS001** for $14.95.

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The new Fox scanner frequency directories will help you find all the action your scanner can listen to. These new listings include police, fire, ambulances & rescue squads, local government, private police agencies, hospitals, emergency medical channels, news media, forestry radio service, railroads, weather stations, radio common carriers, AT&T mobile telephone, utility companies, general mobile radio service, marine radio service, taxi cab companies, tow truck companies, trucking companies, business repeaters, business radio (simplex) federal government, funeral directors, veterinarians, buses, aircraft, space satellites, amateur radio, broadcasters and more. Fox frequency listings feature call letter cross reference as well as alphabetical listing by licensee name, police codes and signals. All Fox directories are $14.95 each plus $3.00 shipping. State of Alaska-**RL019-1**; Baltimore, MD/Washington, DC-**RL024-1**; Chicago, IL-**RL014-1**; Cleveland, OH-**RL017-1**; Columbus, OH-**RL003-2**; Dallas/Ft. Worth, TX-**RL013-1**; Denver/Colorado Springs, CO-**RL027-1**; Detroit, MI/ Windsor, ON-**RL008-2**; Fort Wayne, IN /Lima, OH- **RL001-1**; Houston, TX-**RL023-1**; Indianapolis, IN-**RL022-1**; Kansas City, MO/ KS-**RL011-2**; Los Angeles, CA-**RL016-1**; Louisville/Lexington, KY-**RL007-1**; Milwaukee, WI/Waukegan, IL-**RL021-1**; Minneapolis/St. Paul, MN-**RL010-2**; Nevada/E. Central CA-**RL028-1**; Oklahoma City/Lawton, OK-**RL005-2**; Pittsburgh, PA/Wheeling, WV-**RL029-1**; Rochester/ Syracuse, NY-**RL020-1**; Tampa/St. Petersburg, FL-**RL004-2**; Toledo, OH-**RL002-3**. A regional directory which covers police, fire ambulance & rescue squads, local government, forestry, marine radio, mobile phone, aircraft and NOAA weather is available for $19.95 each. **RD001-1** covers AL, AR, FL, GA, LA, MS, NC, PR, SC, TN & VI. For an area not shown above call Fox at 800-543-7892 or in Ohio 800-621-2513.

Regency® Informant™ Scanners

Frequency coverage: 35-54, 136-174 406-512 MHz.
The new *Regency* Informant scanners cover virtually all the standard police, fire, emergency and weather frequencies. These special scanners are preprogrammed by state in the units memory. Just pick a state and a category. The Informant does the rest. All Informant radios have a feature called *Turbo Scan*™ to scan up to 40 channels per second. The **INF1-RA** is ideal for truckers and is only $249.95. The new **INF2-RA** is a deluxe model and has ham radio, a weather alert and other exciting features built in for only $324.95. For base station use, the **INF5-RA** is only $199.95 and for those who can afford the best, the **INF3-RA** at $249.95, is a state-of-the-art, receiver that spells out what service you're listining to such as Military, Airphone, Paging, State Police, Coast Guard or Press.

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List price $369.95/**CE price $218.95**
11-Band, 55 Channel • Handheld/Portable
Search • Lockout • Priority • Bank Select
Sidelit liquid crystal display • EAROM Memory
Direct Channel Access Feature • Scan delay
Bands: 29-54, 118-136, 144-174, 406-420, 440-512 MHz.
The new handheld *Regency* HX1500 scanner is fully keyboard programmable for the ultimate in versatility. You can scan up to 55 channels at the same time including the AM aircraft band. The LCD display is even sidelit for night use. Includes belt clip, flexible antenna and earphone. Operates on 8 1.2 Volt rechargeable Ni-cad batteries (not included). Be sure to order batteries and battery charger from the accessory list in this ad.

Bearcat® 100XL-RA

List price $349.95/**CE price $178.95/SPECIAL**
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Search • Limit • Hold • Lockout • AC/DC
Frequency range: 30-50, 118-174, 406-512 MHz.
Included in our low CE price is a sturdy carrying case, earphone, battery charger/AC adapter, six AA ni-cad batteries and flexible antenna. Order your scanner now.

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PRO520E-RA *Uniden* 40 channel CB Mobile $59.95
PRO540E-RA *Uniden* 40 channel CB Mobile..... $119.95
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PC22-RA *Uniden* remote mount CB Mobile........ $99.95
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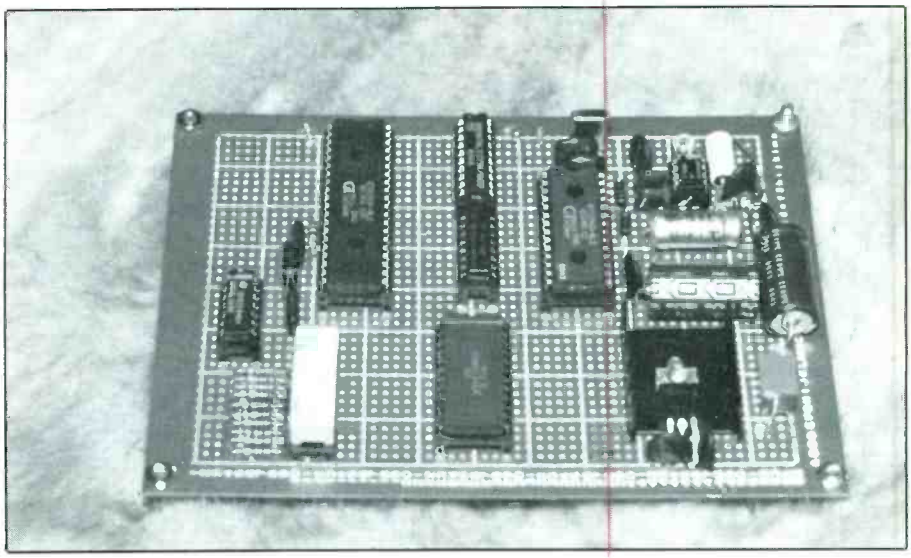
CIRCLE NO. 151 ON FREE INFORMATION CARD

A General-Purpose Speech Synthesizer

This versatile ASCII-to-speech processor can be used with a variety of devices to generate human-sounding speech

By Barry L. Ives



Artifically generated—or so-called "synthesized"—speech has found applications in many areas as a useful way of providing machine-to-human feedback. One obvious application of a speech synthesizer is as a device to assist sightless and/or mute people to communicate with others. In other applications, the speech synthesizer can be used to vocalize instructions to a computer operator in situations where it is not convenient to display characters on a video screen or where the operator is unable to keep a continuous eye on the screen. It can also be used as a teaching/learning tool for children and other individuals to learn spelling, mathematics and even how to read. One popular use is in providing aural feedback in interactive video games. In fact, the uses to which a speech synthesizer like the one to be described are limited only by the imagination of the user.

Our speech synthesizer project accepts ASCII test information from any computer and converts it into vocalized speech. Because it translates the text words fed to it into sounds phonetically with an accuracy of 85 percent or more, the synthesizer's vocabulary is virtually unlimited. For maximum versatility, the project can be configured to accept serial or parallel ASCII data fed to it at any rate between 50 and 9,600 baud. It accommodates both TTL and RS-232C signal levels and any combination of bits and parity and can be set up to handle the user's choice of hardware or software handshaking, with a three-line or X-line serial interface. If you wish, you can even use an ASCII-encoded keyboard to feed data to the synthesizer in place of a computer.

About the Circuit

The speech synthesizer is built around the General Instruments CTS256A-AL2 code-to-speech converter processor, which is basically a dedicated microprocessor, and

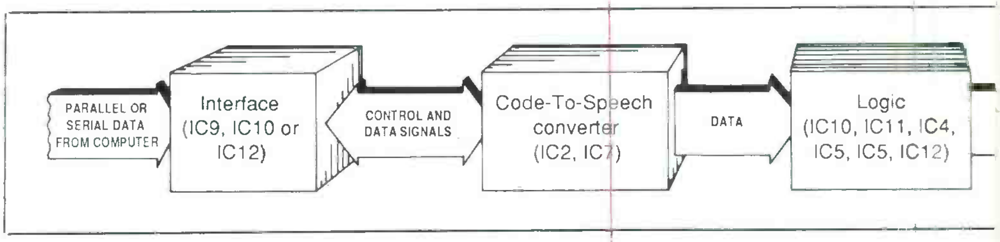


Fig. 1. Block diagram of overall speech synthesizer,

Table 1. Standard RS-232C Signals (partial list)

DB-25 Pin No.	Abbreviation	Name	Direction
1	P. GND	Chassis ground	Both
2	TX	Transmitted data	To modem
3	RX	Received data	From modem
4	RTS	Request to send	To modem
5	CTS	Clear to send	From modem
6	DSR	Data set ready	From modem
7	S. GND	Signal ground	Both
8	DCD	Data carrier detect	From modem
20	DTR	Data terminal ready	To modem

SPO256A-AL2 speech-processor integrated circuits. Both of these chips are readily available from Radio Shack stores and other sources. The block diagram of the synthesizer, minus its ac-operated power supply, is shown in Fig. 1.

Character data from a computer or other ASCII-encoded source is fed into dedicated 8-bit microprocessor *IC2* in Fig. 2. Upon receipt of the ASCII data, *IC2*'s internal program searches through a series of letter-to-sound rules to locate the proper allophone addresses to feed to speech-processor chip *IC3*. The latter chip uses the addresses fed to it to form the required phonetic sounds by means of an internal programmable digital filter and pulse-width modulator configured to imitate the sounds of a human voice.

After passing through an external two-pole filter, the sound signal from *IC2* is amplified by audio amplifier chip *IC8*, which then drives the speaker to produce the vocalized sounds of the typed-in data. (For more information on allophone speech synthesis, see "This is Your Computer Speaking," *Modern Electronics*, June 1986.)

Figure 3 is the schematic diagram of the circuit required to interface the synthesizer to a computer through a *true* RS-232C serial port. As you can see from this interface circuit, you need quad receiver *IC9* and quad transmitter *IC10*. Standard RS-232C uses the signals detailed in Table 1. Some of these signals are for handshaking control to and from the computer and "modem." However, the RX and TX lines carry the actual data.

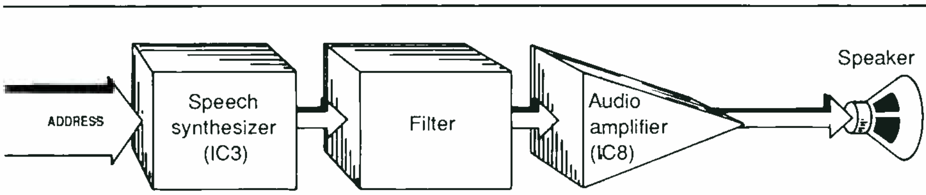
Pin numbers for interface connector *J1* into which the computer/synthesizer link is made are for the standard DB-25 connector commonly used in computer systems. If your computer uses a different connector, refer to the computer's manual to obtain the information needed and adjust accordingly when preparing the linking cable.

Code-to-speech converter *IC2* in Fig. 2 has an input port for ASCII data as well as an output port for software handshaking and a BUSY output line for hardware handshaking. The input port at pin 16 of *IC2* should be connected to the computer's TX data output. The output port at pin 37 of *IC2*, if it is to be used for software XON/XOFF handshaking, should connect to the computer's CTS input. These are the primary signals to and from the speech synthesizer. In the Fig. 3 RS-232C interface adapter circuit, the DCD and DSR lines are pulled high to signal the computer at all times.

If TTL-level signals are used, the connections should be made directly to DB-25 connector *J1* instead of going through the Fig. 3 circuit. The connections shown permit a straight-through interconnecting cable to be used, assuming the computer is configured as a data terminal. (If you plan to use the project in this manner, check the computer's programming manual to be certain that the pin numbers correspond and adjust as necessary. Information on programming the RS-232C port in the computer can also be found in the manual.)

As provided, the CTS256A is programmed to read 7-bit ASCII data with two stop bits and no parity. Baud rate, however, is selectable according to settings of the sections of DIP switch *S3*, as shown in Table 2. If your computer cannot be set up to accommodate these parameters, the optional latch circuit consisting of octal latch *IC11* in Fig. 4 can be added to the basic project to provide additional choices of bits and parity per Table 2. Inclusion of the Fig. 4 programmable parameters circuit requires installation of the jumper wire that connects pin 9 of *IC2* to +5 volts (see Fig. 2).

The parallel interface port circuit shown in Fig. 5 can be used to interface the project with computers that have a parallel but no serial port or simply if you wish to use parallel



including all options but not power supply.

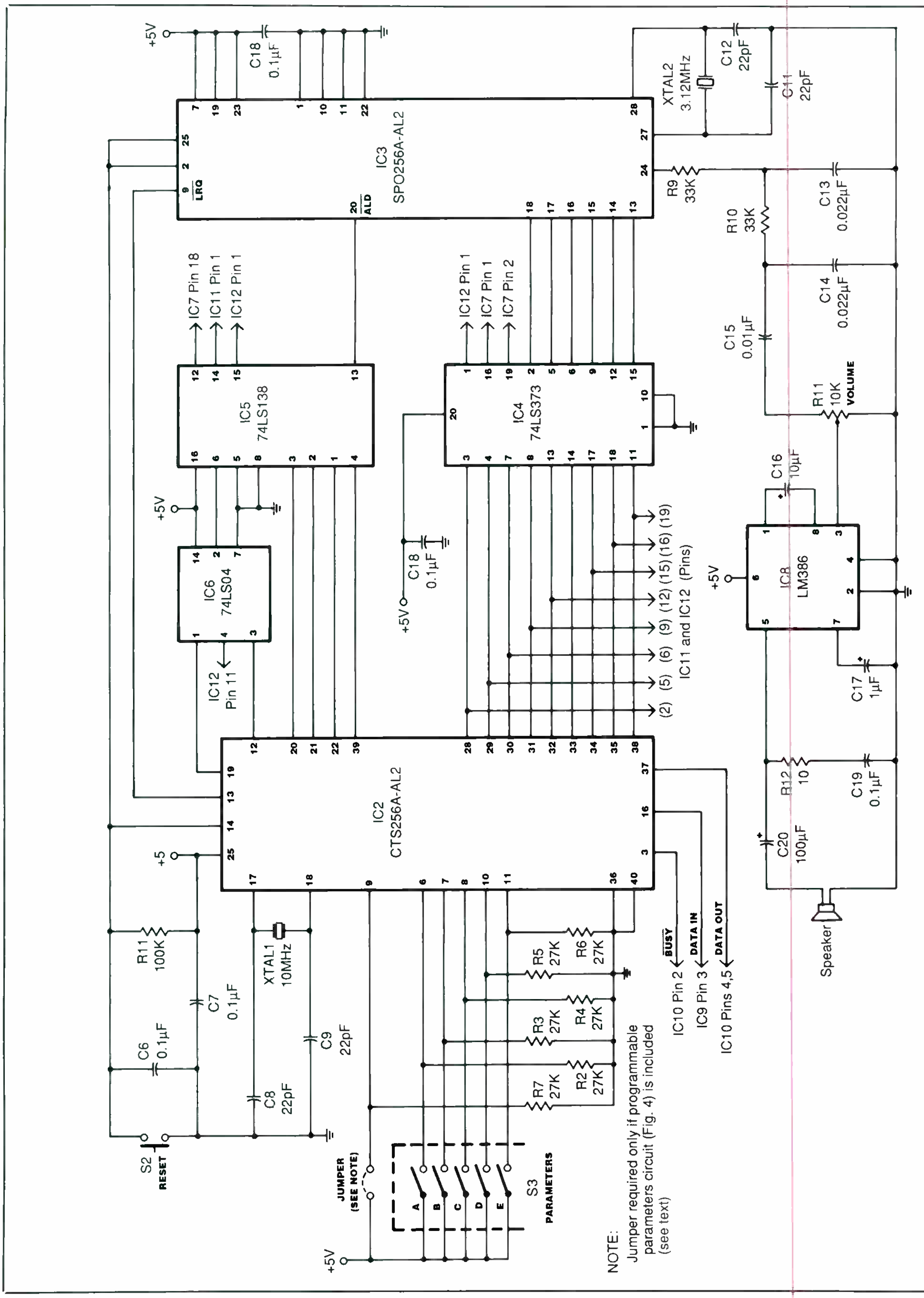


Fig. 2. Basic speech-processing circuitry.

Table 2. Parameters Option Wiring and Setting

S3 Section	To	Settings	
A	IC2, pin6	000 = Parallel	
B	IC2, pin 7	001 = Serial (50 baud)	
C	IC2, pin 8	010 = Serial (110 baud)	
		011 = Serial (300 baud)	
		100 = Serial (1,200 baud)	
		101 = Serial (2,400 baud)	
		110 = Serial (4,800 baud)	
		111 = Serial (9,600 baud)	
	Under "Settings," read A, B, C left to right.		
D	IC2, pin 10	1 = External Ram; 0 = internal RAM	
E	IC2, pin 11	1 = Any delimiter;	
		0 = Carriage return only	
F	IC11, pin 3	1 = 2 stop bits; 0 = 1 stop bit	
G	IC11, pin 7	1 = Even parity; 0 = odd party	
H	IC11, pin 8	1 = Parity; 0 = No parity	
J	IC11, pin 13	00 = Not used	10 = 7 bits
K	IC11, pin 14	01 = 6 bits	11 = 8 bits
	Under Settings," read J, K left to right.		

feed. This circuit latches eight bits corresponding to an ASCII character into *IC12* when the $\overline{S}$ (STROBE) line is brought low. The character is then fed into *IC2* (Fig. 2) and RAM memory. Connections can be made through pins 10 through 18 and pin 7 ground of *J1*.

Though *IC2* comes with a 20-byte input buffer and 26-byte output buffer, this is not sufficient storage space to avoid crashing the system as a result of output buffer overflow. Therefore, the external RAM circuit shown in Fig. 6 is included in the basic design of the speech synthesizer to permit a half-screen full of data to be accepted and spoken from beginning to end.

The final circuit that makes up the speech synthesizer is the ac-line-operated power supply shown schematically in Fig. 7. This is a straightforward regulated +5-volt dc power supply. Transformer *T1* steps down the incoming 117 volts ac to 12.6 volts ac, which is then rectified to pulsating dc by filter capacitor *C1*. After this, the dc is regulated to +5 volts by *IC1* and is further filtered to pure dc by *C3*. Light-emitting diode *LED1* serves as a power ON indicator and is an option you can leave out of the circuit, along with *R1*, if you wish to economize.

Construction

Because of the complexity of the wiring required to assemble the speech

PARTS LIST

Semiconductors

LED1—Red panel-mount light-emitting diode
IC1—7805T +5-volt regulator
IC2—CTS256A-AL2 code-to-speech converter
IC3—SPO256A-AL2 speech processor
IC4,IC11—74LS373 octal latch
IC5—74LS138 1-of-8 decoder
IC6—74LS04 hex inverter
IC7—TMS4016-25 or 6116LP-3 static RAM
IC8—LM386 audio amplifier
IC9—MC1489 quad receiver
IC10—MC1488 quad transmitter
IC12—74LS374 octal D flip-flop
RECT1—50-volt, 1-ampere bridge rectifier

Capacitors

C1,C3—1,000-μF, 25-volt electrolytic
C2,C20—100-μF, 15-volt electrolytic
C4 thru C7,C10,C15,C18,C19—0.0-μF ceramic disc
C8,C9,C11,C12,C13,C14—0.022-μF Mylar
C16—10-μF, 15-volt electrolytic
C17—1-μF, 15-volt electrolytic
C21 thru C25—100-pF disc

Resistors (¼-watt, 5% tolerance)

R1—400 ohms
R2 thru R7, R14 thru R18—2,700 ohms
R8—100,000 ohms
R9,R10—33,000 ohms
R12—10 ohms
R13—1,000 ohms
R11—10,000-ohm audio-taper potentiometer

Miscellaneous

F1—1-ampere fast-blow fuse
J1—Female panel-mount DB-25S connector
S1—Spst toggle switch
S2—Spst normally-open pushbutton switch
S3—10-section DIP switch
SPKR—2" replacement speaker
T1—12.6-volt, 1-ampere power transformer
XTAL1—10.00-MHz crystal
XTAL2—3.12-MHz crystal
6.5" × 4.5" prototyping board (see text); Wire Wrap sockets for IC2 thru IC12 and S3 (use low-profile socket for IC8); suitable enclosure (8.5" × 5" × 2.5" or larger); TO-220 heat sink for IC1; block-type fuse holder for F1; push-in solder posts; ac line cord with plug; rubber grommet; ½" spacers for circuit board (4); lettering kit; 4-40 machine hardware; assorted wire and cable; solder; etc.

Note: All components are available from local Radio Shack stores and/or Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002.

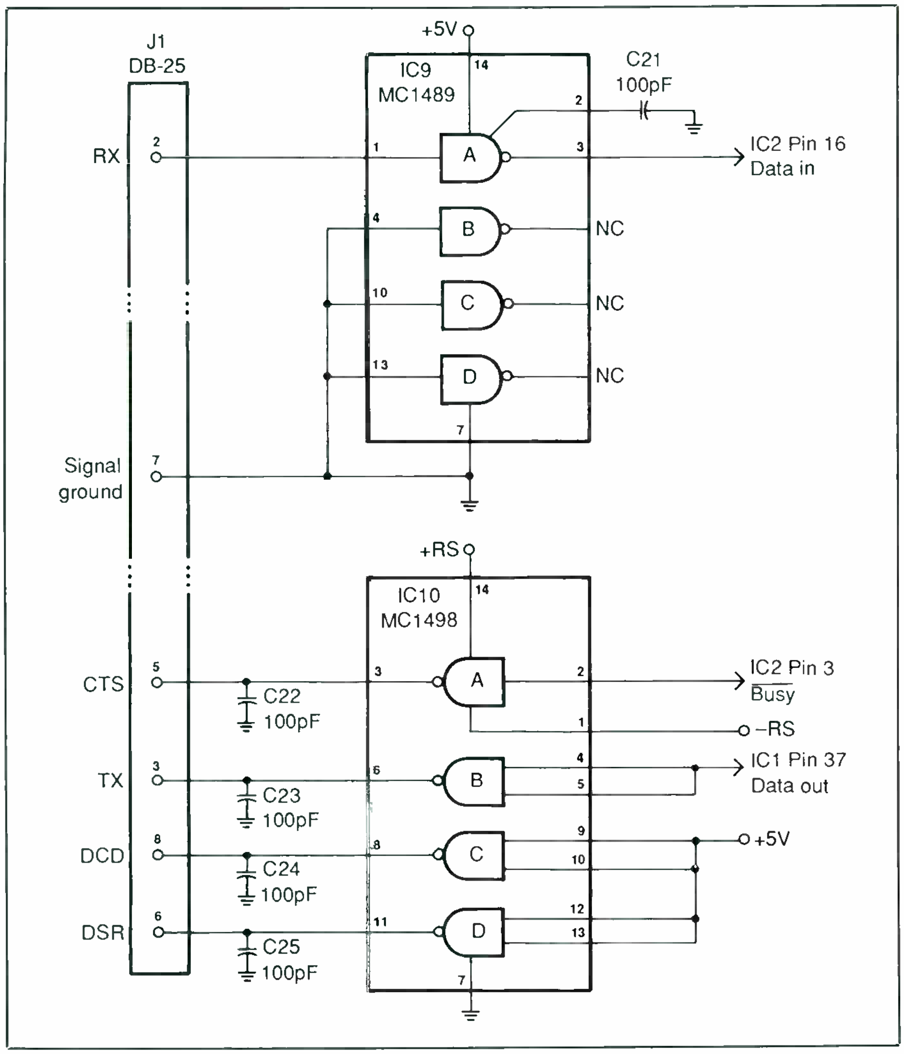


Fig. 3. RS-232C interface circuitry. Include this circuit for true serial feed from computer.

Before beginning to wire the project, determine which portions of the circuit you will need for use with your computer or other input device. At the very least, you need the basic circuit shown in Fig. 2 and the external RAM circuit shown in Fig. 6. synthesizer, I used a combination of Wire Wrap and traditional point-to-point wiring techniques. Almost all components (exceptions are the speaker, *F1* and its holder, *T1, J1, S1, S2, R11* and *LED1*) mount neatly on a 6.5″ × 4.5″ prototyping board with plated-through holes on 0.1″ centers but otherwise not clad with copper.

Whatever remaining circuitry you need will depend on the I/O capabilities of the input device that will be used to feed ASCII data to the speech synthesizer. For example, if you need only a parallel interface, all you need add to the basic circuit is the Fig. 5 circuit. In this case, you do not need the Figs. 3 and 4 circuits. On the other hand, if you need a serial interface, you need the Fig. 3 circuit (and the programmable parameters Fig. 4 circuit if your computer has no means for setting baud rate, parity and other parameters) but can omit the Fig. 5 parallel circuit.

The simplest approach, if your computer can support it, is a direct feed without an interface built into the speech synthesizer. To be able to do this, however, your computer must be able to provide 5-volt dc TTL signal levels through a serial or pseudo-RS-232C port or through an asynchronous receiver/transmitter I/O port. Only if your computer has a true RS-232C port and you want to feed ASCII data to the synthesizer via a serial line is the Fig. 3 circuit needed.

From the forgoing, it should be obvious that whatever circuits are not needed can be omitted from the synthesizer project if you wish to economize. However, the cost of the additional components to build in all the options described to meet any interfacing situation you might encounter is reasonably low enough that you might want to consider a full-blown version.

A suggested component layout on the circuit board is shown in Fig. 8. Plan on using Wire Wrap sockets for all ICs except *IC1* and DIP switch *S3*. Install only the sockets—*not* the ICs themselves—during the wiring phase.

Start stuffing the circuit board by plugging in the IC sockets and sparingly soldering one or two pins on both sides of each to physically anchor them into place as per Fig. 8. Make sure to minimize the length of pin that gets coated with solder. Also, use a small sharp knife to scrape away all traces of flux after soldering; otherwise, when you wrap wires to the pins, the flux is likely to insulate the pins from the wires.

Use 18- to 22-gauge solid wire for the runs from the +5-volt and ground power-supply input pins to the IC sockets and wherever else on the board the power buses are to go.

Once the IC sockets are in place and the wires for dc power distribution have been connected, install all 0.1-microfarad bypass capacitors as close as possible to the V_{CC} (+5-volt) pins of the sockets.

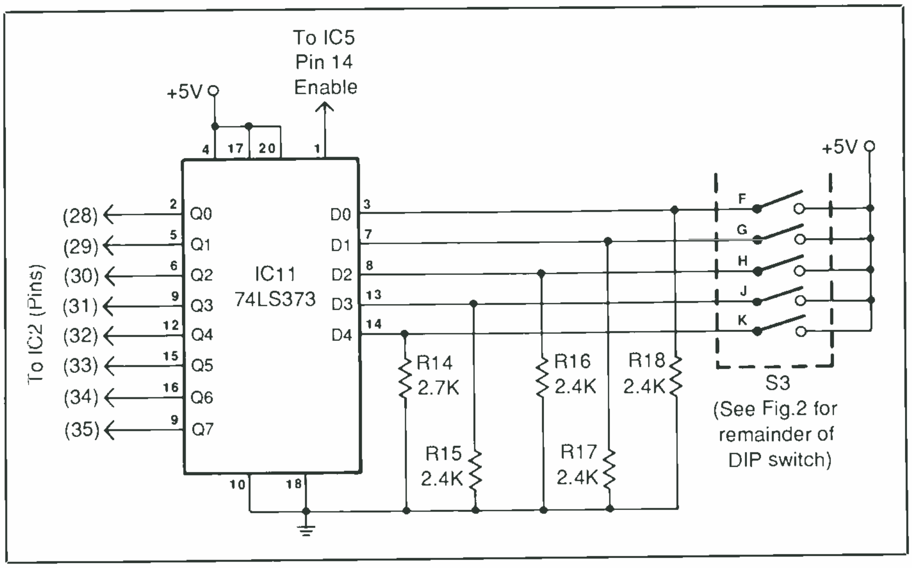


Fig. 4. Optional programmable parameters circuit provides means for setting baud rate, parity, etc. if these facilities are not built into computer with which project is to be used.

Mount voltage regulator *IC1* on a TO-220 heat sink and secure both to the board using a 4-40 × ½″ machine screw, lockwasher and nut. Connect *C4* and *C5* right at the pins of *IC1*, using as little lead length as possible.

Wire all signal lines with 30-gauge Kynar wire with the aid of a Wire Wrap tool. A good way to keep track of all connections and wire runs is to go over photocopies of the schematic diagrams with a red pen or pencil as each is made to avoid confusion and guard against missed wires.

Use push-in pins and solder to make all component lead connections for the *IC8* audio amplifier section. Ditto for the tap-off points for off-the-board components and connections.

Once the circuit is fully wired and all wiring has been double checked (do *not* install the ICs in their sockets until after you have made voltage checks and are sure that your wiring is correct), mount it inside a suitably sized enclosure. The selected enclosure should be large enough to accommodate all components, including the speaker, without crowding.

Figure 9 illustrates a suggested layout. It shows the circuit-board assembly, power transformer and fuse holder mounted to the floor and the speaker mounted to the lid of the enclosure. Use ½″ spacers and 4-40 × ¾″ machine screws, lockwashers and nuts to mount the circuit-board assembly and be sure to drill a number of holes in the enclosure's lid to allow the sound from the speaker to project outward. Infrequently used RESET switch *S2* and DB-25 connector *J1* are best mounted on the rear panel of the enclosure, which should also have a rubber-grommet-lined hole for entry of the ac line cord. Tie a knot in the line cord inside the enclosure to serve as a strain relief. On the front panel of

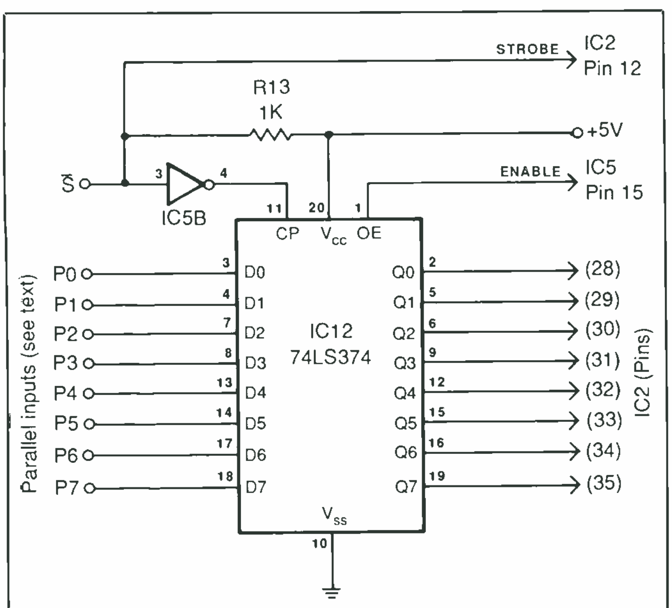


Fig. 5. Circuitry needed for parallel feed from computer.

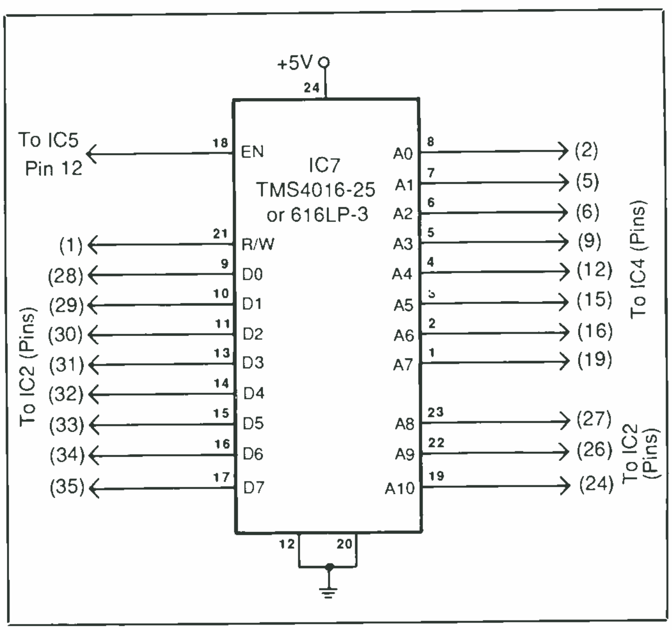


Fig. 6. External RAM memory circuit.

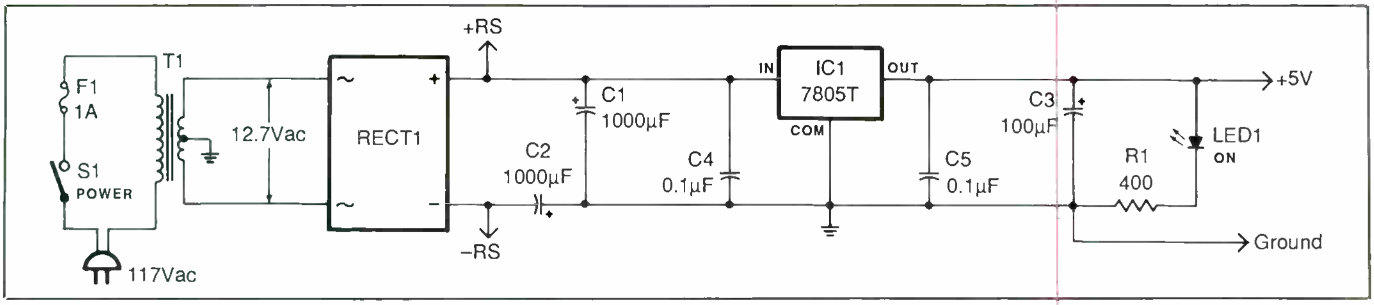


Fig. 7. Schematic diagram of ac-line-operated power supply for speech synthesizer.

the enclosure should be mounted VOLUME control *R11*, POWER switch *S1* and power ON indicator *LED1*.

After the project has been fully wired and assembled (still without the ICs in their sockets), label the POWER and RESET switches, VOLUME control; *J1* input and ON LED.

If you do not have a suitable cable to use between your computer and the speech synthesizer, you will have to make one yourself or have one made by a service that does this sort of thing. To make the cable, you need a male DB-25P connector and hood on one end and the proper connector for your computer on the other end. Any stranded wire or ribbon cable between the two connectors will work properly. However, for very long lines (in excess of, say, 12 feet), you should use shielded cable for the data lines.

Checkout and Use

With the ICs still not installed in their sockets, plug the speech synthesizer's line cord into an ac outlet and turn on the power. The ON LED should light. If it does not, power down the project and rectify the problem. Then repower the synthesizer and use a multimeter set to read at least 5 volts dc to check for the proper voltages at points in the circuit as follows. First connect the meter's common probe to circuit ground at the negative side of *C3*. Then touch the meter's positive probe (observe the meter indication) to:

- ☐ positive (+) side of C3
- ☐ pin 25 of IC2
- ☐ pin 20 of IC3
- ☐ pin 20 of IC4
- ☐ pin 16 of IC5
- ☐ pin 14 of IC6
- ☐ pin 20 of IC7
- ☐ pin 6 of IC8
- ☐ pin 14 of IC9
- ☐ pin 14 of IC10
- ☐ pins 4,17,20 of IC11
- ☐ pin 20 of IC12

You should obtain a reading of +5 volts in all cases. If you do not obtain this reading, power down the circuit, pull the line cord from the ac outlet and recheck all wiring to correct the problem before proceeding further.

Once you do obtain the proper readings in all cases, turn off the power and wait a minute or so to allow the charges to bleed off the electrolytic capacitors in the power supply. Then install the ICs in their respective sockets. Handle these ICs with the same care as you would any other MOS-type device to avoid damaging them with static electricity. Make sure the proper ICs go into the sockets, that they are properly oriented (see Fig. 9) and that no pins

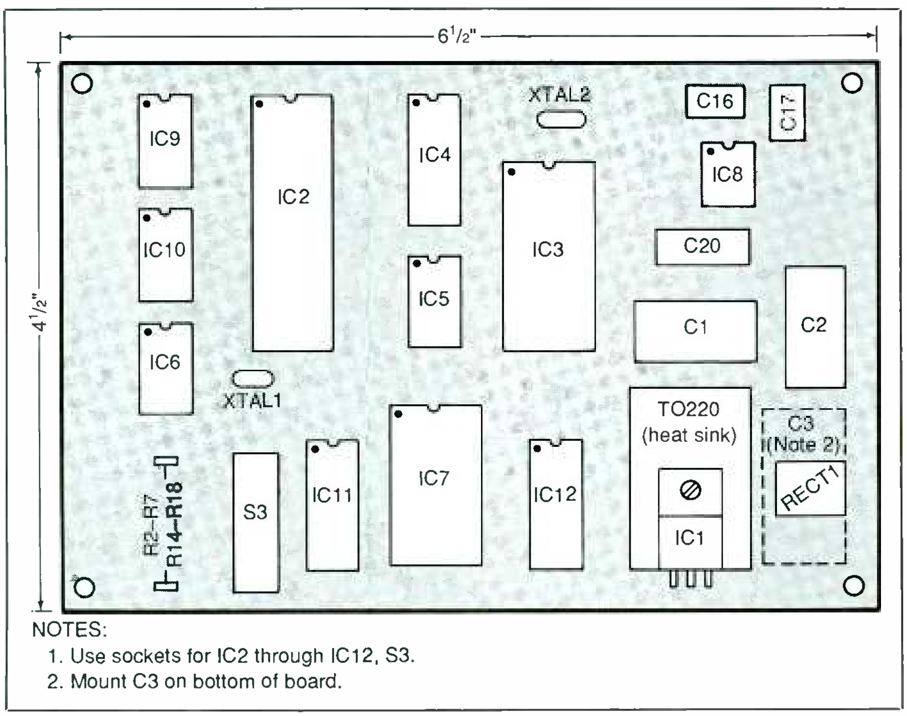


Fig. 8. Most components that make up project mount on relatively small circuit board. In this layout on prototyping board, all options are shown installed.

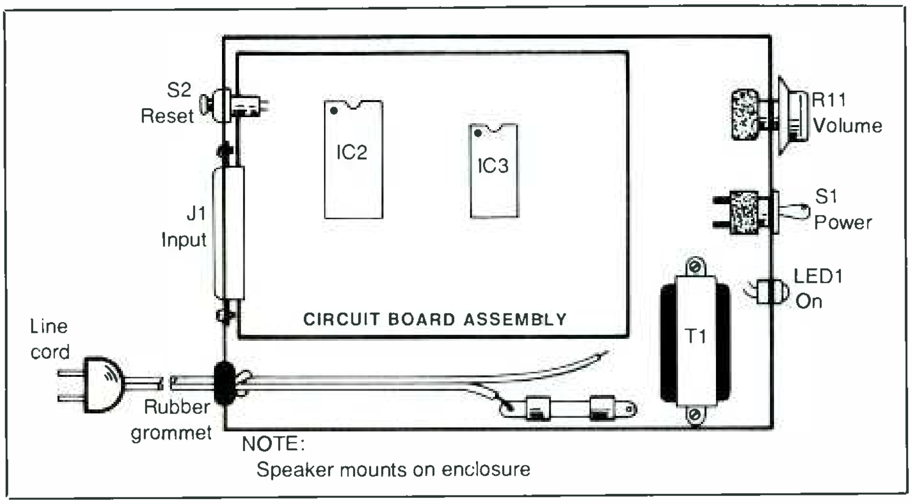


Fig. 9. Suggested component layout inside enclosure.

overhang the sockets or fold under between IC and socket as each is pushed solidly into place.

The speech synthesizer is very easy to use. Two operating modes are available, selectable by toggling section E of DIP switch *S3*. In the "any delimiter" mode (switch closed), any ASCII character that is not a letter or number, including the space, will cause the project to immediately vocalize the characters stored in the output buffer. For example, if you were to type "Modern Electronics." (without the quotes, of course), the synthesizer will begin "speaking" as soon as the space is reached and once again when the period is reached. This mode requires continuous typing unless the strings are stored in the computer's memory. The result will be a halting speech pattern, rather than a smooth flow of words and phrases.

Switching to "carriage return only" mode (section E of *S3* open) makes for more convenient operation. In this mode, long strings of characters (up to 600 characters at 1,200 baud) with all punctuation are sent to the synthesizer and automatically stored in the external RAM memory. Only upon receiving a carriage return (hex 0D) will the synthesizer vocalize what has been typed.

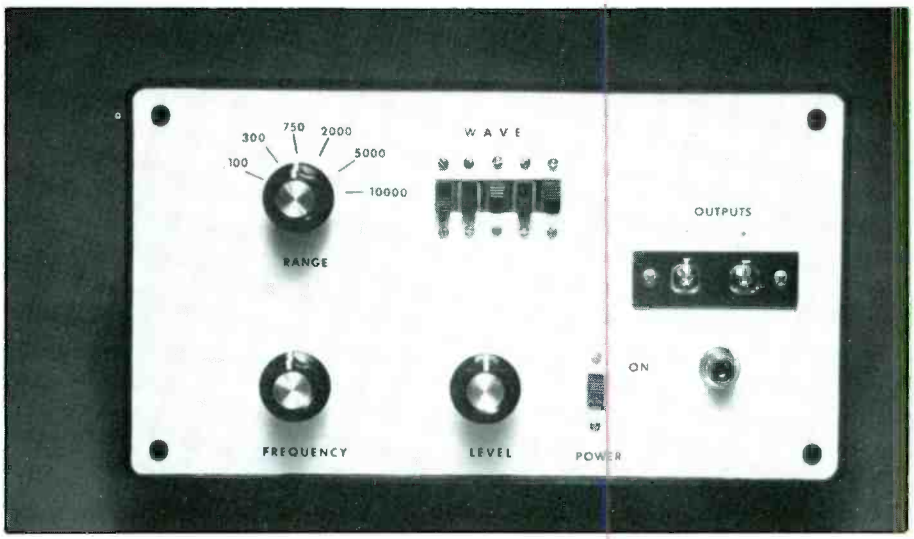
Sending an "escape" (ESC, hex 1B) at any time from the computer will clear the synthesizer's RAM and terminate all speech. If the buffer becomes overloaded, all you need do is press and release the RESET button on the rear of the synthesizer to get back into action. Doing this clears the synthesizer and returns an "OKAY" message on the computer's display screen. More information on the speech processor and code-to-speech converter is given in the data sheets Radio Shack provides with these chips.

A final note: Bear in mind that the speech synthesizer is a literal *phonetic system*. It will properly vocalize most text character strings sent to it. However, it cannot second guess non-phonetically spelled words in which characters are silent ("phlegmatic," for example) or are not pronounced as spelled ("Sioux," for example). Therefore, you will have to experiment on the proper misspellings to make such words come out sounding the way they should, such as "flematic" and "soo" or "sue." As you experiment with various words, you will discover that quite a number, even some that appear to sound exactly as they are spelled, will have to be judiciously misspelled to make them sound as they should. ME

A Programmable Waveform Generator

An audio-frequency test instrument that generates up to 32 different waveforms at frequencies up to 10 kHz

By Paul Renton



Audio frequency generators made their mark as a signal source for audio trouble-shooting, design and setup work. A typical generator provides sine waves, but some function generators, which many people use instead of a sine-wave-only generator, also provide square and triangular waves. The programmable waveform generator described here goes far beyond this by allowing you to select up to 32 different waveforms to suit a wide variety of testing needs.

Three main characteristics can be used to describe a repetitive waveform: frequency (repetition rate), amplitude and the shape of the waveform (sine, square, triangle, etc.). To make a waveform generator useful, each of these characteristics must be alterable independently without affecting the other two. This criterion is met in our programmable waveform generator by separate frequency, amplitude and waveform controls.

Though our programmable waveform generator is extremely flexible, it is relatively easy to build at only moderate cost for components. In fact, your parts cost should be just about $50, including the enclosure in which to house the project. Part of the reason for the simplicity is that the circuitry—mainly readily available and low-cost ICs— wires together on a printed-circuit board. The only specialty device used in the project is an erasable programmable read-only memory (EPROM) in which the waveform parameters are stored for recall by front-panel switches.

About the Circuit

In operation, the programmable waveform generator repetitively "reads" digital values from the EPROM and uses a digital-to-analog (D/A) converter to change these values into the selected output waveform. Varying the rate at which new values are read from the EPROM changes the output frequency (repetition rate) of the generator without affecting the type of waveform being generated. Waveform selection is a function of the program stored in the EPROM and the settings of five switches. Finally, by adjusting the gain of the output stage, the amplitude of the output wave can be varied.

As shown in Part 1 of Fig. 1, eight-bit counter *IC2* generates addresses that call the data stored in EPROM *IC3*. The rate at which the counter is clocked is determined by the rate at which new values are read out from *IC3* and, thus, determines the frequency of the waveform being generated. Since 256 different addresses can be generated by the eight address lines of an 8-bit counter, the wave will repeat every 256 clock inputs to the counter. Therefore, the output wave will have a frequency equal to *IC2*'s clock rate divided by 256.

The oscillator used to generate the clock pulses for the *IC2* counter is *IC1*. In this dual multivibrator, one section uses FREQUENCY control potentiometer *R2* and any one of capacitors *C2* through *C7* selected by section A of RANGE switch *S1* to set the period of its output pulse. Using a six-position switch for *S1* conveniently divides the audio frequency range into segments that make it easy for *IC1* to tune. The output pulse from the first multivibrator drives the second multivibrator in *IC1*.

In the output multivibrator of *IC1*, the pulse length is held to about 40 nanoseconds by *R3*, which needs no timing capacitor. The not-Q output from the second multivibrator, at pin 12, is fed back to pin 2 of the first multivibrator to retrigger the first stage and cause oscillation. The Q output at pin 5 from the second stage is used to clock the *IC2* counter.

An 8K × 8-bit EPROM used for *IC3* holds the data to generate 32 different waveforms, each consisting of 256 bytes. To select the desired waveform, switches *S2* through *S6* are selectively connected to the five higher-order address lines (A8 through A12) of *IC3*. Single in-line package (SIP) resistor *R4* contains five 10,000-ohm resistors that are individually used to pull these address lines high when the switches are open. Closing any *S2* through *S6* switch grounds the selected address line and brings it low. Chip select at pin 20 and output enable at pin 22 of *IC3* are both permanently grounded.

Access time of the *IC3* EPROM is important to proper operation of the circuit. If a slow version of this EPROM were to be used, one with an access time of 450 nanoseconds, output values could not be expected to reliably change at a rate greater than about 2.22 MHz. Since output frequency will be 1/256 of the counter's clock rate, this is equivalent to an output frequency from the generator of 2.22 MHz/256, or only 8680 Hz. Though this might be sufficient in some applications, to ensure that the generator will operate out to a full 10 kHz, an EPROM with a 350-nanosecond or faster access time is needed.

After data for the selected waveform exits from *IC3* on data output pins 11, 12, 13 and 15 through 19, it is latched by octal flip-flop *IC4* (see Part 2 of Fig. 1). Inputs to *IC4* are directly connected to the data output lines of *IC3* in the proper sequence. In turn, the outputs from *IC4* become the inputs to digital-to-analog converter *IC5*.

Output data from *IC4* must be latched to hold the output data from one location in *IC3* while the next location is being addressed. Otherwise, the data sent to *IC5* will change while *IC3* is reading the next memory location, causing noise and random errors to occur in the waveforms.

As shown in Part 1 of Fig. 1, the clock input at pin 11 of *IC4* is the same as that used to increment *IC2*. The counter increments on the falling edge of this clock pulse, generating a new address for the EPROM to read. Data on the rising edge of the clock pulse is latched by *IC4* (Part 2). Since the output from *IC1* is a pulse with a rising edge followed by a falling edge about 40 nanoseconds later, *IC4* will latch the data output from *IC3* just before the EPROM is given a new address from which to read. This prevents any errors from being generated as a result of the changing of the EPROM address.

Digital-to-analog converter *IC5* (Part 2 of Fig. 1) is fed reference currents by grounding pin 15 through *R7* and fixing pin 14 at 2.8 volts above ground potential with the zener diode *D1* and resistor *R5* arrangement. By using the same value for *R5* and *R7*, the currents cancel to assure that errors do not occur. Capacitor *C9* connected from pin 16 to ground provides compensation for *IC5*.

The eight digital inputs from *IC4* are converted by *IC5* to an output current. This output current is normally available at pins 2 and 4. However, in this project, the negative current at pin 2 is connected to ground, and the output at pin 4 is used to drive one of the four operational amplifiers in *IC6*, which is used here as a current-to-voltage converter. (Details of what input data is converted to what output voltage are covered under "Programming Waveforms.")

Since slew rate determines how fast the output signal of an op amp can change and a fast slew rate is needed in this generator, a fast-slew-rate TL084 quad op amp was chosen for *IC6*. A second reason for choosing a TL084 is that it has four independent op amps in a single package. Since three op amps were required in the programmable waveform generator, only a single TL084 takes the place of three independently packaged devices.

One op amp in *IC6* converts the output from *IC5* to a voltage. A generated waveform may contain some sharp edges at the points where the signal changes voltage levels, due to reconstruction of a sampled signal, rather than a continuous waveform. These sharp edges produce a waveform that is not continuous unless the residue of the sampling is removed. This is done in the generator's circuit with the low-pass filter made up of a second op amp in *IC6*.

The low-pass filter should be set at about 80 to 200 times the output frequency so that only the unwanted components are filtered out. RANGE switch *S1B* is used to select which of capacitors *C11* through *C16* will be used in the low-pass filter. This allows the filter to maintain a proper frequency relationship as the frequency is stepped from range to range.

A third op amp in *IC6* serves as the output amplifier that delivers the generated signal to the device under test through OUTPUT jack *J1*. The output signal from the second op amp (at pin 8) is ac coupled through *C17* to the output op amp so that the output signal will be centered about circuit ground.

AMPLITUDE control *R14* provides a means for adjusting output signal level as needed by controlling the gain of the output op amp. Resis-

PARTS LIST

Semiconductors

D1—1N5224B or other 2.8-volt zener diode
D2,D3—1N4001 silicon rectifier diode
IC1—74LS123 dual multivibrator
IC2—74HCT393 or 74LS393 counter (see text)
IC3—2768 (8K × 8) EPROM (see text)
IC4—74HCT374 or 72LS374 octal flip-flop (see text)
IC5—DAC-08 digital-to-analog converter
IC6—TL086 quad op amp
IC7—7805 +5-volt regulator

Capacitors

C1,C8,C9—0.1-μF disc
C2—0.02-μF disc
C3,C11—0.01-μF disc
C4,C12—0.033-μF disc
C5,C13—0.001-μF disc
C6—270-pF disc
C7,C10,C16—100-pF disc
C14—470-pF disc
C15—220-pF disc
C17—22-μF, 15-volt electrolytic
C18,C19—1,000-μF, 25-volt electrolytic
C20—220-μF, 15-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1—3,300 ohms
R3,R10,R11,R12—2,200 ohms
R5,R7,R9—1,000 ohms
R6—470 ohms
R8—220 ohms
R13—10,000 ohms
R4—10,000-ohm × 5 SIP resistor assembly (see text)
R2—10,000-ohm, linear-taper, panel-mount potentiometer
R14—100,000-ohm, linear-taper, panel-mount potentiometer

Miscellaneous

J1—Panel-mount phono jack
J2—Power jack (see text)
S1—2-pole, 6-position nonshorting rotary switch (Radio Shack Cat. No. 275-1386 or similar)
S2 thru S7—Spst slide or toggle switch (see text)

9- to 10-volt ac power transformer or plug-in adapter; printed-circuit board; sockets for IC1 through IC6; suitable enclosure (Radio Shack Cat. No. 270-232 or similar); small TO-220 heat sink for IC7; knobs for R2 and R14; ⅜" or ½" spacers (4); lettering kit; color-coded ribbon cable; machine hardware; hookup wire; solder; etc.

Note: The following are available from Paul Renton, P.O. Box 1525, Mercer Island, WA 98040: Etched and drilled pc board and programmed EPROM for $24; kit containing pc board, programmed EPROM and all board-mounted components (does not include power supply, enclosure and front-panel controls) for $44. Prices include shipping in U.S. Washington residents, please add state sales tax.

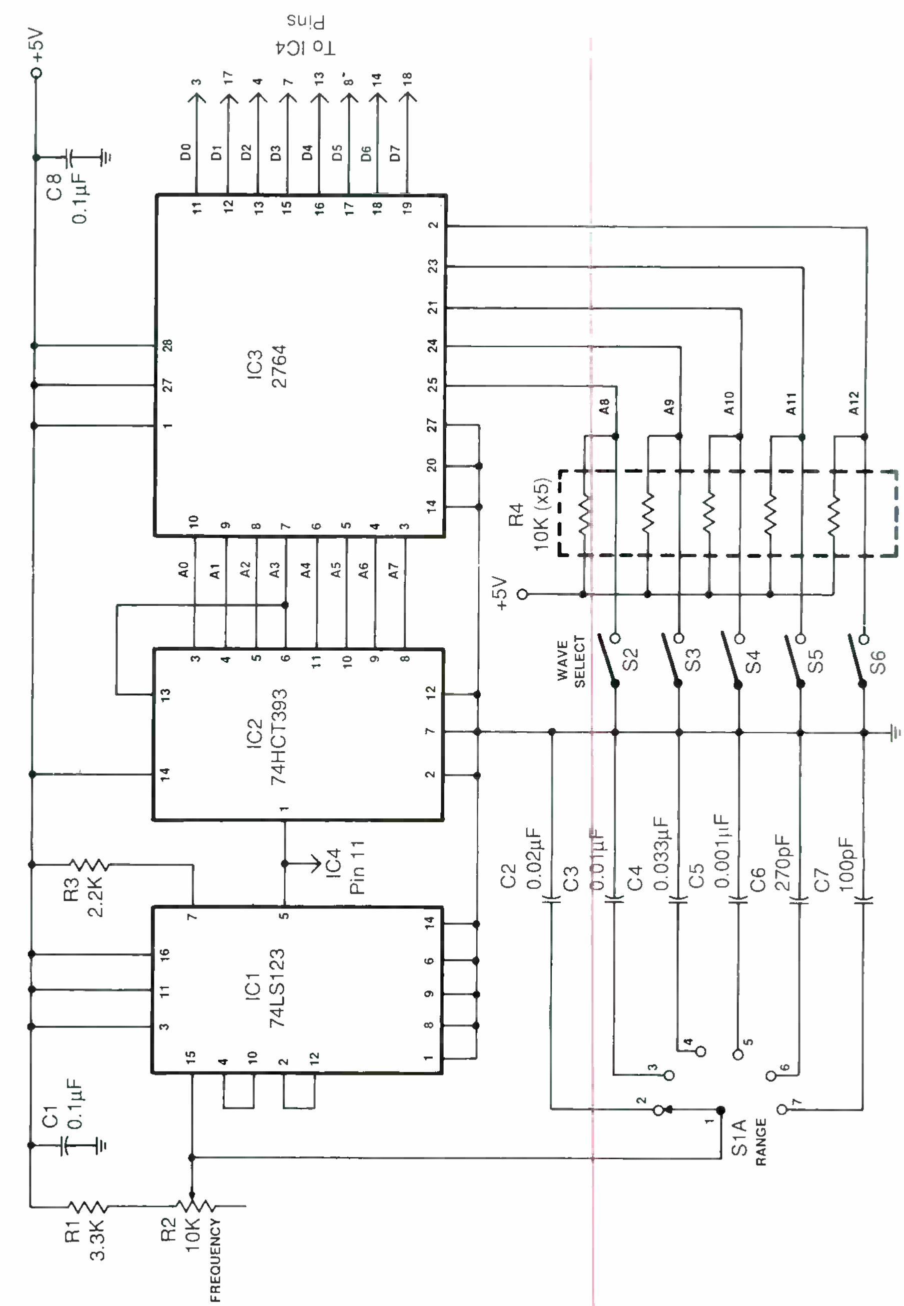
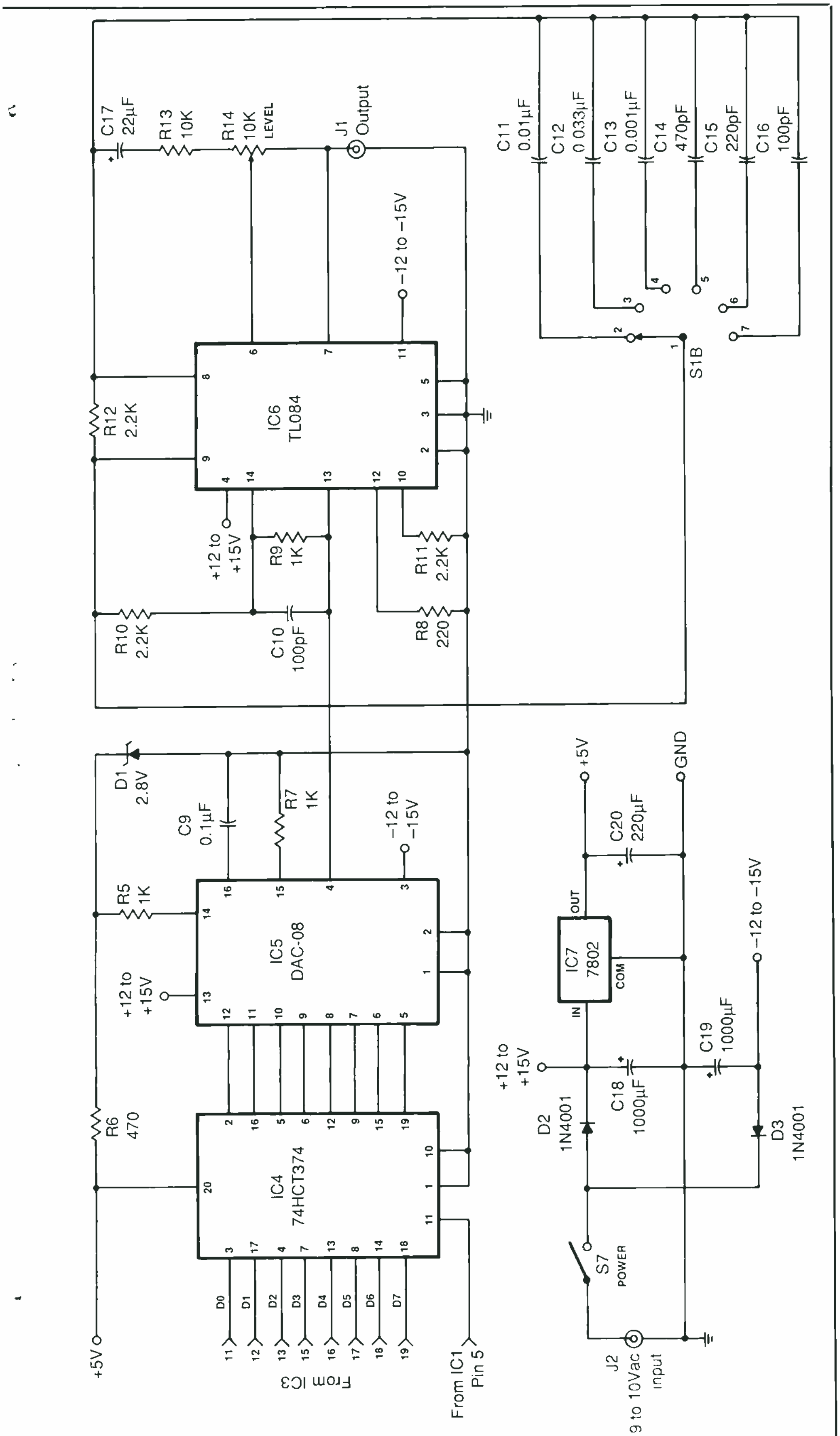


Fig. 1 Complete schematic diagram of programmable waveform generator, including power supply but not power transformer.



tor *R13* in series with *C17* prevents the signal delivered to the output op amp from being over-amplified and clipping.

Although high-speed CMOS ("HCT") devices are specified for *IC2* and *IC4* in Fig. 1, standard low-power Schottky ("LS") devices can be used instead. The CMOS versions require less operating current, resulting in cooler operation of the voltage regulator in the power supply. No circuit changes are needed if you use the LS devices.

Shown below the main circuit in Part 2 of Fig. 1 is the power supply that operates the generator circuit. This is a standard full-wave supply, with rectification provided by *D2* and *D3* and main filtering provided by *C18* and *C19*. The +12- to +15-volt output from the rectifier/filter arrangement is regulated to +5 volts (which is further filtered by *C20*) to power *IC1* through *IC5*. Note also that a pair of unregulated bipolar supply lines (at +12 to +15 and −12 to −15 volts) are provided for powering *IC6*. Input power for the supply is provided by any 9-to-10-volt ac source, including a plug-in transformer if you should have one lying about.

Construction

Assembly of the programmable waveform generator is best done on a printed-circuit board. You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2. Alternatively, you can purchase a ready-to-wire pc board from the source given in the Note at the end of the Parts List.

Installation of the components on the pc board is fairly straightforward. Use sockets for *IC1* through *IC6* only. As shown in Fig. 3, begin populating the board by installing and soldering into place the IC sockets—*not* the ICs themselves. Then install the diodes (observe polarity), resistors and smaller capacitors. Leave the large electrolytic capaci-

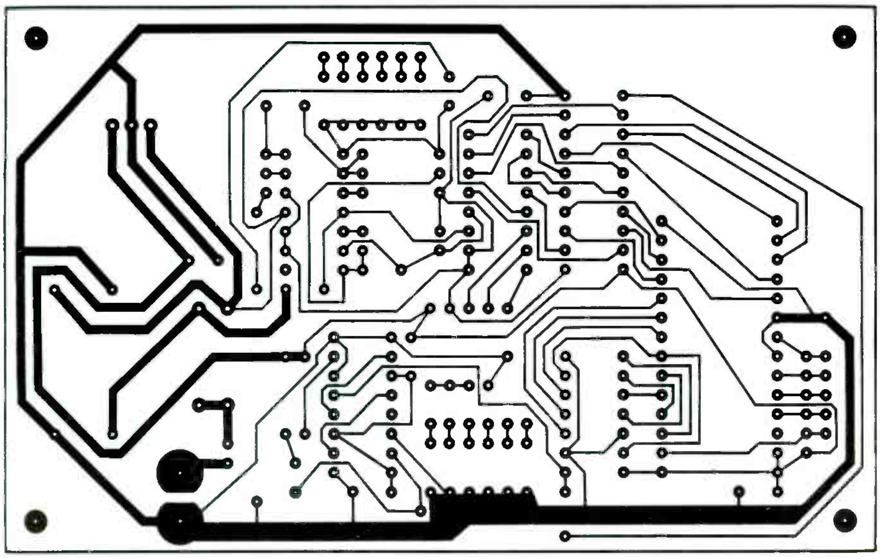


Fig. 2. Actual-size etching-and-drilling guide to be used for fabricating printed-circuit board.

tors and *IC7* for last. Work carefully to avoid creating solder bridges between the closely spaced solder pads and conductor traces.

There are several choices with regard to bringing power to the circuit board. You can mount a pc-type connector that is compatible with the connector on the 9-to-10-volt ac input source directly on the board. You can mount a panel-mount version of the same type of connector off the board. Or you can dispense with a connector arrangement altogether by using a 9-to-10-volt transformer that mounts inside the selected project enclosure and use a permanent ac line cord and appropriately rated fuse in its holder in place of an external transformer.

Once the other discrete components have been soldered into place on the board, install the electrolytic capacitors (observe polarity) and *IC7*, after bolting to the latter a small TO-220 heat sink. At this point, *IC1* through *IC6* should still not be installed in their sockets; they will be installed after voltage checks have been made. Install and solder into place the four wire jumpers on the board. For these, you can use bare or insulated solid hookup wire or even cut-off resistor or capacitor leads.

Place the circuit-board assembly on the floor of the enclosure in which the project is to be housed and mark the locations of the four mounting holes. Remove and set aside the circuit board and then drill the holes in the marked locations. Using ⅜" or ½" spacers and machine hardware, loosely mount the circuit board with POWER jack *J2* toward the rear wall of the enclosure. Carefully mark the outline of the jack on the rear wall. Once again, remove and set aside the circuit board.

Drill a ¼" hole in the marked location for the power jack. Then use a small file, nibbler or other suitable tool to carefully trim the cutout to appropriate size and shape. Test fit the jack occasionally to check your work. If you opt for the panel-mount jack or an internal power transformer, you need drill only a single round hole in which to mount the jack or pass through the line cord.

Preparation of the front panel will require a little more effort. Start by accurately marking the mounting locations for the switches, controls and INPUT jack *J1*. Make sure before you do any drilling or cutting that the controls and switches will not interfere with each other or the circuit-board assembly when mounted in place. When you are sure of the locations, drill the holes for mounting *J1, R2, R14* and *S1*.

Ordinarily, use of slide-type switches makes mounting a major operation because they require rectangular slots for their toggles plus two mounting holes for each. In the case of *S2* through *S6*, which mount side by side in this project, all you

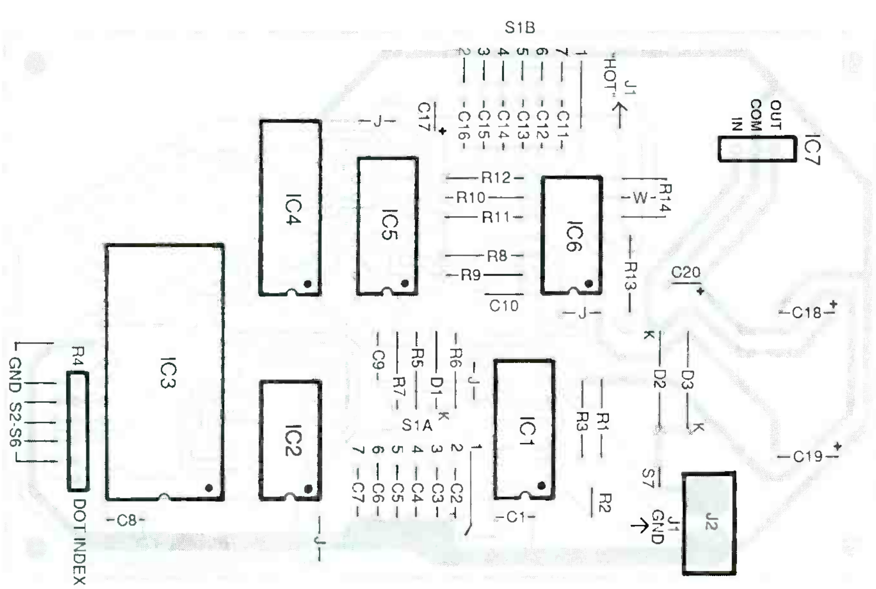


Fig. 3. Wiring guide for pc board.

need is a single long slot for the five toggles, though you must still drill 10 small holes for their mounting screws. (If you prefer not to have to cut a slot, you can substitute miniature toggle switches, in which case all you need is a single mounting hole for each switch.)

Assuming you have decided to use slide-type switches, you will find the slot to be relatively easy to cut. Start by accurately measuring the size of the slot, leaving about a 1/16" leeway all around, and transferring the dimensions to the front panel. Drill a hole at each end of the slot within the drawn rectangle and use a nibbling tool to cut away the unwanted material. If you do not have a nibbler, drill a 1/8" hole in each of the four corners of the drawn rectangle and then a series of holes spaced about one drill bit diameter apart all around the drawn slot shape. Then use a coping saw, Moto Tool or other suitable tool to cut through the material between the holes to remove the unwanted material. Any ragged edges or rounded corners can be dealt with using a small flat file or a Moto tool.

Once the slot is cut, test fit all five switches to make sure that enough material has been removed to assure smooth switch toggle operation. Mark the locations and drill the holes for the mounting screws. Then cut the slot or drill the hole for the POWER switch, depending on whether you are using a slide-type or miniature toggle switch.

Note in the lead photo that a two-contact screw-type terminal strip OUTPUT connector was also included in the prototype of the project. This is an option that is not really needed, though its inclusion will allow you to connect to the generator's output cables other than the usual phono type. If you decide to incorporate this option into the project, simply cut an appropriately sized slot for its solder lugs and drill the two holes for the mounting hardware.

Once the front panel has been prepared, temporarily mount the rotary switch and potentiometer controls in their respective holes and slip the control knobs onto their shafts. Use a pencil to very faintly draw the outlines of the knobs onto the front panel. Then rotate the knob on the range switch stop to stop in both directions and note the position of the pointer in both cases. Remove the knob and adjust the orientation of the switch to balance the locations of the stops. Then, after tightening the mounting nut and replacing the knob, rotate the latter to each position and mark this on the panel.

Remove the switch and controls and set them aside. Now, using a dry-transfer lettering kit, label the various controls, switches and OUTPUT jack (and identify the + and − contacts of the OUTPUT terminal strip if you have decided to incorporate it) as shown in the lead photo. If you wish, you can punch and cut appropriate-size holes and slots in and do all your labeling on a heavy white sheet of cardboard that then goes in front of the aluminum panel that comes with the enclosure. This done, spray on two or three *light* coats of clear acrylic to protect the lettering. Allow each coat to completely dry before spraying on the next.

When the acrylic spray has completely dried, mount the OUTPUT connector(s), rotary switch and potentiometer controls. Then use an ohmmeter or continuity tester to determine which position the toggles of the slide or toggle switches must be in to be on. Connect the probes of the meter or tester to the lugs of the switches and move the toggles to their alternate positions. Leave each toggle in the "on" position, as indicated by a short circuit, which will be zero ohm on the meter or will light an indicator or sound a buzzer on the continuity tester.

Without disturbing the toggles, install the five WAVE switches in the long rectangular slot for slide-type switches or in individual round holes for toggle switches so that all toggles are facing toward the *bottom* of the panel. Then install the POWER switch so that its toggle is toward the *top* of the panel. Rotate the knob on the RANGE switch stop to stop and note the pointer's position in each case. If the pointer does not align with the panel markings, reposition the switch until it does.

An easy way to make connections to the rotary RANGE and individual WAVE switches and the potentiometer controls is to use color-coded ribbon cable to provide a means for keeping track of wiring. Trim the cable to the length needed, separate the conductors at opposite ends a distance of 1" and 1/2" and strip 1/4" of insulation from all conductors at both ends. A length of 25-conductor ribbon cable is all that is needed. Separate this into bundles of seven, seven, six, three and two conductors.

At the circuit-board end, use the 1/2" separated ends of the cables. Plug the two-conductor cable into the *R2* holes in the circuit board and solder into place. Similarly, plug the three-conductor cable into the *R14* holes and solder them into place. The six-conductor cable goes to the holes labeled A8 through A12 and GND near R14. Finally, the seven-conductor cables go to the S1A and S1B holes on the circuit board.

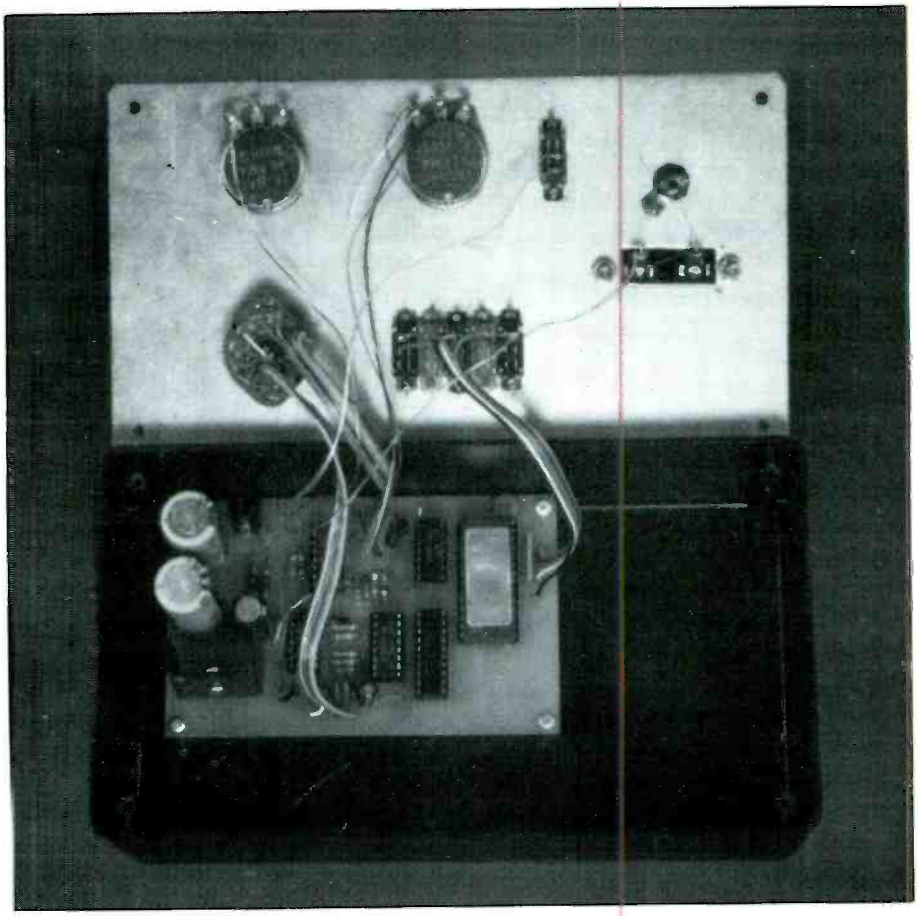
Connect and solder the free end of the two-conductor cable to the lugs on the FREQUENCY control. Similarly, connect and solder the three-conductor cable to the lugs on the LEVEL control (center conductor goes to wiper lug on control). Referring back to Fig. 3, connect and solder all but the GND wire of the six-conductor cable to the lower lugs of the appropriate WAVE switches. Run a bare solid wire through the upper lug holes of all five switches to tie them in common with each other, hook the GND wire of the six-conductor cable through one of these lugs, and solder all six connections.

Use an ohmmeter to figure out

which conductors in the S1A and S1B groups correspond to the different positions of the RANGE switch (identified by number on Figs. 1 and 3) and connect and solder the free ends of the two seven-conductor cables to the appropriate lugs of the rotary switch.

Use ordinary hookup wire to interconnect the appropriate points on the board with the POWER switch and OUTPUT connectors. Then, if you are using an internal power transformer, drill the holes for it through the floor of the enclosure in an area where it will not interfere with the circuit-board assembly or controls and an entry hole for the ac line cord through the rear wall. Mount the transformer with machine hardware, sandwiching the mounting tab of a two-lug terminal strip (both lugs isolated from the tab) between the head of one mounting screw and the transformer mounting tab. Route the free end of the ac line cord through the entry hole and tie a knot about 4" from the free end inside the enclosure to serve as a strain relief.

Connect and solder one transformer primary wire and one conductor of the line cord to one lug of the terminal strip. Connect the other line-cord conductor and one end of a 4" hookup wire to the other lug of the terminal strip and solder the connection. Connect and solder the other end of the 4" wire to one lug of the POWER switch. Then connect and solder the other primary lead to the other lug of the POWER switch and wire the transformer's secondary directly into the circuit in place of *J2*.



Interior view of project shows panel-mounted controls, switches and output connectors and floor-mounted circuit-board assembly. Note how pc-mount power jack fits into cutout on rear wall of enclosure.

Checkout

Before installing *IC1* through *IC6* in their sockets, power up the circuit and use a dc voltmeter set to measure 20 volts dc or so to check for proper voltages at key points in the circuit. With the meter's common probe connected to circuit ground at all times, touching the following socket pins should give you a +5 volt reading: *IC1* pins 3, 11 and 16; *IC2* pin 14; *IC3* pins 1, 27 and 28; *IC4* pin 20; and *IC7* pin 3 (output). At *IC5* pin 13, *IC6* pin 4 and *IC7* pin 1 (input), the reading should be between +12 and +15 volts, while at *IC5* pin 3, *IC6* pin 11 and the anode of *D3*, the reading should be between −12 and −15 volts. Though some variation in the +12- to +15-volt and −12- to −15-volt lines is permitted, in no case should these potentials exceed +/−18 volts.

Once you have verified that the proper potentials exist at the above key points in the circuit (or have rectified the problem if they did not), power down the circuit and allow the charges to bleed off the electrolytic capacitors. Then, exercising care in handling and orientation, install the ICs in their respective sockets. Make sure that no pins overhang the sockets or fold under between sockets and IC bodies.

Testing of the generator is fairly simple. Connect an oscilloscope to the generator's output via either *J1* or the terminal strip and turn on both the generator and the scope to view the waveform being generated on the latter's screen. Rotate the FREQUENCY control's knob and note that the frequency displayed increases as the control knob is rotated clockwise and decreases in the counterclockwise direction. Rotating the LEVEL control should cause the amplitude of the displayed waveform to increase and decrease in the clockwise and counterclockwise directions, respectively. If you note just the opposite results in either case, power down the project and rewire the offending control(s).

Setting the WAVE switches in different combinations of on and off should cause the waveform being displayed to change to another shape. If the generator does not appear to be working as it should, check components for proper placement, identification and polarity. If everything seems to be okay here, check for clock pulses at pin 1 of *IC2* and pin 11 of *IC4*. Also check to make sure that the address lines to *IC3* and the inputs to *IC5* (pins 5 through 12) are changing.

If clock pulses are being generated but *IC3*'s address lines are not changing, *IC2* is bad and must be replaced or is improperly connected. If the output data from *IC3* is changing but the inputs to *IC5* never do, *IC4* is the problem.

Waveform Programming

Generation of waveforms with the programmable waveform generator requires programming of the EPROM. This is best accomplished with a simple computer program that can generate the values to be stored in the EPROM for each of the desired waveforms. The *IC5* DAC-08 accepts data inputs in the 0-to-255 range and will produce a larger negative current for larger values of data inputs. A value of 255, for example, generates the largest negative current, while a value of 0 generates the largest positive current. Data values between 0 and 255 produce intermediate currents.

Since the *IC6* TL084 quad op amp has three stages operated as inverters, an input value of 255 to *IC5* will produce the largest output voltage swing. This makes it easier to generate EPROM programming data because the greater the voltage desired, the larger the value to program into a given EPROM byte.

Each waveform has 256 samples, meaning that the waveform must be broken down into 256 distinct sample values. For a 50-percent-duty cycle square wave, there will be 128 samples with a value of 0 followed by 128 samples with a value of 255. A pulse with a 25-percent duty cycle would have 192 samples with a value of 0 followed by 64 samples with a value of 255.

For waveforms that contain rounded curves, the procedure is more complex. The sine wave, for example, must complete one cycle in 256 samples. With one cycle consisting of 360 degrees (2π radians), each sample is 360/256, or 1.41 degrees. Since most computers calculate the sine function in radians, this is also $2\pi/256$, or 0.0245 radian.

The computer program used must calculate the value of the sine function 256 times, with 0.0245 radian between each value. The values must then be converted into integers between 1 and 255. With 1 representing a sine value of −1 and 255 representing a value of +1, 128 would represent a value of 0. A 1-to-255 range is used to give the wave 127 values above and below 0 volt. If a 0-to-255 range were to be used, the signal generated would not be symmetrical about the ground reference of 0 volt because there would be 128 values above but only 127 values below below 0 volt.

Program 1 both sets the 1-to-255 range and saves the values in memory using the Poke command. (The EPROM programmer I use requires the data to be sitting in memory to be programmed into the EPROM, which is why I "poked" it into memory.) The computed values could be stored in an array, sent out a serial port or saved on a disk, depending on how your EPROM programmer requires the data to be sent to it.

Program 2 is an example in which proper values are calculated for the function sin(X) + sin(2X), where X goes from 0 to 2π. This program generates a sine wave plus its second harmonic that has the same amplitude as the fundamental. A similar approach could be used to generate other functions that are a fundamental sine wave plus harmonics by changing the function calculated.

For a waveform that is not a simple function, you may have to use several program steps to generate the function. Or you may have to draw the waveform on graph paper and calculate the values by hand—a tedious task at best.

Waveforms Programmed Into EPROM

Waveform Number	Type of Waveform
0	sine
1	square
2	triangle
3	sawtooth (slow rise)
4	sawtooth (slow fall)
5	sin(X) + sin(2X)
6	sin(X) + sin(2X) + sin(4X)
7	sin(X) + ⅓sin(3X)
8	sin(X) + ⅓sin(3X) + ⅕sin(5X)
9	pulse (10% duty cycle)
10	pulse (20% duty cycle)
11	pulse (30% duty cycle)
12	pulse (40% duty cycle)
13	pulse (50% duty cycle)
14	pulse (60% duty cycle)
15	pulse (70% duty cycle)
16	pulse (80% duty cycle)
17	pulse (90% duty cycle)
18	absolute value of sin (X)
19	ringing (exponential decay, slow)
20	ringing (exponential decay, medium
21	ringing (exponential decay, fast)
22	staircase (eight steps up)
23	staircase (16 steps up)
24	spare waveforms
.	.
.	.
.	.
31	spare waveforms

Note: Ringing waveforms are at four times generator frequency and repeat at generator frequency rate.

Program 1. Sets 1-to-255 Range & Saves Values in Memory

```
5 REM GENERATE VALUES FOR SIN WAVE
6 REM AND PLACE IN MEMORY FROM $6000 TO $60FF
10 PI=3.14159
20 FOR T=0 TO 255
30 X=(2*PI)*(T/256): REM COMPUTE X IN RADIANS
40 Y=SIN(X):REM COMPUTE SIN VALUE
50 W=(Y*127):REM FIND OFFSET FROM ZERO IN RANGE +-127
60 Z=ABS(W):R=Z-(INT(Z)):REM DO ROUNDOFF
70 IF R<.5 THEN Z=INT(Z):GOTO 90
80 Z=INT(Z+1)
90 IF W<0 THEN P=128-Z:GOTO110:REM IF SIN<0 THEN NEG. VOLTAGE
100 P=128+Z:REM IF SIN POSITIVE THEN POS. VOLTAGE
110 POKE 24576+T,P
120 PRINT T,P
130 NEXT
140 END
```

Each waveform is 256 bytes in length and must begin with an address that is either 0 or a multiple of 256. The first waveform will be from bytes 0 to 255, the second from 256 to 511, and so forth. The generator's WAVE switches select a waveform by changing the higher-order address lines (A8 through A12). If all *S2* through *S6* switches are open (all higher-order address lines low), the waveform will start at address 256 × 0 = 0. With the A8 switch (*S2*) closed and all other switches open, the waveform will be read starting at address 256 × 1 = 256. Other combinations will result with different settings of the switches.

The starting and ending bytes for a waveform should be very close to each other in value; otherwise, the waveform will have a sharp edge generated each time the address counter starts over at 0. For sine waves generated as mentioned above, the starting and ending values for the waveform make a smooth transition. The waveform starts at 128 and ends at 125. For the square wave, the waveform starts at 0 and ends at 255, and it should have a sharp falling edge at the end of the wave.

Uses for this programmable waveform generator and the waveforms it can generate are limited only by the imagination of the user and the restriction of the 256 samples per waveform. Considering that each of the 256 samples can have different values, there are more than 10 to the 256 different possible waveforms that could be generated. This should be enough for even the most imaginative user. **ME**

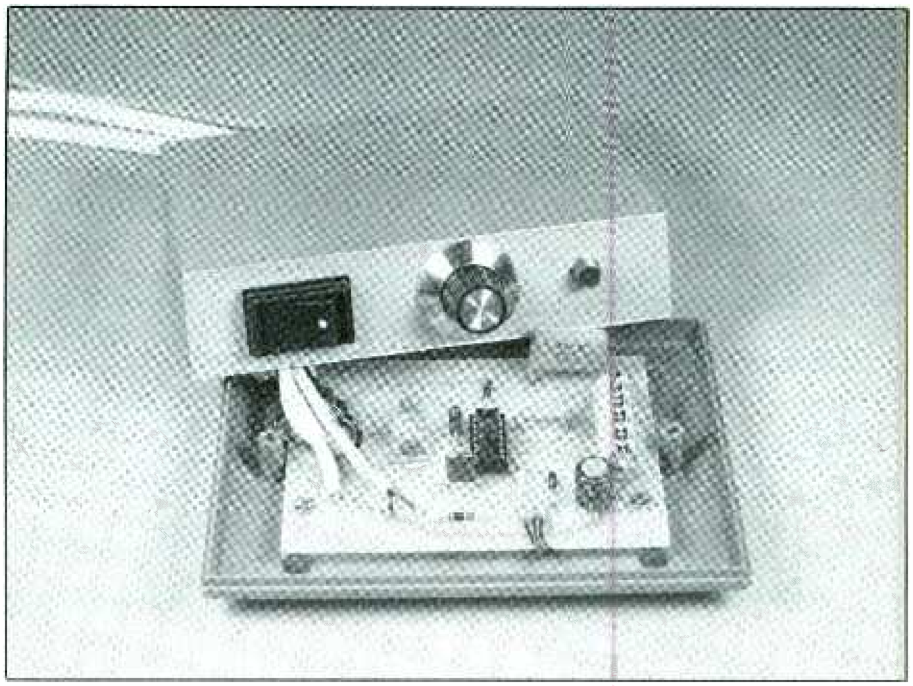
Program 2. Calculates Function Sin(X) + Sin(2X)

```
5 REM GENERATE VALUES FOR SIN(X)+SIN(2X)
6 REM AND PLACE IN MEMORY FROM $6000 TO $60FF
10 PI=3.14159
20 FOR T=0 TO 255
30 X=(2*PI)*(T/256): REM COMPUTE X IN RADIANS
40 Y=SIN(X)+SIN(2*X):REM COMPUTE SIN VALUE
50 Y=Y/2:REM KEEP IN RANGE OF -1 TO +1
60 W=(Y*127):REM FIND OFFSET FROM ZERO IN RANGE +-127
70 Z=ABS(W):R=Z-(INT(Z)):REM DO ROUNDOFF
80 IF R<.5 THEN Z=INT(Z):GOTO 100
90 Z=INT(Z+1)
100 IF W<0 THEN P=128-Z:GOTO120:REM IF <0 THEN NEG.  VOLTAGE
110 P=128+Z:REM IF SIN POSITIVE THEN POS.  VOLTAGE
120 POKE 24576+T,P
130 PRINT T,P
140 NEXT
150 END
```

Proportional Temperature Controller

A circuit that provides precise control of temperatures for darkroom film processing and other applications

By Jan Axelson & Jim Hughes



Proportional control is a type of automatic control that is used in applications where precision is important, such as in developing color photographic film. For consistent results, film-developing chemicals must be maintained at a specific constant temperature during processing (for example, 100 degrees Fahrenheit ±0.5 degree for color slides).

A proportional controller can automatically maintain this or a lower or higher temperature used in other processing applications. The controller described here automatically maintains a constant preset temperature in three gallons of water that serves as a holding bath for containers of photographic chemicals. Our controller's design is made quite simple, and the project is low in cost to build, thanks to the Signetics TDA1023 integrated circuit time-proportional triac trigger device that controls current through a triac and an immersion heater.

Proportional Control Concept

Understanding how proportional control works requires a basic understanding of how controllers in general work. Figure 1 is a block diagram of a simple on/off temperature-control system you might find in an oven or household heating system. The system consists of a sensor, setpoint selector, error detector, controller and, finally, a heater.

Temperature changes caused by perhaps a change in resistance, voltage or volume causes the sensor to react. The setpoint adjustment (a temperature setting dial, for example) tells the system what temperature is desired. The error detector compares the sensed temperature with the desired temperature and signals the controller to take action to reduce

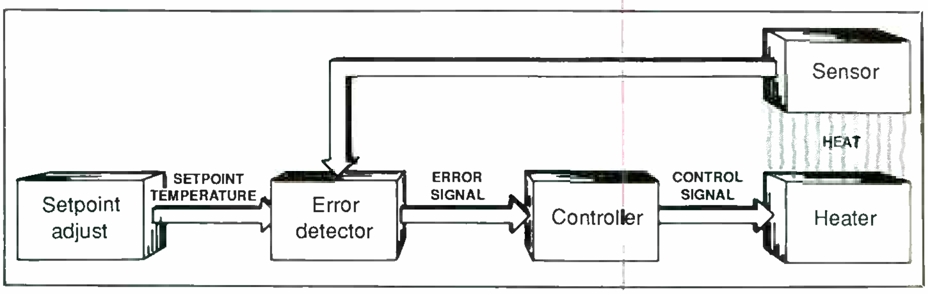


Fig. 1. A simple on/off temperature-control system for an oven.

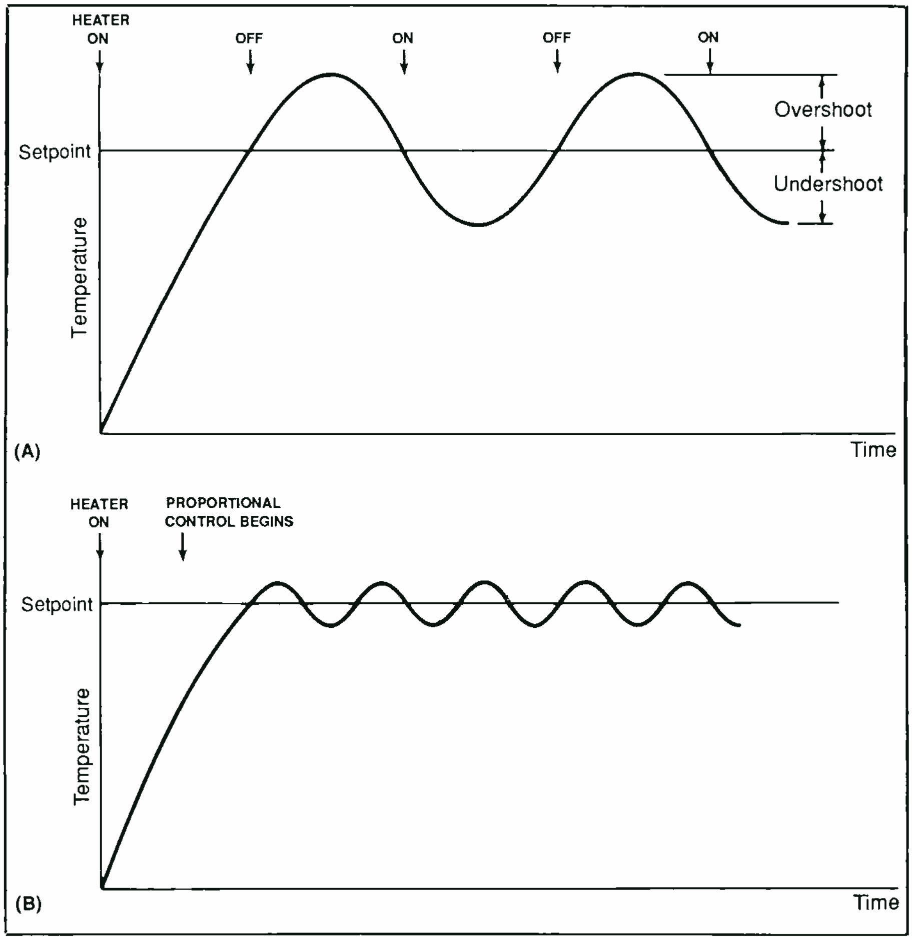


Fig. 2. Characteristic performance of on/off temperature-control system (A) and proportional control system (B).

the error if there is a difference between the two temperatures. The controller then turns the heater on or off as instructed.

Figure 2A shows the limitation of this kind of control. Because the heater does not turn off or on until the temperature has already reached the setpoint, the temperature overshoots and undershoots the desired level. In many situations, a few degrees fluctuation like this is not critical. However, for photography applications, where there is little room for error, a way of keeping the temperature precisely "on the mark" is needed.

Figure 2B shows the more precise control made possible by proportional control. Precision is achieved by anticipating the setpoint. As the temperature approaches the desired value, the controller gradually cuts back power to the heater. This fine tunes the system and prevents large deviations from the setpoint.

Signetics' TDA1023 is specifically meant for use in proportional controllers. As shown in Fig. 3, this IC contains buffers for setpoint and sensor inputs, a comparator, control gate, timing generator and even a small dc power supply. (Pinouts for the TDA1023 are shown in Fig. 4.)

Power from the 117-volt ac line is provided to the TDA1023 at RX. The on-chip supply provides an 8-volt reference for the sensing circuit at Vz, eliminating any need for a separate dc power supply.

A comparator compares the setpoint voltage at CI with the sensor voltage at UR and generates an error signal that is fed to a control gate. Notice that a timing generator also affects the comparator. Inputs PR and TB set the range and period of a control cycle, which typically lasts anywhere from a fraction of a second to a minute. This control cycle is the key to the proportional-control action of the circuit.

As the sensor voltage approaches the setpoint, the control gate is enabled for just part of each cycle, in proportion to the magnitude of the measured error. In turn, the control gate enables an output amplifier to provide gate-current pulses to a triac connected in series with a heater.

When the temperature is near the desired point, the heater is turned on just long enough to maintain the temperature without overshooting it. Figure 5 shows how the current through the heater varies as the temperature changes in relation to the setpoint.

Other features of the TDA1023 are a fail-safe circuit, an internal resistor for use with sensitive triacs, adjustable hysteresis in the comparator, and an optional translation circuit for finer setpoint control. To minimize radio-frequency interference (rfi), a zero-crossing detector synchronizes the gate pulses with the zero crossings of the ac line voltage.

About the Circuit

Shown in Fig. 6 is the complete schematic diagram of the heater control circuit. Power is applied to it via the RX input at pin 6 of *IC1* through the current-limiting network made up of *C3* and *R6*.

Temperature sensor *R2* is a negative-temperature-coefficient (ntc) thermistor. As the thermistor's temperature rises the resistance of *R2* drops. At room temperature, *R2*'s resistance is about 50,000 ohms. Raising the temperature to 100 degrees Fahrenheit causes *R2*'s temperature to drop to about 25,000 ohms.

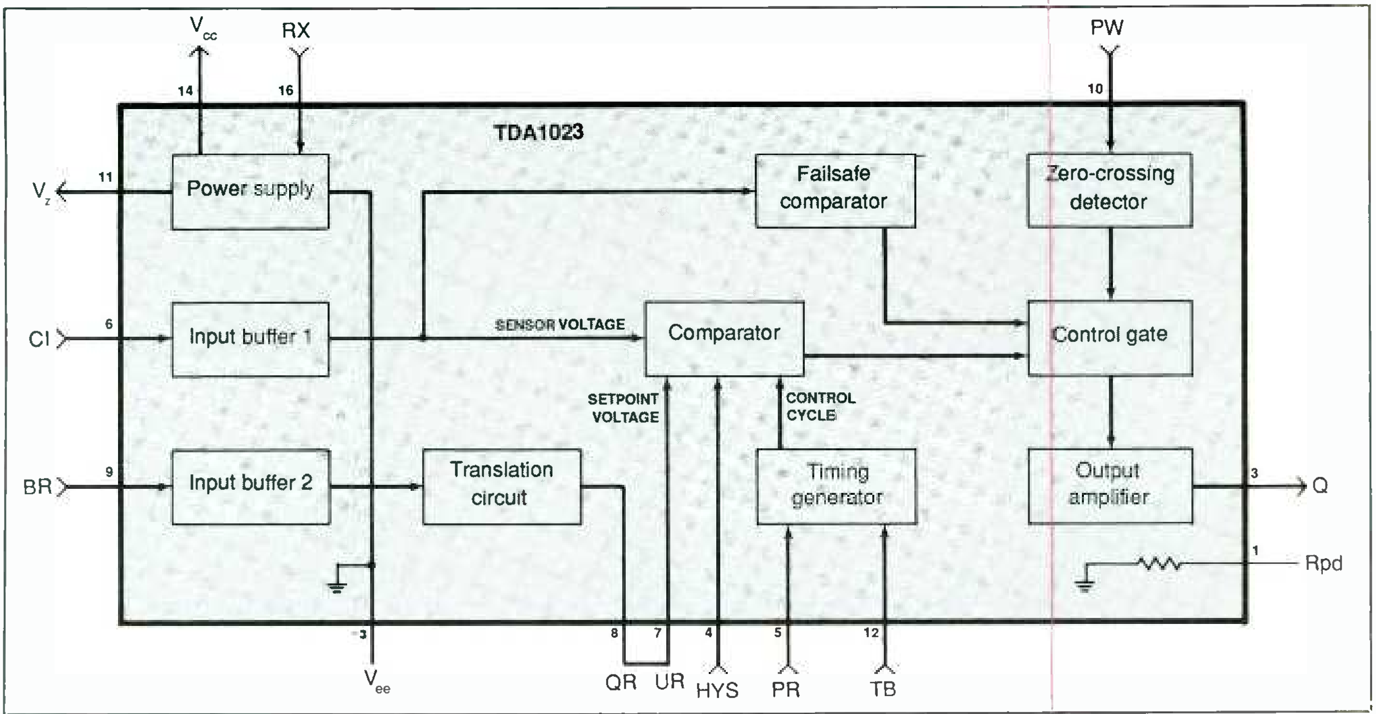
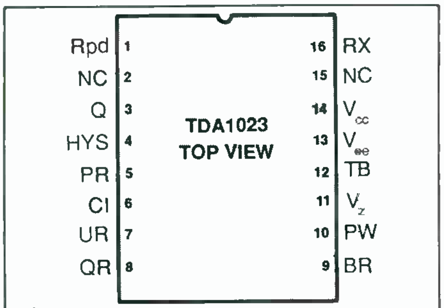


Fig. 3. Internal details of Signetics' TDA1023 time-proportional triac trigger integrated circuit.



Pin No.	Legend	Meaning
1	Rpd	Internal pull-down resistor
2	NC	Not connected
3	Q	Output
4	HYS	Hysteresis control input
5	PR	Proportional range control input
6	CI	control input
7	UR	Unbuffered reference input
8	QR	Reference buffer output
9	BR	Buffered reference input
10	PW	Pulse width control input
11	V_Z	Reference supply output
12	TB	Firing burst repetition control input
13	V_{ee}	Ground connection
14	V_{cc}	Positive supply connection
15	NC	Not connected
16	RX	External resistor connection

Fig. 4. Case configuration and pinouts for the Signetics TDA1023.

Resistor *R1* and thermistor *R2* make up a voltage divider between the 8-volt reference and ground, and the voltage at pin 6 of *IC1* is the sensor input to the internal comparator. Resistors *R3* and *R5* and potentiometer *R4* control the setpoint at pin 9 of the IC, which connects via the translation circuit at pin 7.

Capacitor *C4* sets a period of about 6 seconds for the control cycle. Pin 5 of *IC1* is left open (no connection) to select a proportional range of 80 millivolts. This means that the duty cycle (on time) of the gate pulses at pin 3 varies from 0 to 100 percent over an 80-millivolt change at pin 6. Grounding pin 5 would increase this range to 400 millivolts.

The open HYS input at pin 4 of *IC1* selects minimum hysteresis, or dead band, of 20 millivolts in the comparator.

This circuit is designed to control a 200-watt immersion heater that plugs into ac receptacle *SO1* and whose heating element is immersed in a 4-gallon plastic tub filled with water. Triac *Q1* controls power to the heater. When pin 3 of *IC1* outputs gate pulses, *Q1* turns on and current flows through the triac, heater and neon-lamp indicator *I1*. When the gate pulses cease, *Q1* turns off and cuts off power to the heater.

Resistor *R8* limits the current to *Q1*'s gate, and resistor *R7* sets the width of the triac's gate pulse. Smoothing is provided by *C1*.

Construction

Just about any traditional board-wiring method can be used to build this project. If you wish, you can fabricate your own printed-circuit board using the actual-size etching-and-drilling guide shown in Fig. 7. Alternatively, you can use unclad perforated board with holes on 0.1″ centers and suitable Wire Wrap or soldering hardware. Whichever method you choose, it is a good idea to use a socket for *IC1*.

Though most component values and types are not critical, here are some things to keep in mind when selecting components: Resistor *R1* should be a 1-percent precision type because it is part of the temperature-sensing circuit (its exact value is not

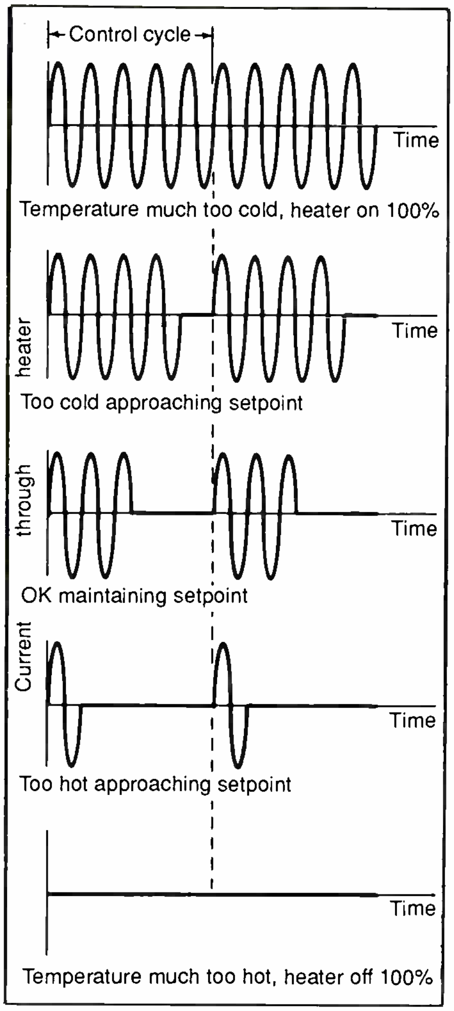


Fig. 5. Using proportional control current to power a heater varies according to how close the temperature is to the setpoint.

that important, but its resistance must be stable and not vary with temperature). Notice, too, that *R6* is a 1-watt power resistor and is used with *C3* to take care of the important function of limiting input current to *IC1*. If you must make a substitution in this network, it is safer to experiment with slightly smaller values for *C3* or larger values for *R6*. Finally, *C4* can be either a tantalum (preferable) or aluminum electrolytic capacitor. Though aluminum electrolytics are not recommended for use in timing circuits, due to their characteristically high leakage, you can use one here because the exact length of the timing cycle is not super-critical.

After installing the IC socket, wire the board exactly as shown in Fig. 8 (or use the layout in Fig. 8 as a rough guide to component arrangement on perforated board and refer back to Fig. 6 for wiring details). Be sure to orient *C1, C4* and *Q1* properly before soldering their leads into place. Also, to provide adequate heat dissipation, mount power resistor *R6* so that there is ⅛" of air space between it and the top of the board.

Use pliers to bend the leads of the triac to conform to the hole arrangement on the board for its leads and mounting tab. Bend the leads at the appropriate points so that they form a right angle pointing toward the metal rear surface of the triac. Plug the leads into the holes in the board, solder them into place and trim away any excess lead length. Then place a small washer between the triac's mounting tab and board and use a 4-40 × ¼" or ⅜" machine screw and nut to secure it to the board.

To make the cables for the circuit, you need a standard ac extension cord or an ac line cord with plug and a chassis-mount ac receptacle, 48" of two-conductor cable (zip cord will do fine) and some solid hookup wire. Cut the extension cord in half, separate the cut ends for a distance of about 2" and strip about ¼" of insulation from all four conductors. Tightly twist together the fine wires in each conductor and sparingly tin with solder.

Strip 2" of insulation from both conductors at one end of the two-conductor cable. Remove ¼" of insulation from both and slide a 1" length of small-diameter heat-shrinkable tubing over each. Trim the leads of the thermistor to ¾" long and form a small hook in each. Connect and solder the leads of the thermistor individually to each of the prepared conductors of the cable. Push the tubing up over the soldered connections and shrink into place.

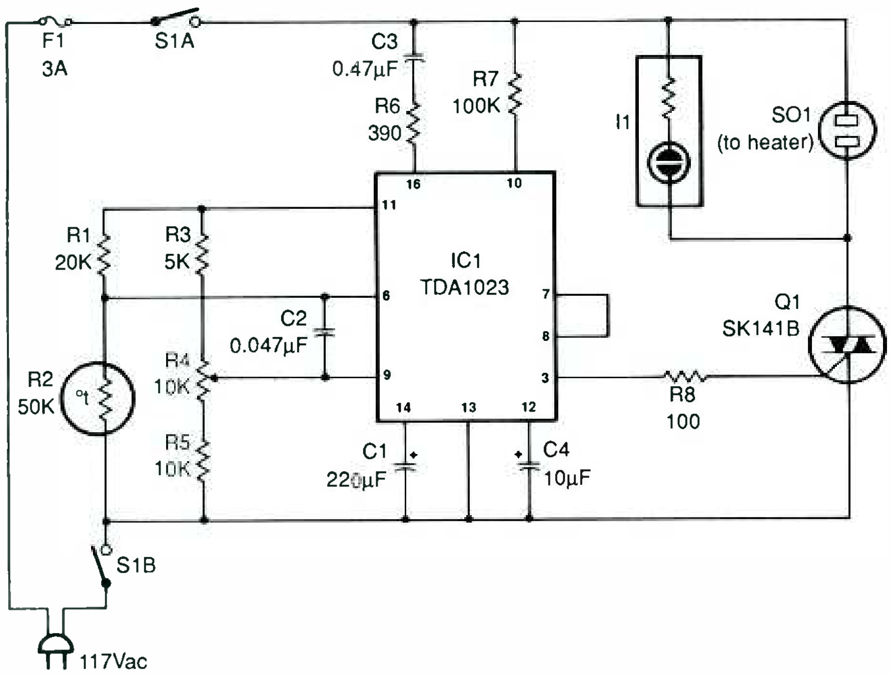
Slip a 2" length of ¼"-diameter heat-shrinkable tubing over the thermistor end and shrink it into place so that only the thermistor is visible and that all connections and wires are sealed inside. Separate the conductors at the other end of the cable for a distance of about 1" and trim ¼" of insulation from each. Once again, tightly twist together the fine wires in each conductor and sparingly tin with solder.

Now strip ¼" of insulation from both ends of eight 8" lengths of hookup wire. Connect and solder one end of two of these wires to the the leads of the neon-lamp assembly, three more wires to the lugs of the potentiometer and the three remaining wires to the lugs of the switch. Slide a ½" to ¾" length of small diameter heat-shrinkable tubing over the lamp assembly wires and shrink it into place to cover the connections.

To prepare the enclosure, begin by machining the mounting holes for the lamp assembly, switch, potentiometer, fuse holder and circuit-board assembly and the entry holes for the thermistor cable and line cord. You have a choice of using either a chassis-mount ac receptacle or the receptacles at the end of a standard ac extension cord for *SO1*. If you use the former, you must cut a slot and two hardware mounting holes for it in the chassis; if the latter, simply drill a single hole for exit of the cord. Use of an ordinary ac extension cord, of course, is the easier way to go in terms of work involved

A chassis-mounted ac receptacle for *SO1* requires an extra 5" or so length of two-conductor zip cord or separate 14-gauge stranded hookup wire to connect it to the circuit board assembly.

Mount the lamp, potentiometer and fuse holder in their respective holes. Then, referring to Figs. 6 and 8, plug the free ends of the wires on these components into the respective holes in the circuit board and solder them into place. The 4" wires con-



PARTS LIST

Semiconductors
C1—TDA1023 time-proportional triac trigger (Signetics)
Q1—SK141B or similar 200-PIV triac
Capacitors
C1—220-µF, 200-volt electrolytic
C2—0.047-µF ceramic disc
C3—0.47-µF, 200-volt polyester film
C4—10-µF tantalum (or aluminum electrolytic; see text)
Resistors (¼-watt, 10% tolerance)
R1—20,000 ohms (1% tolerance; see text)
R2—Negative temperature coefficient thermistor; 50,000 ohms at 25 degrees Celsius
R3—5,000 ohms
R5—10,000 ohms
R6—390 ohms (1 watt)
R7—100,000 ohms
R8—100 ohms
R4—1,000-ohm, linear-taper, panel-mount potentiometer
Miscellaneous
F1—3-ampere fuse
I1—Panel-mount neon-lamp assembly
S1—Dpst 3-ampere switch
Printed-circuit board or perforated board and Wire Wrap or soldering hardware; 16-pin IC socket; suitable enclosure; standard ac extension cord or ac line cord with plug and chassis-mount ac receptacle (see text); fuse holder; pointer-type knob for R4; two-conductor cable; plastic tube for thermistor (see text) and silicone adhesive; heat-shrinkable tubing; cable ties; ½″ metal spacers; machine hardware; hookup wire; solder; etc.

Fig. 6. Complete schematic diagram of the proportional temperature controller.

nected to the switch and fuse holder will be connected later. Line the ac line cord hole, thermistor entry hole and extension-cord exit hole if you use the extension-cord arrangement for *SO1* with rubber grommets. Pass the free ends of the cords through their respective grommet-lined holes and tie a knot about 6″ from the prepared ends inside the enclosure to serve as strain reliefs.

Plug into the appropriate holes in the board and solder into place the *SO1* lines and the *R2* thermistor cable. Then mount the circuit-board assembly using ½″ spacers and 4-40 or 6-32 × ¾″ machine screws, lockwashers and nuts.

Locate the free end of the last wire coming from the switch and connect and solder it to one lug of the fuse holder. Then connect and solder one ac line cord conductor to the other lug of the fuse holder and the other to the remaining switch lug.

Plug the fuse into its holder and the IC into its socket. With regard to the latter, make sure that the IC is properly oriented (see Fig. 8) and that no pins overhang the socket or fold under between IC and socket as you seat the IC. Now gather up the loose wires into a neat bundle and use plastic cable ties or waxed lacing cord to hold them together. Slide the knob onto the shaft of the potentiometer control.

Checkout and Use

With no heater plugged into *SO1*, rotate the control to roughly mid-position and plug the controller's line cord into an ac outlet. Using a multimeter set to read dc volts, check at pin 14 of *IC1* for the presence of about 14 volts. This voltage is not smoothly regulated; hence, a variation of about ±0.3 volt or so is normal. Also check for the 8-volt dc reference potential at pin 11 of the IC. (*Caution:* When working inside the powered project, keep firmly in mind that several points of the circuit are at potentially hazardous 117-volt ac line potential, including *Q1*'s hold-down screw. So exercise caution when taking voltage readings in the circuit.) If the voltages check out okay, power down the project. If not, double check all wiring and soldering and all components for proper placement and orientation.

To fully check out and use the proportional temperature controller, you need a so-called "beverage heater" like the one shown in the lead photo. Immersible heaters that have a skirt around the heating element are best because the skirt holds the element away from the side of the holding tub with which it is used.

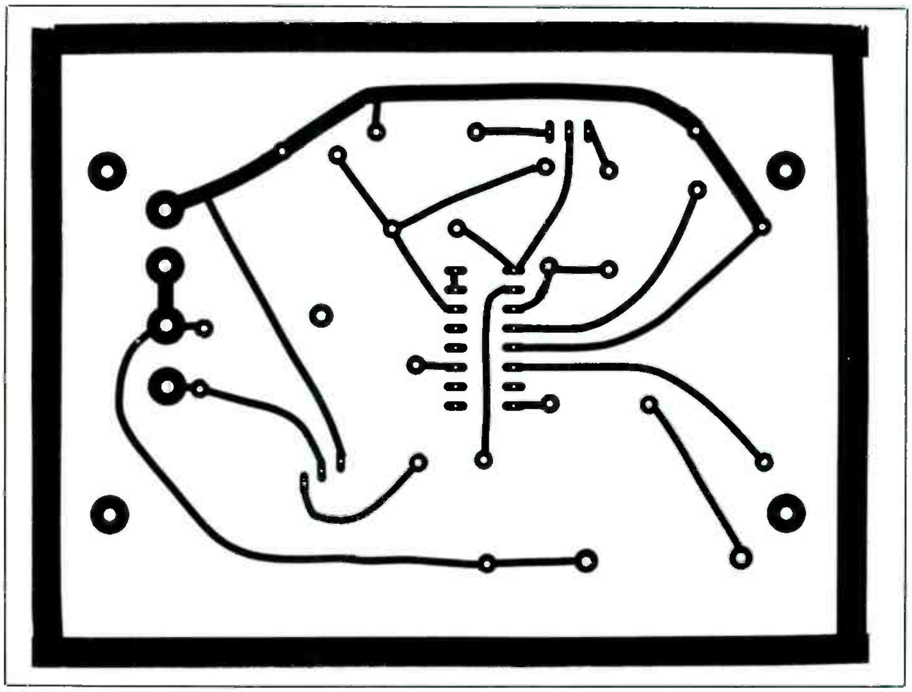


Fig. 7. Actual-size etching-and-drilling guide for printed-circuit board.

You also need a four-gallon plastic tub, a plastic or metal tube that is sealed at one end to hold the thermistor, and an accurate thermometer for monitoring and calibration.

Slide the thermistor into the tube and seal the open end with silicone adhesive or gasket seal. If you are unable to locate a tube with one sealed end, you can use one with both ends open simply by sealing both with silicone adhesive.

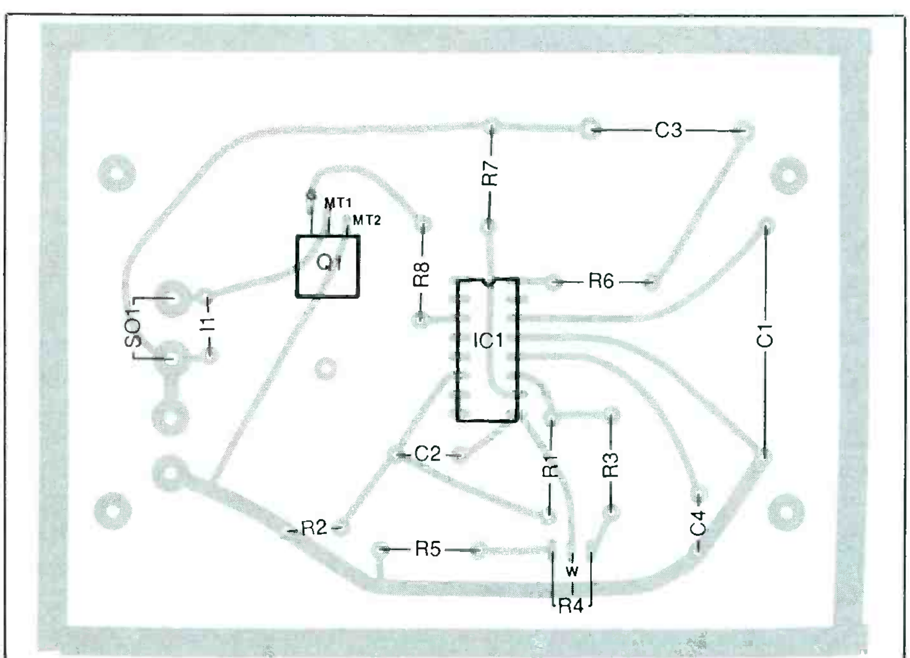


Fig. 8. The wiring diagram for the pc board. Use this layout as a guide to component placement if you wire the circuit on perforated board.

Securely fasten the thermistor assembly and immersible heater to the side of the plastic tub. One way to do this is to punch holes in the tub well above the water line and loop the ties through the holes and around the tube and the plug on the heater. Do not allow the heater's coil to rest against the side of the tub. Fasten the heater so that filling the tub with 2.5 gallons of water will immerse the heating coil but not the electric cord. Use the "maximum fill" line on the heater as a guide to maximum water level in the tub.

Never attempt to operate the immersion heater unless it is in water. Most heaters have a safety fuse that will permanently blow if you do this and the coil overheats.

Fill the tub to the proper level with cold water and place an accurate thermometer in the water. Plug the heater's power cord into *SO1* and turn on the project. The neon-lamp indicator should now light up, indicating that the project is delivering power to the heating element to heat the water.

As the water warms to the setpoint, you will see the proportional controller in action as the neon lamp turns off for a short portion of each cycle, indicating that the heater is being cycled off. At this point, the temperature should begin to stabilize, as indicated on the thermometer.

If the heater does not turn on at all, however, measure the voltages at the sensor and setpoint inputs at pins 6 and 7 of *IC1*. For the heater to come on, the voltage on pin 6 must be greater than that on pin 7.

By adjusting the setting of the potentiometer control on the project's front panel in increments and monitoring the temperature, you should be able to set the temperature of the water in the tub to any point in a range from about 80 to 105 degrees Fahrenheit. Of course, the exact range depends on the values of your

thermistor and the *R3/R4/R5* combination.

When the temperature of the water has reached 100 degrees, set *R4* so that the neon lamp is on for about half the period of each timing cycle. Give the system 15 minutes or so to stabilize and then check the temperature on the thermometer. If the temperature has strayed from 100 degrees, adjust the front panel control until it is brought into line. When all is working properly, mark the setpoint on the project's panel for future reference.

For best control, once the water heats up, the controller should operate within its proportional range, which means that the heater should never be on or off for an entire control cycle. Varying cycle duration may make a difference in how well the system exercises its control; so feel free to experiment with different values of capacitance for *C4*. (Halving the value of *C4* will halve the length of the control cycle.) Of course, the wattage rating of the immersion heater, how much water it is heating, room temperature and selection of setpoint all affect the controller's ability to maintain the desired temperature.

For super-accurate control, use a small electric fountain pump to agitate the water to keep layers of different temperatures from forming in the water. Keep in mind that every time you add a new bottle of chemicals to the tub that you will have to give the system time to heat them to the proper temperature before using them. How long it takes for the added bottles of chemicals to come up to optimum temperature will depend on how cool they are with respect to the water in the tub. The larger the temperature difference between the two, the longer the waiting time. However, you can considerably shorten the waiting time by immersing the chemicals in a basin of hot water for a few minutes to reduce the temperature differential. **ME**

Process Control With Personal Computers

(Part II)

Sensors, stepping motors and interfaces for computerized control systems

By Dr. H. Edward Roberts

Last month, Part I introduced the basics of process control with IBM PC/XT/AT or compatible computers and an internal and external controller bus system to allow such standard computers to perform these "real world" tasks. The system used consisted of Datablocks' LINK interface board and an A-II external bus structure in a shielded case, the latter allowing a host of encased control modules to be plugged in. This creates some 2,000 additional I/O channels without interfering with the normal computer system's operation.

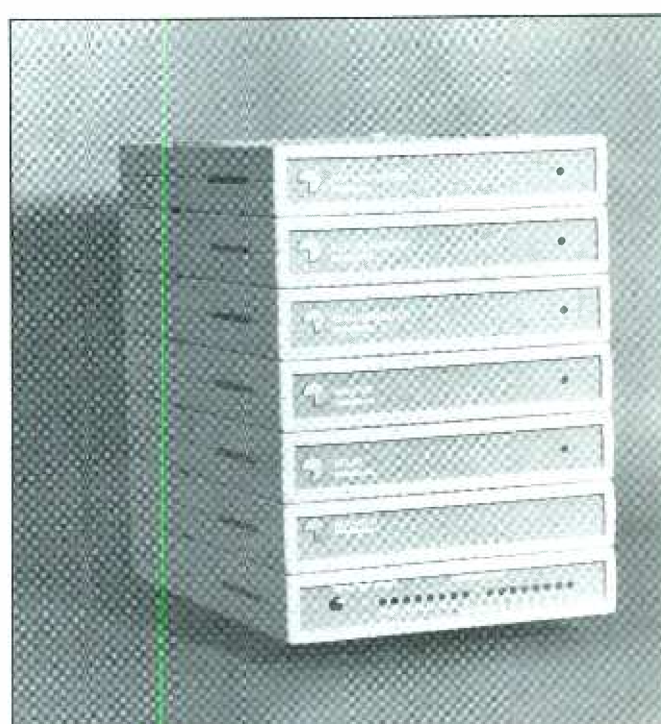
Block diagrams of the interface boards and the parts they contain are shown in Figs. 4 and 5, with construction plans, parts required and a kit source noted. Now we'll discuss external devices, such as sensors and stepping motors, that are needed to make it all happen, as well as software control and a few simple control projects.

Transducers

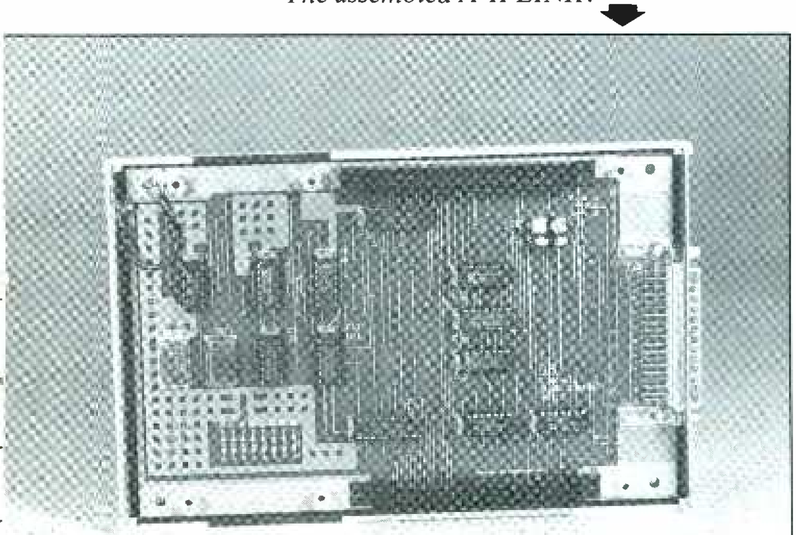
Transducers or sensors are needed to "hear," "see" and "feel" the outside world. Basically, they're devices that convert a physical change to an electrical value, say, temperature to voltage. This allows a computer to deal with various physical quantities or energy to be measured, monitored and/or controlled. The sensors generate analog electrical signals which must then be converted to digital signals through an analog-to-digital converter (ADC) in order for a computer to handle them. A digital-to-analog converter (DAC) is employed to send signals from the computer to the physical device to be controlled.

Transducers come in many types

DataBlocks A-II external control modules plug together as function blocks.



The assembled A-II LINK.



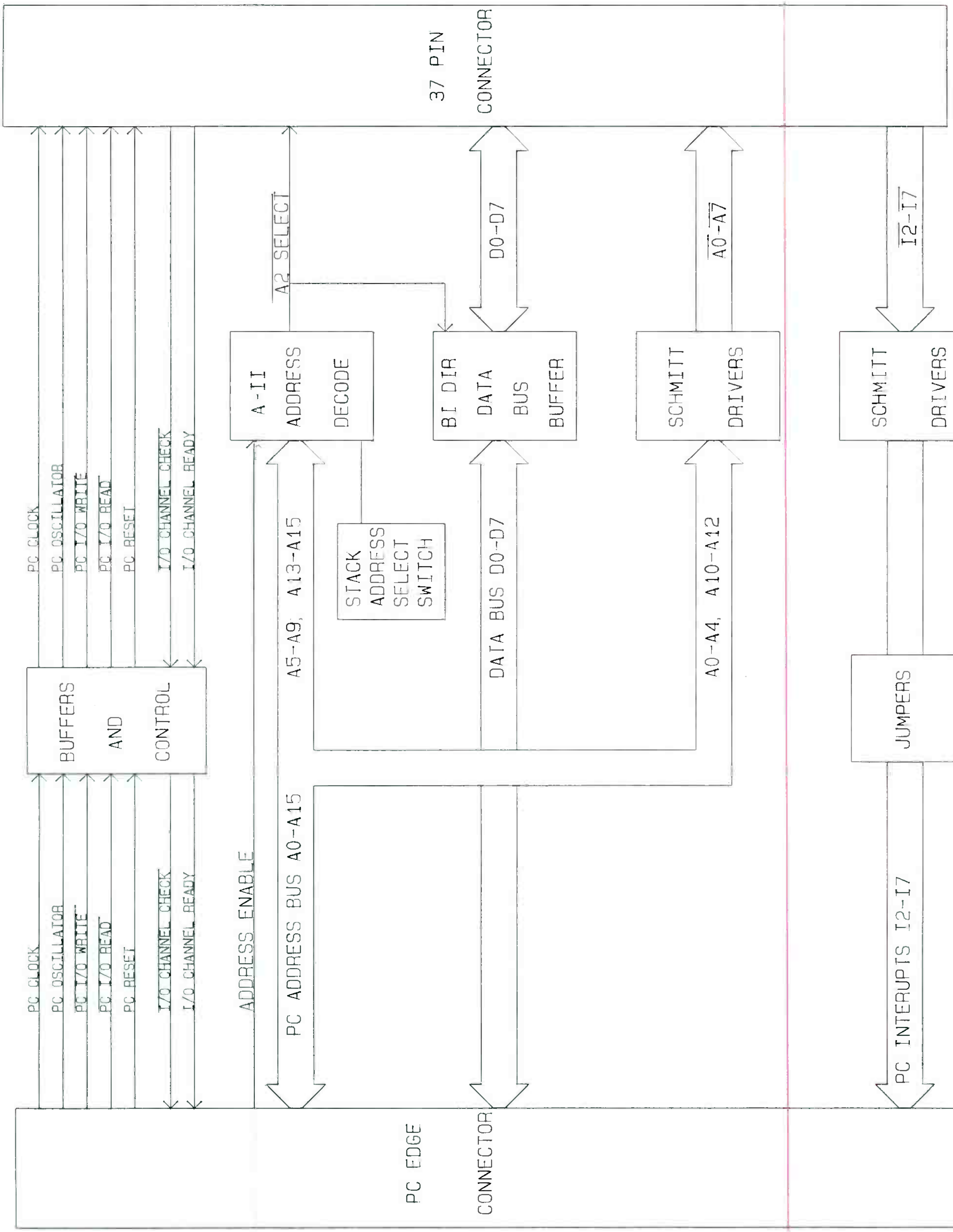


Fig. 4. Block diagram of PC-LINK, PC side.

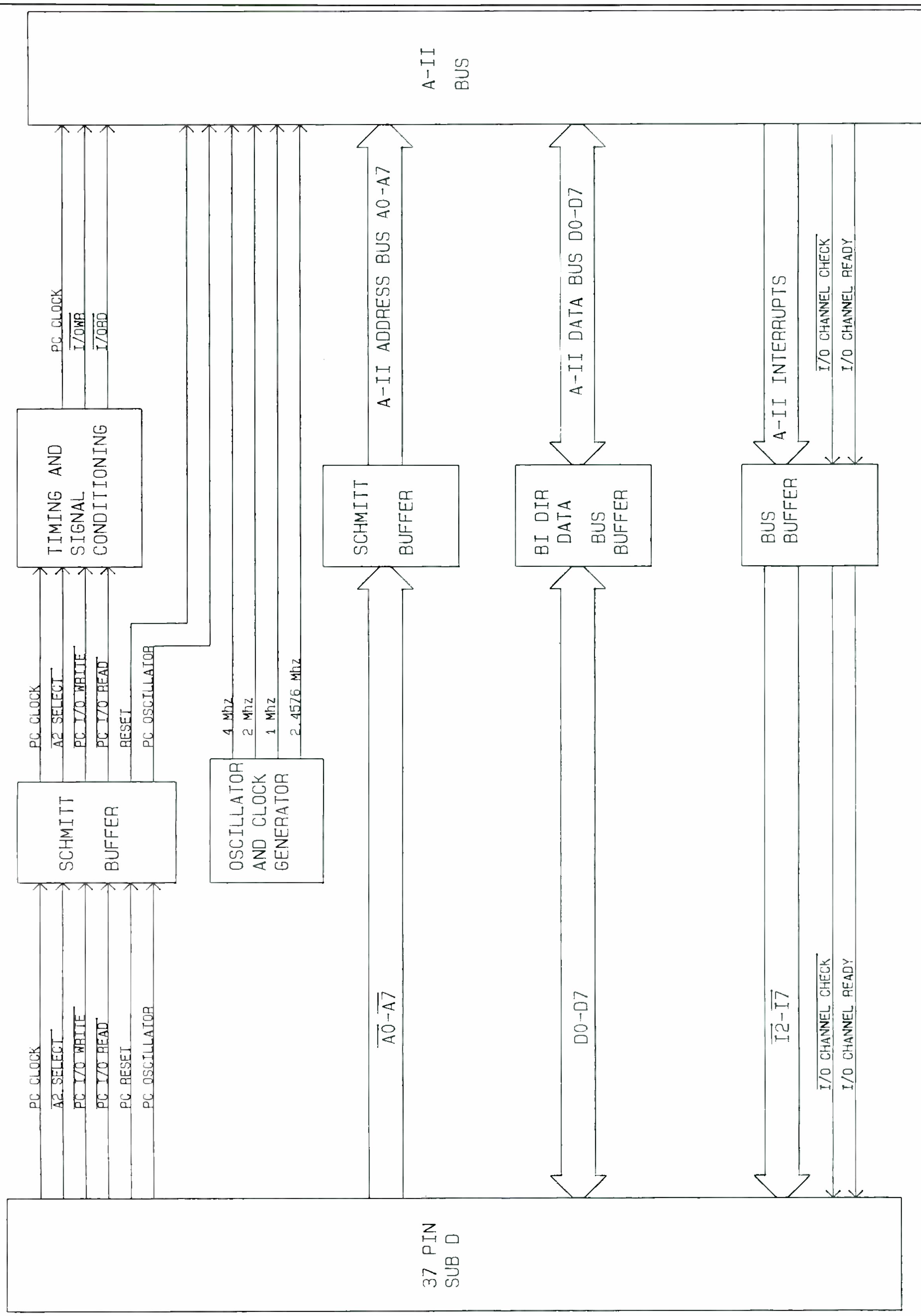


Fig. 5. Block diagram of PC-LINK, A-II side.

PARTS LIST

(PC Side)

Integrated Circuits

IC1—74HC03 open-drain NAND gate (Motorola)

IC2—74HC688 8-bit equality detector (Motorola)

IC3—74HC245 octal transceiver (Motorola)

IC4 thru IC7—74HC14 inverting Schmitt trigger (Motorola)

IC8—74HC00 quad 2-input NAND gate (Motorola)

Capacitors

C1 thru C8—0.47-μF ceramic disc

Resistors (¼-watt, 5% tolerance)

R1 thru R14—10,000 ohms

Miscellaneous

SW1—4-position spst DIP switch

Printed-circuit board and mounting bracket with screw (DataBlocks); six 14-pin and two 20-pin IC sockets; 37-pin D-type right-angle connector; machine hardware; solder; etc.

(A-II Side)

Integrated Circuits

IC2,IC2—74HC245 octal transceiver (Motorola)

IC3,IC11—74HC73 dual J-K flip-flop with clear (Motorola)

IC4,IC10—74HC74 dual D flip-flop with preset and clear (Motorola)

IC5,IC6,IC7—74HC14 hex inverting Schmitt trigger (Motorola)

IC8—74HC00 quad 2-input NAND gate (Motorola)

IC9—74HC04 hex inverter (Motorola)

IC12—74HC10 triple 3-input NAND gate (Motorola)

Capacitors

C1 thru C12—0.47-μF ceramic disc

C13,C16—47-μF, 16-volt electrolytic

C14,C15—47-μF, 10-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1 thru R8—10,000 ohms

Oscillators

OSC1—8.0 MHz (NEC)

OSC2—2.4576 MHz (NEC)

Miscellaneous

Printed-circuit board (DataBlocks); ten 14-pin and two 20-pin IC sockets; 37-pin D-type male right-angle connector (Amp); 37-pin shielded cable with 37-pin D-type connector on both ends (DataBlocks); two male 60-pin Molex connectors; two 60-pin female Molex connectors; machine hardware; solder; etc.

Note: The following items are available from DataBlocks, Inc., P.O. Box 449, Alamo, GA 30411 (tel.: 800-652-1336): IBM (or compatible) half of LINK—double-sided, plated and silkscreened pc board, $29; complete kit of parts, including pc board, ICs, etc., $65. Complete LINK, IBM and A-II halves—pc boards only, $49; complete kit of parts, including pc boards, connectors, cabling, ICs, etc., but excluding case, $118; complete assembled and tested LINK, in case, $187. shielded A-II case, $12. All schematics and foil patterns (included with foregoing kit) are available separately for $8. Add $5 P&H. Georgia residents, please add state sales tax.

and forms, depending on the physical properties they must sense. Consequently, there are transducers specifically designed to sense temperature, pressure, light, humidity, flow, chemical action, etc. There are a variety of different types within each category, of course, giving users a great deal of flexibility. For example, to measure or control temperature, one could use a thermocouple-junction device that produces voltages that are proportional to temperatures. These are low-cost, rugged devices, but don't feature tight accuracy or quick response time. Other choices for this purpose include thermistors, which react to temperature changes with a shift in its resistance, but their operating range is rather narrow; resistance-temperature detectors, which are more refined (and costlier) devices than thermistors, feature fast response time and precision measurement capabilities when used with bridge circuitry; and semiconductor temperature sensors feature great linearity.

Once transducers have been selected, it might be necessary to calibrate them. Typically, conversion tables to correct for temperature dependencies, nonlinearities, etc., are supplied by the transducer's manufacturer. Once the transducers have been selected, calibration curves prepared and the microcomputer interfaced to the transducer(s), channels for data collection and device control are established. Next comes the software, which must gather and prepare information as it's collected for output, whether for controlling an external device or for printed reports. For the former, this might mean transmitting the necessary information in the appropriate format to, perhaps, increase or decrease flow, raise or lower pressure or temperature, and so on. For data logging, this might mean transferring data to a hard-copy device such as a printer, or to a disk for information storage.

Sensor Systems

Let's look at some of the more common types of transducers to gain a better understanding of how to design a sensor system. Consider a pressure transducer, which is used to convert a fluid pressure, say, air or liquid, into a proportional voltage that may then be input to a computer device such as an A/D converter. An integral component of most pressure transducers is the strain gauge, which is itself a transducer.

Strain gauges are, in the simplest terms, merely devices that alter their electrical characteristics when subjected to stress that slightly deforms them. Strain is formally defined as the ratio of mean deformation per unit length.

The piezoelectric effect has long been employed in strain-measuring devices by utilizing crystals as strain gauges. Capacitive and inductance effects have also been used. However, each of these display some weaknesses. The most common strain gauges are those that provide a change in resistance proportional to the applied strain. Semiconductor strain gauges have also been used which, while physically small, are

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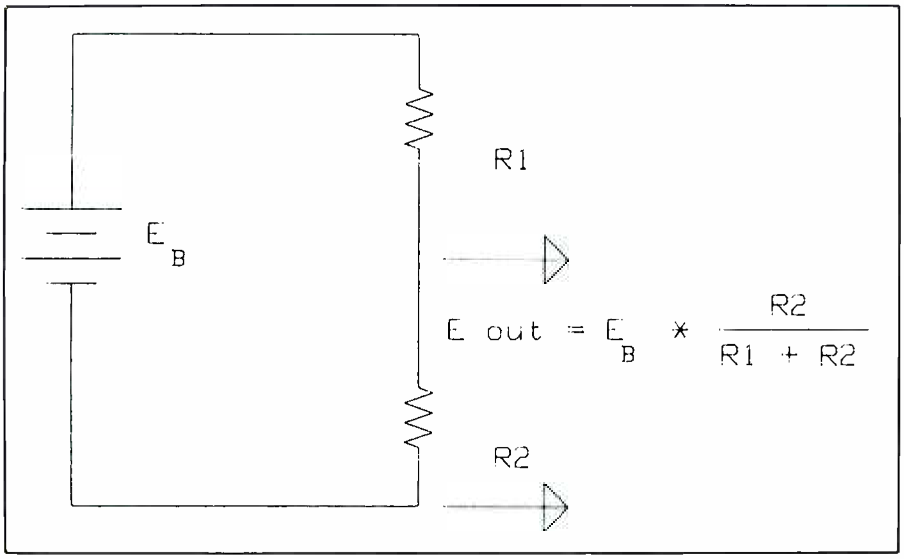


Fig. 6. A typical voltage divider.

capable of providing relatively large output voltages (for example, 5 volts full-scale). They also exhibit a great sensitivity to strains applied and are inherently nonlinear. Semiconductor devices also exhibit an undesirable strong temperature dependence that must be corrected in order for the readings to be accurate.

The bonded resistance strain gauge is the most widely used tool for strain measurement. It consists of a grid of fine wire or metallic foil bonded to a thin insulating material called the carrier matrix. The resistance gauge is glued to the object in which strain is to be measured, and the strain is determined by measuring the resulting change in resistance in the gauge when the object is loaded. These devices can be used to produce a pressure transducer by bonding the resistance strain gauge to a flexible diaphragm which is in contact with the gas or liquid whose corresponding pressure is to be measured. Such devices are usually provided with a compensation network. The latter provides control over sensitivity, zero balance, thermal effects on sensitivity and the thermal effect on the zero setting of the transducer.

Historically, the Wheatstone bridge, due to its simplicity and sensitivity, has proven to be the most common device for measuring resistive changes in strain gauges. The microcomputer, in combination with bridge-circuit technology, allows use of simpler circuits, increased measurement accuracy and collection of larger amounts of data by utilizing multichannel systems. This is accomplished, in part, by utilizing the microcomputer to balance the bridge circuit, compensate for nonlinearities, and handle switching and storing in multichannel applications.

Another popularly used transducer is the photoconductive device. To examine how it works, let's first review the voltage divider. In Fig. 6, a simple voltage divider, we see two resistors in series. The voltage across *R2* is equal to the input voltage times R2/(R1 + R2). If we increase *R2*, the voltage across it will increase and, likewise, if we decrease *R2*, the voltage across it will decrease.

Now let's replace *R2* with a photoresistor, a device whose resistance is a function of the light striking its surface. As light increases, resistance decreases. Thus, output voltage will be inversely related to the brightness of the light shining on the photoresistor. Photoresistors are quite easy to use, as you can see. The value of *R1* is selected to be approximately equal to the value of the photoresistor at the light level to be used. In general, one should select photoresistors with a relatively low "on" resistance to minimize noise pickup. Photoresistors are relatively slow devices. Therefore, they will not respond to high-speed changes in light intensity as will photodiodes and phototransistors. However, their simplicity and sensitivity make them a good choice for a wide variety of light-sensing applications.

There are a variety of sensors available for temperature control. Among the simplest and most versatile in this category is the thermistor, a resistor whose resistance varies as a function of temperature. Actually, this is true of all resistors, but thermistors are especially sensitive to temperature changes. Thermistors can be used in voltage-divider circuits like the photoresistor circuit cited. The output in this case varies as a function of temperature. You select thermistors based on the temperatures at which you expect them to normally operate.

The foregoing transducer examples are representative of sensors used in process control systems. In actual practice, virtually any sensor that's capable of producing an electrical output can be used as an input device for a control system.

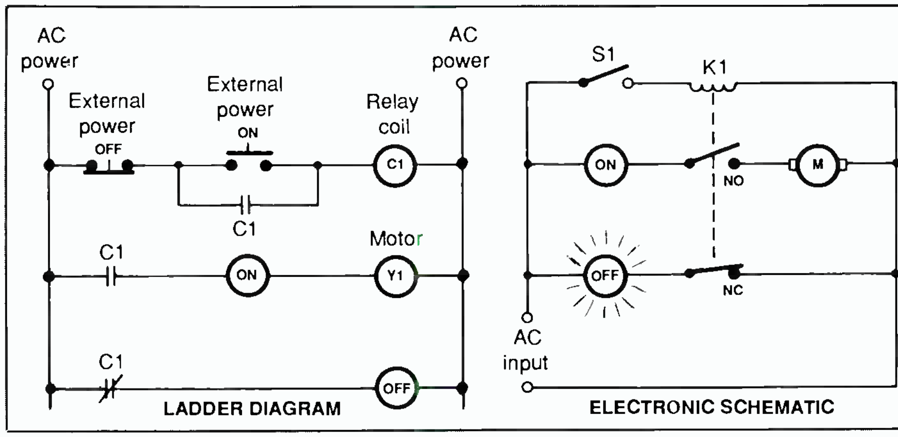
Stepping Motors & Resolvers

Stepping motors are ideally suited for digital control systems because they move a predictable amount for each input pulse.

A stepping motor rotates a predetermined amount each time it "steps." Typical rotations are 1.8, 7.5 and 15 degrees per pulse. Since this is totally predictable, the "feedback is implied." Thus, we can predict the motor's location by keeping track of the number of pulses we have sent. A stepping motor operates

Relay-Ladder System

The relay language is the oldest and most widespread of process control "languages." Actually, it's both a language and a schematic logic representation much like the flow diagrams we use routinely for software design. It was developed when the electromechanical relay was king in the industrial control field. So it's no surprise that the relay contact is the key symbolic element of the language.



The system is often referred to as relay ladder programming or ladder diagrams because the drawing format resembles that of an ordinary ladder. It consists of vertical lines or rails, one at the left and one at the right, that represent input and output power-line legs. Connected between are horizontal rungs of devices, such as relays, switches, motors, etc. Industrial programmable controllers often use keyboards with relay logic symbols on keys.

Input representations such as an input module or a relay contact switch are traditionally placed at the left side of a rung, while outputs follow to the right of them. What seem to be the two small vertical lines that represent a capacitor in an electronic schematic are actually normally open input switches (say, a relay's contacts) in a relay ladder diagram. The same drawing with a diagonal line through it indicates that the contacts are normally closed. Outputs, in turn, are represented by circles.

Further, letter or number labels are used to identify these symbols. For example, an "X" (X1, X2, etc.) might be used to indicate control switches, while a "C" (C1, C2...) designation would identify a relay, which might be in the form of the capacitor-like symbol for contacts or a circle for the energizing coil. Other output devices are frequently designated as "Y" (Y1, Y2...). Note, however, that commercial programmable controllers often use a number system. This might be a four-digit system, with specific I/O number assignments and blocks set aside for particular devices. For example, numbers 0001 to 0050 may be reserved for control relays only. Assignment numbers cannot be repeated for another device except for multiple switch contacts that work with a single relay coil. Accordingly, a dual-contact relay might be shown as two separate switches (capacitor-like symbols) with the same C1 label, while their common coil would be the only other device to carry a C1 label. Assignment numbers would be different, though. (Some manufacturers maintain separate symbol or label numbers, however.)

A variety of sequences and logic operations can be formed by appropriate designs. For example, a rung could have two power control switches (X1 and X2) and a motor (Y1) in series between the two power rails, which would represent an AND logic arrangement. If the switches were in parallel, it would constitute an OR logic setup. In the former, both switches would have to be closed in order for the motor to be powered, while in the latter setup either switch could be closed to run the motor.

In the illustration shown here, you'll observe how the same electronic setup would be drawn for a ladder diagram and an electronic diagram equivalent. Here, if power is off, the "off" lamp indicator, which is in series with the relay's normally closed contact, is lighted since the rung is directly across the ac power line. When power is switched on, the coil is energized and closes the normally open contacts, causing the "on" lamp to light and the motor in series with it to be powered. In turn, the normally closed contact automatically opens and the "off" lamp extinguishes.

This is a simple example, but it illustrates the principle of drawing ladder logic diagrams as contrasted to electronic schematics.

in an anticipated manner by pulling the rotor from one electromagnet to another. This is accomplished externally by applying voltages in sequence from one winding to another. Figure 7, a Stepping Motor Truth Table, depicts the four windings of a typical stepping motor and indicates how the sequential application of voltage to the windings controls shaft movement. If we keep track of which windings were last used, we can determine which winding needs to be activated in order to rotate the motor in either direction.

Unfortunately, there are a couple of "flies in the ointment." First, keeping track of which winding needs to be activated and controlling the appropriate driver is relatively complicated, at least if you don't have a computer. Of course, if you have a computer in the system, this problem is easily taken care of. That

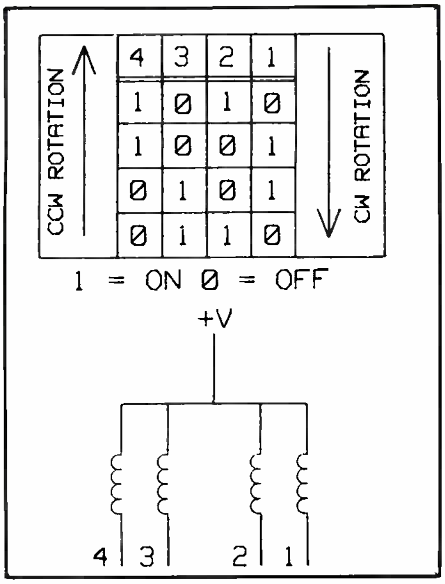


Fig. 7. Stepping motor truth table.

is, a stepping motor either makes a complete step or it doesn't move at all when it is pulsed. If the motor is overloaded, it may stall. Since the feedback is only implied, the controller will not be able to recognize the problem. Therefore, it's important to make sure the system either does not overload the stepper or include some type of override feedback system to warn of a stepper failure.

Another problem with steppers is that they are relatively expensive, especially in large sizes. In addition, high-torque steppers are not available. The maximum practical size stepper is limited to torques of a few foot-pounds. Of course, this torque can be amplified with gears, lead screws, etc., at the expense of speed. Stepping motors are relatively slow devices, operating typically between 30 and 300 rpm.

How about using plain dc and ac motors for rotary motion, you might ask? Unfortunately, it will not be easy to tell what the motor position is at any given point in time. If a typical dc motor is turned on and then off, the number of rotations or the exact angular position of the shaft is not known. This can be solved by using resolvers, however.

A resolver is simply a device that measures the location of a shaft and reports this to a controller by feeding information back to it. A two-bit resolver in Fig. 8 illustrates an example of a low-precision resolver. This particular resolver divides one complete revolution into four parts and provides a feedback signal describing the angular location of the shaft to an accuracy of two bits. A three-bit resolver would resolve the location into eight parts; a four-bit into 16 parts; etc.

This device works by detecting the presence or absence of light on the photodetectors. For instance, in our example, light striking both detectors would place the rotation in the first 90 degrees. Light on the inner detector and not on the outer detector would place the resolver in the second 90-degree position. You can see how this technique can be expanded to whatever degree of accuracy is required.

Such a technique has the additional advantage of the resolver being completely independent from the rotor. Therefore, a motor failure or other problem would be easy for the computer to detect. The disadvantage is that this technique is more expensive in low-torque applications than stepping motors. But in high-power applications, a resolver coupled with a motor becomes very attractive.

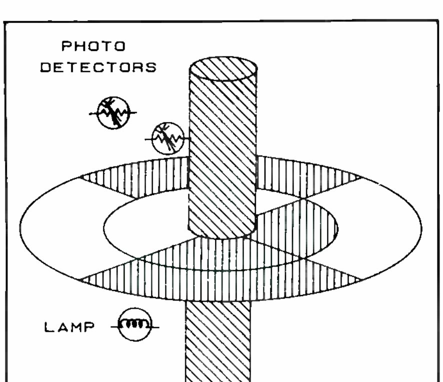


Fig. 8. A two-bit resolver.

So far, we've been discussing rotary techniques. It's often necessary to convert this to linear motion to make operations practical. To do this, we can drive a screw (called a lead screw) with a nut attached. A sophisticated, low-backlash. low-friction lead screw is called a ball screw. It uses a ball bearing as one half of the thread.

Earlier it was pointed out that the standard rotation for a stepping motor is 1.8 degrees per pulse. Seems like an odd choice, doesn't it? Standard machine tools, such as lathes and milling machines use lead screws to move their mechanisms. These lead screws are designed so that one complete rotation of the lead screw produces 0.2 inch of linear movement. A stepping motor that rotates 1.8 degrees per pulse, therefore, requires 200 pulses for it to make one complete revolution. Therefore, if we connect the stepping motor to a lead screw, each pulse would produce exactly 0.001 inch of linear motion.

By using a stepping motor to produce linear motion, we can then directly convert the number of pulses to linear movement. This makes for simple programming of linear movement. In a similar manner, we can generate linear motion using a conventional motor/resolver combination. Other types of linear-motion devices include simple solenoids, hydraulic and pneumatic cylinders, etc. Resolvers are also required for these linear-motion mechanisms. Resolving techniques similar to the rotary technique described above are possible. Also, a simple linear resistor connected to an A/D converter is a reasonable method to measure linear motion in many applications.

Special Interfaces

Among the typical interfaces needed to move data from one state to another and from one location to another, as previously mentioned, the

IEEE Standard Digital Interface for Programmable Instrumentation is particularly important in control work. It's an accepted standard that allows for the exchange of digital information between system components and instrumentation. Originally developed by Hewlett-Packard and sometimes referred to as the GPIB or HP-IB interface, it is most often called the IEEE-488 interface.

The interface has become so popular that many companies specializing in electronic instrumentation now make it available on their instruments. Additionally, several sources provide personal computer add-on cards to establish the interface. As a result, system integrators now have a compatible means of communication between instrumentation manufactured by different companies and their own systems.

Devices interconnected by this interface fall into three groups: listeners, talkers and controllers. Listeners are devices that have been configured to receive messages. In contrast, talkers are devices that are configured to send messages to other devices, while controller devices configure other devices, including themselves, to be talkers or listeners. Additionally, the controller causes another device to perform a specific action, such as send or receive data. The devices send and receive two types of messages: interface messages and device-dependent messages. Interface messages are those that are sent to cause the interface to react in a certain way. For example, such a message might cause a device to be a listener only, a talker only or both listener and talker.

An interface message may also command the interface on a device to send data or prepare a device's interface to receive data. Device-dependent messages are those that are carried by the interface, but are not processed or used by it. Such a message contains information for the device itself, such as a set of control commands to cause a tape recorder to rewind or the data to be recorded on the recorder.

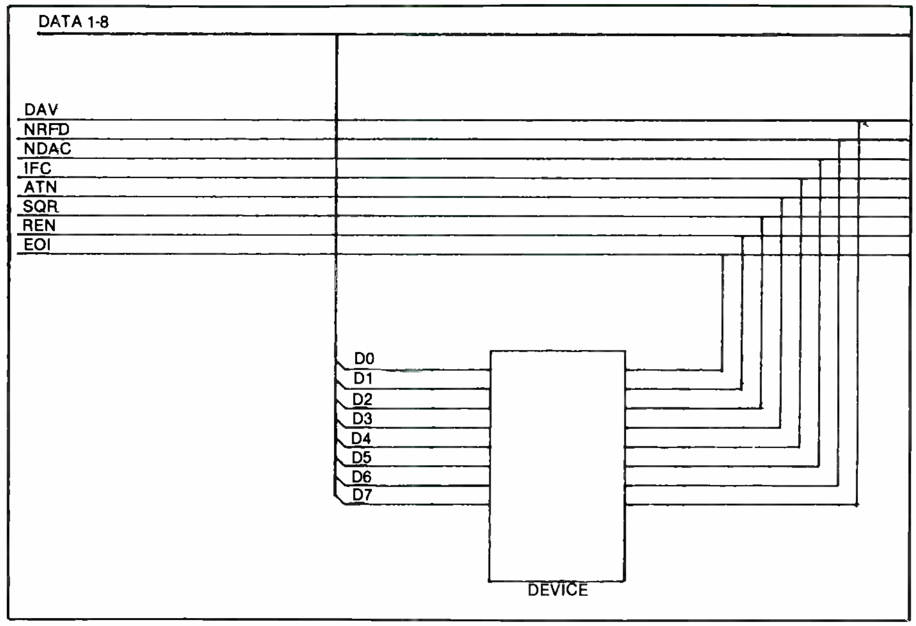


Fig. 9. The IEEE-488 interface bus configuration.

The message exchange across the interface is accomplished through a byte serial, bit parallel transfer between devices. This means that there are eight lines that simultaneously transfer the eight bits in a byte, with multiple bytes transferred sequentially. In addition to the data lines, the interface also contains eight control and handshake lines. Three of these—DAV, NRFD and NDAC—control the data byte transfers by performing a "handshake" between the sending and receiving devices. The other five lines—ATN, IFC, SRQ, REN and EOI—are used to perform system management and control functions and sending control commands, requesting service and clearing devices. Figure 9 illustrates the IEEE-488 interface bus configuration.

Communication over the system is managed by the controller. When a device needs to be "serviced," it informs the controller. The controller thus knows whether the device requesting service needs to send information, that is, becomes a talker, or whether it needs to become a listener and receive information. If the device needs to talk, the controller also knows which device or devices need to listen to the communication. The controller configures the appropriate device to talk and the appropriate device or devices to listen. Once this is done, the controller relinquishes control of the bus and the talker transmits its message to the listeners. At the end of the message transmission, the controller can reconfigure the devices on the bus to meet the talk/listen requirements of the next message.

One of two methods is generally used to interface the system to inform the controller that a device is ready for service: a serial poll or a parallel poll. In the serial poll method, the device that needs servicing asserts the SQR line. The controller senses this and informs the interface system that a serial poll is about to begin. Following that, the controller sequentially addresses each device to determine which one requested service. The one requesting service responds to the poll by setting data bit 7 true.

In the other polling method, a par-

Fig. 10. The X-10 Powerhouse Serial Data Stream.

allel poll, the controller assigns each device a dedicated data line that the device uses to respond to a parallel poll. When the controller issues a parallel poll command, each device needing service will respond by asserting as true the data line assigned to it. This allows the controller to get status from all devices at one time.

The standard IEEE-488 interface accommodates up to 15 devices on the system at one time. If these devices are equipped with open-collector drivers, they can communicate at 250,000 bytes per second if the total length of the interconnecting cables doesn't exceed 20 meters. If the devices are equipped with tri-state drivers, the communication rate can increase to 500,000 bytes per second. With shorter cable lengths and specially designed interface timing, the system can achieve a maximum of 1,000,000 bytes per second.

We'll be using an IEEE-488 interface module in a later construction project. Additionally, we'll employ a popular, modestly priced and widely available stand-alone remote-control system, the X-10 Powerhouse system. This system is designed to control up to 16 on/off functions at remote locations. Primarily used to control lighting and appliances in the home, it consists of a centrally located controller and remote stations that are plugged into power outlets or wired into light switches. Each remote can be addressed by the central controller and responds to commands such as off, on, bright and dim. Communication between the controller and remotes is over existing power wiring using a patented data protocol.

The power-line interface is a serial transmission system that transmits binary data from the central controller to the remote stations. The serial data stream, shown in Fig. 10, an X-10 Serial Data Stream, consists of a 4-bit start code, a 4-bit house code and a 5-bit code that's either a number code or a function code. The start code is always 1110. The 16 unique addresses allowed by the 4-bit house code enables adjacent homes to run the X-10 system without interfering with each other. This also permits more than one controller to be operated in the same home if more functions need to be automated than the number and function keys can accommodate.

The number and function code is a unique 5-bit code for each of the 16 number keys and the six function keys on the controller. When a number key or a function key is pressed, the appropriate binary code is transmitted to the remotes over the power line. The codes are transmitted in the order of a start code, house code and number or function code. They are represented on the power line as a sequence of short bursts from a 120-kHz oscillator occurring at a rate of one bit per cycle.

The central controller modulates a 120-kHz signal on the power line to transmit a "1." The burst is 1 millisecond long and is transmitted coincident with the zero crossing of the 60-Hz power signal. The next bit is transmitted at the beginning of the next cycle. If it is another "1," a 120-kHz signal that lasts for 1 millisecond is again transmitted. If it is a "0," no signal is transmitted. The complement of each of the bits is transmitted on the alternate half-cycle of the power waveform. That is, if a "1" is transmitted at the begin-

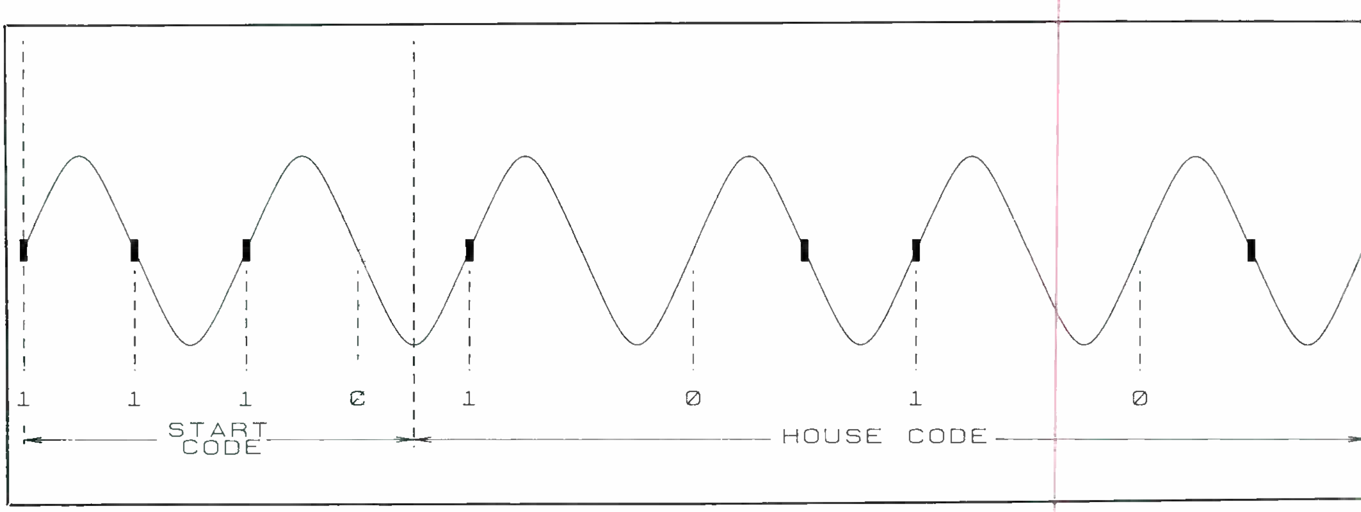


Fig. 11. Transmitted bit representation for X-10.

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ning of a cycle, a "0" is transmitted at the zero crossing that occurs one half-cycle later. Similarly, if a "0" is transmitted at the beginning of a cycle, its complement, a "1," is transmitted one half-cycle later.

This Transmitted Bit Representation is depicted in Fig. 11. Here, a start code, 1110, and a house code, 1010, are shown as they might look on an oscilloscope screen as they are being transmitted. Note that the complement of the bits is not transmitted on the start code. This is the only sequence for which the complement buts are not transmitted on the alternate half-cycle.

Each remote module can be configured to respond to the transmitted code by setting a rotary switch on the module to the desired house number and number code. This allows each of the 16 remote modules to be "addressed" from the central controller.

Once addressed, the remote will respond to a function command from the controller. For example, if key number 10 is pressed, the remote module with rotary switch set to 10, say, an outlet module, will be conditioned to receive a function command. If the function key "on" is pressed, module 10 will turn on. The device, say, a lamp that's plugged into module 10 will then be turned on. This can be extended to any of the modules in the system. Some controllers can be programmed to cause commands to be transmitted based upon the time-of-day. Thus, a simple home security system can be devised just by making the house look "lived in" simply by programming various lights in different parts of the home to turn on and off at appropriate times of the day.

One of the most useful modules from the standpoint of the computer user is the Powerhouse X-10 Universal module. This module, available later this year, provides all the hardware needed to interface the X-10 system to a personal computer. With this module, the personal computer user can provide control for up to 256 X-10 modules by taking advantage of all 16 house codes.

Next month, we'll conclude with software control typically used in computerized systems. We'll also design and build two process control systems. One will be for controlling the environment and security in a home, and the other for automatic testing and data logging while using the IEEE-488 interface. ME

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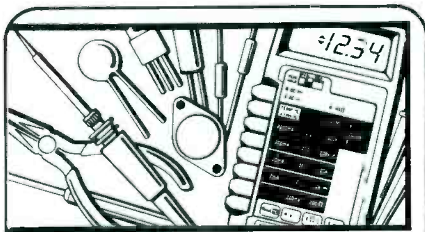

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Troubleshooting & Repair of Audio Equipment by John D. Lenk. (Howard W. Sams & Co. Soft cover, 181 pages, $21.95.)

This large-format (8½″ × 11″) book covers the core audio equipment that makes up a stereo hi-fi system, stressing their servicing aspects. Separate chapters are devoted to amplifiers and loudspeakers, linear-tracking turntables, audio cassette decks, AM-FM stereo tuners, and CD players, all preceded by an introductory chapter that discusses troubleshooting approaches and test equipment.

Each chapter opens with a general description of the component to be examined and then delves into almost stage-by-stage circuit detail. This is followed by troubleshooting procedures in which symptoms are given and circuit examinations advance pinpointed steps. That is, isolating problem areas, voltages or signals are traced with specific examples based on representative schematics: "Check to make sure that pin 29 of IC3 is low. If not, suspect IC3 . . . ."

The text's writing style is lucid, supported by plentiful schematics. Of all the chapters, the one on linear-tracking turntables is the best. This type of turntable has become very popular and, unlike conventional turntables, is packed with electronic circuitry. Coverage of other audio components suffers from insufficient space to fully explore them. After all, the author write a whole book on CD player troubleshooting, while "only" 38 pages are devoted to it here.

Nonetheless, the troubleshooting coverage is sufficient to get the grey matter working on how to approach audio component repairs for each given piece of gear, while issuing fine information on the most commonly encountered problems. Consequently, this book is a fine introductory overview to troubleshooting all types of audio equipment that's suitable for serious hobbyists and service technicians.

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Amateur Electronics Research

By Forrest M. Mims III

In his editorial in the July 1987 issue of *Modern Electronics*, Editor Art Salsberg cited such advances in electronics as application-specific ICs, smart power chips, surface-mount components and the projected billion-transistor chip. Art then discussed the impact of these developments on electronics experimenters and then asked: "What then will happen to home circuit brewers who build unique products from plans or their own designs? Will they disappear the way independent researchers have, giving way to monster-size corporate laboratories? I don't think so!"

I very much agree with Art. In fact, I've staked my career as an electronics writer on a strong conviction that there will always be a dedicated network of amateur researchers and electronics experimenters.

Recently, I had the opportunity to see firsthand the intriguing projects of more than a thousand young amateur researchers whose results were displayed at a major regional science fair in Texas and the International Science and Engineering Fair in San Juan, Puerto Rico. And I also observed some of the work performed by members of the Dallas Area Rocket Society. The remainder of this column will describe some of these projects. After reading about them, I hope you will be as optimistic as Art and me about future prospects for amateur research.

Fig. 1. Some of the 680 projects at this year's International Science and Engineering Fair in San Juan, Puerto Rico.

Science Fairs

While attending high school, I learned more from planning and executing science fair projects than I did from any of the required courses. Indeed, the articles and books I write about electronics are a direct outgrowth of those science fair years.

My senior year science fair project was a sequential analog computer capable of translating into English up to 20 words of a foreign language dialed into a control panel. Each word of the machine's vocabulary was stored as a unique resistance on a panel of miniature trimmer resistors. Unfortunately for me, the judges were unable to determine how to operate the language translator, and it received no awards. However, a few years ago, a curator at the Smithsonian Institution asked me to donate the language translator to the National Museum of American History. That non-award-winning science fair project is now considered an early example of a do-it-yourself home computer!

When I was assigned to the Air Force Weapons Laboratory in 1968, I again became involved in science fairs, but as a judge instead of a participant. Since then, I have judged at local and regional fairs in New Mexico and Texas and at the International Science and Engineering Fair in San Juan, Puerto Rico.

Those who are rightly concerned about today's serious problems in education will find cause for optimism by visiting one of the more than 4,000 science fairs held each spring all across the United States. According to Science Service, in 1986, more than 60,000 projects were exhibited at some 352 regional science fairs. A survey of 91 of these fairs revealed that their exhibitors were selected from among nearly 600,000 students who had entered school, city or other preliminary science fairs.

Some regional science fairs are huge. One of the largest in 1986, with 3,570 projects, was the 38th Greater St. Louis Science Fair. In 1986, a combined total of 2,035 projects were displayed at two big fairs in Mississippi. Fairs in Fort Worth and Houston had 863 and 819 projects, respectively. Another large fair is San Antonio's Alamo Regional Science Fair. In 1987, 724 projects were exhibited at this fair.

The top two winners of each regional science fair are eligible to participate in the annual International Science and Engineering Fair (ISEF). In 1987, ISEF was affiliated with 359 regional fairs from the United States, American Samoa, Puerto Rico, the Virgin Islands, Brazil, Canada, Ireland, Japan, the Republic of China, the Republic of Philippines and the United Kingdom. In 1987, 680 projects were exhibited at the 38th ISEF in San Juan, Puerto Rico (Fig. 1). Many of the projects, especially those in the categories of physics, engineering and Earth and space sciences, involved electronic circuits and computers. Let's look at some of them.

An Optical-Fiber Seismometer

In June of 1986, my son, Eric Ryan Mims, began work on a new kind of seismometer. Eric's seismometer sensed movements of the Earth's crust when an optical fiber attached to a pendulum moved with respect to a pinhole mounted on a high-brightness LED bolted to the concrete slab of his bedroom. The resultant change in light entering the fiber from the LED was detected by a photoresistor, changed into a voltage, amplified and fed into the joystick port of a Radio Shack Color Computer. A hard copy of movements of the pendulum was provided by a pen plotter connected to the computer.

When Eric began his seismometer project, he had no idea how sensitive the device would be or that it would result in numerous science fair awards and a trip to the International Science and Engineering Fair. Among the most interesting events detected by the seismometer were two nuclear tests in Nevada, around 1,200 miles from our home in south-central Texas. The seismometer detected the three principal seismic waves generated by both these tests.

Eric's project, which is shown in Fig. 2, was the grand-prize winner at Seguin High School in Seguin, Texas, and the second-place winner in the physical-science division at the Alamo Regional Science Fair. At this fair, Eric also received the prestigious Wylie Award for the project judged best in research. His project also received a third grand award in the Earth and space sciences category of the ISEF in Puerto Rico and a dozen or so special awards and scholarships.

A Computer-Controlled Satellite Weather Station

Some students manage to earn a second or even a third trip to ISEF by expanding on a previous ISEF project. It's very rare for a student to participate in two successive ISEFs with two completely different projects. Yet Matthew Ray Stahl, like Eric a senior in Seguin High School, did just that.

Matthew's 1986 project was a computer-controlled apparatus for detecting internal gravity waves. This project, which incorporated a great deal of electronic

Fig. 3. Matthew Stahl's computerized weather satellite receiving system.

Fig. 2. Eric Ryan Mims and his award-winning optical-fiber seismometer system.

Fig. 4. Robert Chapa and his robotic arm project.

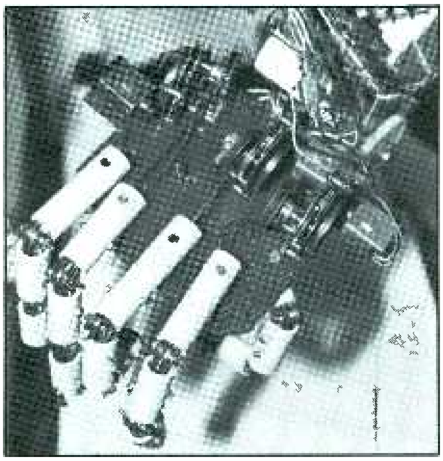


Fig. 5. Close-up view of another robotic arm exhibited at the ISEF.

circuitry, received many awards, including a trip to ISEF.

For 1987, Matthew assembled from scratch the complete computer-controlled satellite receiving station shown in Fig. 3. The station incorporates even more circuitry than Matthew's previous project. Among its most interesting features is a homemade thermal imaging system that generates a hard-copy image on paper of the signal transmitted by a weather satellite.

Matthew's project earned second place at the Seguin High School science fair and first place in the physical-science division of the Alamo Regional Science Fair. His project also received a fourth-place grand award in the engineering category of ISEF in Puerto Rico and, like Eric, a dozen or so special awards and scholarships.

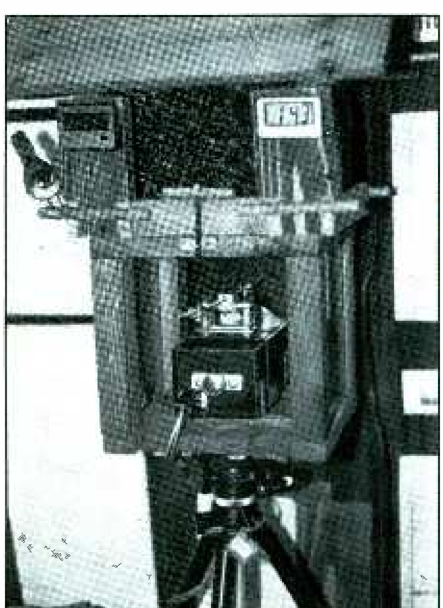


Fig. 6. Melvin Holmquist's photovoltaic bird feeder system.

A Robotic Arm

When I was touring the projects at ISEF in Puerto Rico, I met Robert Chapa, a senior at Powell Senior High School in Powell, Wyoming. The centerpiece of Robert's project, shown in Fig. 4, was a homemade bionic arm constructed from readily available materials and components. A unique feature of this bionic arm was that its motions can be controlled without manually actuating switches or controls. Instead, the operator's hand is placed in a slot between matching pairs of LEDs and photodetectors. Movements of the operator's hand block or expose one or more of the detectors to radiation from the LEDs to provide control signals for the bionic arm.

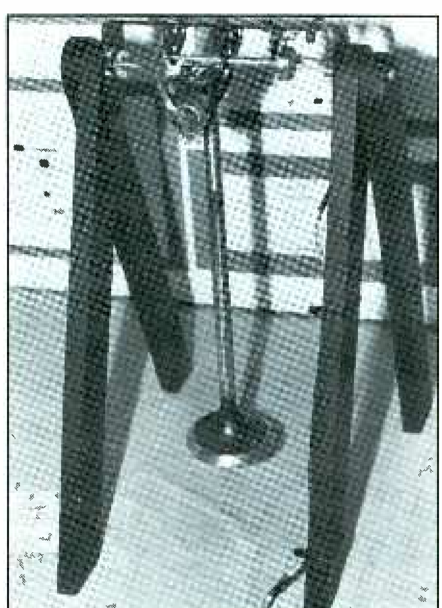


Fig. 7. A two-axis accelerometer designed by Kevin Bergner.

For his effort, Robert received a third grand award in the engineering category of ISEF as well as other awards and honors. Incidentally, on a personal note, I was gratified to learn that Robert picked up some of his circuit design skills from books I have written for Radio Shack.

Several other robotic arms were also exhibited at this year's ISEF. A close-up view of one of the best is shown in Fig. 5. Unfortunately, I neglected to record the number of this project and am unable to credit its builder.

A Photovoltaic Bird Scale

Another project that attracted a lot of attention at this year's ISEF was a cleverly designed system for weighing wild birds while they eat from a specially designed feeder. This project was designed and built by Melvin M. Holmquist of Grand Rapid Senior High School in Grand Rapids, Minnesota.

Though I was unable to meet Melvin, I did read the text of his exhibit and was impressed to learn that his scale, shown in Fig. 6, could detect a bird's ingestion of a single seed. In other words, Melvin's apparatus can be used to actually count the number and even types of seeds a bird consumes during a session at the feeder. For this innovative project, Melvin received a fourth grand award at ISEF and various other special awards and honors.

Other ISEF Projects

Many other excellent electronics- and computer-related projects were exhibited at this year's ISEF. Kevin William Bergner of Columbus East Senior High School in Columbus, Indiana, exhibited a pendulum accelerometer for measuring the acceleration of a vehicle. The accelerometer, shown in Fig. 7, consisted of an X-Y arrangement of two potentiometers connected to a pendulum.

Adrian Douglas of Ruston High School in Ruston, Louisiana, exhibited his sonic compass for the blind. This

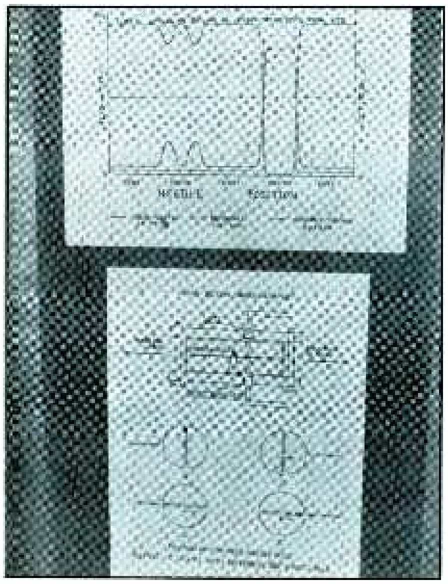


Fig. 8. Operational and construction details of Adrian Douglas's sonic compass for the blind.

clever device is a compass equipped with a phototransistor facing an LED. When the compass is pointed north, the needle blocks the path between the LED and phototransistor and an audible tone is sounded. Figure 8 is a photo of the two drawings exhibited with this project.

Jeff Herath of Albermarle High School in Charlottesville, Virginia, exhibited a model airplane propelled by a solar-powered electric motor. Two rows of large solar cells are attached to the upper surface of Jeff's aircraft (Fig. 9).

Chad Carr of Grand Junction High School in Grand Junction, Colorado, exhibited his experimental ice chips, semiconductors made from frozen liquids. Chad's data clearly showed that some of his devices functioned as rectifiers when exposed to an alternating current. Figure 10 shows Chad's exhibit, and Fig. 11 shows his experimental ice-chip device.

Other projects at ISEF included a piezoelectric raindrop detector, nitrogen and excimer lasers, optical-fiber studies, speech recognition and synthesis, a magnetohydrodynamic power generator, robotics, artificial intelligence, data encryption, an image-processing workstation and many others.

In short, as in years past, this year's ISEF demonstrates that there is no shortage of young scientists. Another interesting observation is that many of the top award winners are from small towns.

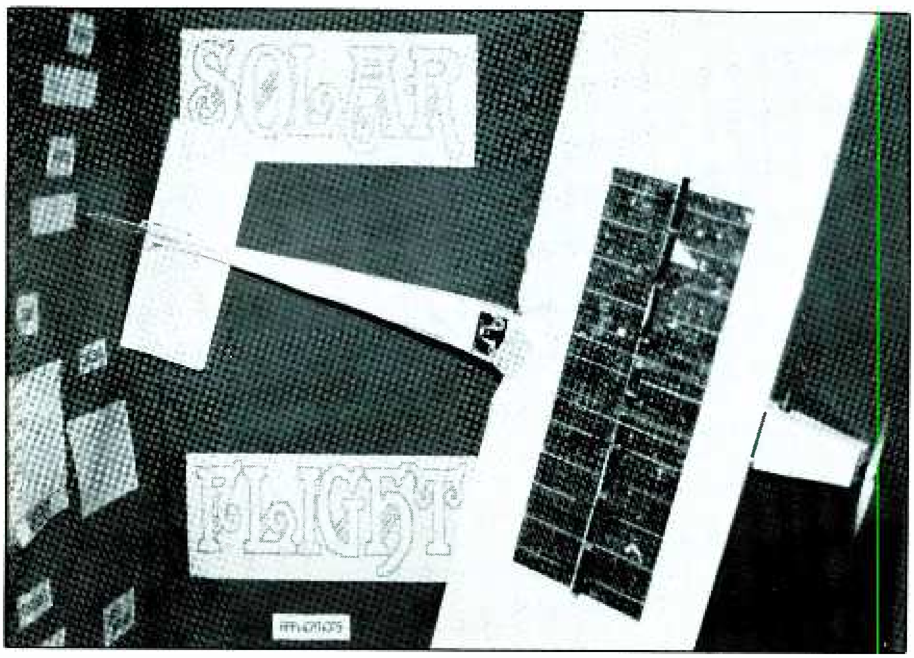


Fig. 9. Jeff Hearth's solar-powered aircraft.

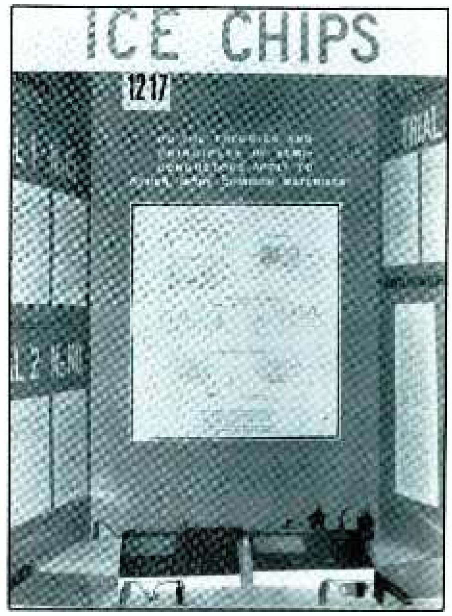


Fig. 10. Chad Carr's exhibit on rectifying junctions made from frozen liquids.

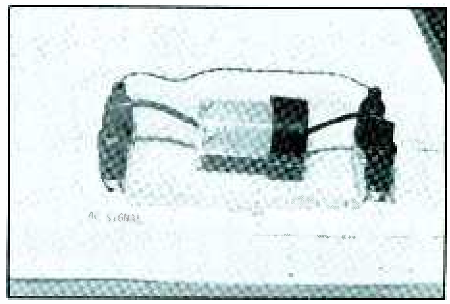


Fig. 11. Close-up of one of Chad Carr's "ice chips."

The Southwest Spacemodeling Convention

Model rocketry is a multifaceted hobby whose participants include those with special interests in scale construction, finishing techniques, high-altitude flights, electronic launch systems and research and development. The National Association of Rocketry recognizes these and other areas of interest in competitions conducted during its annual con-

ELECTRONICS NOTEBOOK . . .

Fig. 12. Ted Mahler describes the rocket-launched disk camera system he designed, built and launched.

Fig. 13. G. Allen Wilcox and one of the sophisticated model rocket launch systems he has designed and built.

vention. Local model rocketry clubs also sponsor many such competitions.

Recently, I was invited to give a couple of talks at the Southwest Spacemodeling Convention sponsored by the Dallas Area Rocket Society. One of the most interesting sessions of this meeting was the presentation of the results of several engineering and research and development projects conducted by members of the Dallas Area Rocket Society.

Ted Mahler described in detail his mechanical modifications to a disc camera designed to be flown inside a special enclosure mounted atop the large model rocket shown in Fig. 12. A small prism permits the camera to look down the side of the rocket as exposures are made. Ted also showed some spectacular photographic sequences produced by his airborne camera system.

G. Allen Wilcox described and demonstrated the sophisticated model rocket launch control system shown in Fig. 13. Allen's system, which is powered by a self-contained storage battery, includes an automatic countdown capability, built-in public-address system, beeper, current meter and digital display. Allen understands the real world of electronics (Murphy's Law and the like) well enough to have designed a bypass system into his launch controller that permits it to be used should one or more of the solid-state circuits malfunction.

Finally, Martin Catt described miniaturized microprocessor systems designed to be flown aboard a model rocket. Martin discussed potential applications for rocket-launched microprocessors, including data acquisition and storage. He also displayed the miniaturized flight-capable microprocessor (Fig. 14).

Going Further

This column differs from those I have previously written for *Modern Electronics* in that it presents no circuits. Nevertheless, I hope you have enjoyed learning about the accomplishments of the amateur scientists presented here.

For additional information about science fairs in your area, call any local junior or senior high school. For information about the International Science and Engineering Fair, write Science Service, 1719 N St., N.W., Washington, DC 20036. For additional information about model rocketry organizations in your area, contact hobby stores that sell model rocketry supplies. You should also contact the National Association of Rocketry, 182 Madison Dr., Elizabeth, PA 15037. Members of NAR receive a monthly magazine, liability insurance and various other benefits.

Next month, I shall again present working and tested circuits. Meanwhile, you might think about starting work on that personal research project you've always thought about starting but have never gotten around to. Remember that none of the projects described above were developed by those "monster-size corporate laboratories" Art Salsberg wrote about in his Editorial. Nor were any developed with big government grants. **ME**

Fig. 14. Martin Catt with one of the model rocket microprocessor systems he designed.

Floppy Disk Drive Testing

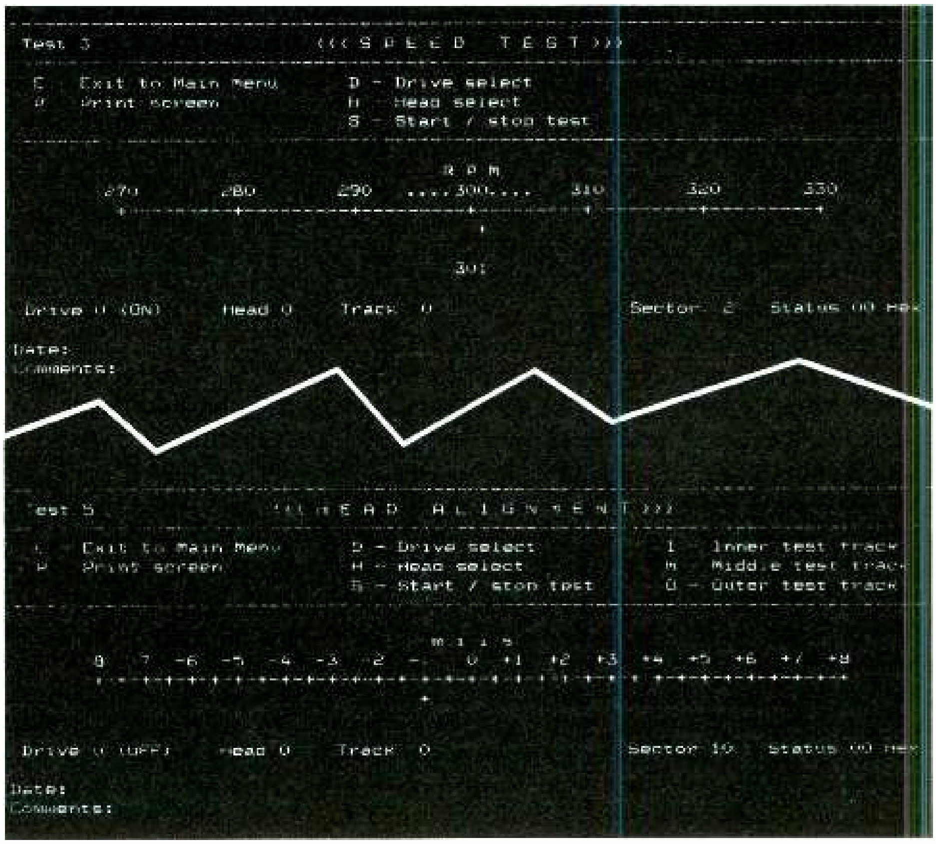
By Art Salsberg

There are a variety of programs available to test disk drives. Some manufacturers, such as IBM and Heath/Zenith, make available diagnostic disks that include such tests. Typically, the tests examine basic disk operations, such as data write, read, compare with sequential and random-seeks, as well as a speed test. IBM's provides only a cryptic reference to actual speed, with 2000 being equivalent to 300 rpm, the standard 5¼" floppy-disk drive speed.

J&M Systems of Albuquerque, NM, however, sells a disk drive testing program that really digs into the the many facets of a drive to test its quality. Moreover, it does this quickly. Called Memory Minder™, it works in conjunction with a provided Dysan DDD (digital diagnostic disk) program. Thus, it's a two-disk program, with the DDD one not copyable.

There are versions for TRS-80, Kaypro and IBM or true IBM-compatible computer floppy-disk drives. The one we used was for an IBM, MM Version 2.00 and Dysan's 508-400 48-track double-density, double-sided disk. The MM program is priced at $70, while Dysan's is $40, for $110 total. You need both, of course. A nicely illustrated 44-page manual accompanies the disks. Memory Minder is also available in 3½" 80-track format and 5¼" 1.2-Mbyte format.

The program tests Clamping, a Quick Test, Speed, Alignment Sensitivity, Head Alignment, Head Rotation, and Directional Seek. It also contains an Analog Alignment Aid for use with a scope, Changing of Test Parameters and a Read/Write Test.



Screen printouts obtained when J&M's Memory Minder was used to check Speed (upper) and Head Alignment (lower) of a disk drive in an actual computer.

Working With MM

To start up, Memory Minder's disk is booted from a selected drive. When loaded, the program's Main Menu appears and the DDD disk is then substituted. This disk must remain active in the drive.

A Status Line is displayed at the bottom of the screen, which indicates the Drive number, Head number, Track number, Sector number and Hex Status. Most users will only be concerned with the Drive and Head numbers, which can be changed by pressing D for drive select or H for head select. Other commands are P for printing the screen and X for exiting the system.

Each test is numbered in order, so to start a test for, say, speed, simply press number 3. Doing this, an RPM test display appears, with a horizontal bar ranging from 270 to 330, with 300 rpm, the precise speed that standard 5¼" floppy drives rotate, at the center. Speed tolerance is noted as ±2% or 294-306 rpm. Any measurement outside this range indicates that the speed is improperly adjusted.

My diskette drive A (or 0) measured 301 rpm, while drive B (or 1) shifted between 302 and 303. Not on the nose, but well within the prescribed range.

The Quick Test garnered my drives a straight "GOOD" in all categories, so I did not anticipate any deviations beyond normal tolerances. Indicators were good, fair or poor. It was interesting to go through the tests, though, because the measurements and display indicators revealed in a quantitative way how far from perfection, though still within tolerance, my drives were.

A Clamping test, which depends on the quality of the diskette hub itself, as well as the drive bearing, displayed perfect results with eight bars pointing away from the spindle and eight toward it. Head Rotation tests, which illustrate if the head center-line is parallel to the track tangent line, scored tops, too, with column bars extending the full +42 angular displacement minutes to −42, all at 100% levels. All other tests revealed the degree of imperfection that exists, though still in the good category.

For alignment sensitivity, which relates head-read electronics to head-misalignment tolerance, one steps through the drives and the heads while choosing from the menu inner, middle and outer test tracks. A histogram appears on the screen during the tests with horizontal numbers indicating Radial Displacement in mils from −13 to +13 and the vertical bars indicating Read Rate ratio of good to bad reads in percentage.

Drive A, Head 0, on the inner track test (I) ranged from −12 to +9 at 100%, while +10 jittered from 80% to 100%. Middle tracks were 100% at −12 to +11; outer tracks were 100% from −12 to +11, while +12 bounced from 40% to 100%. Head 1 was a bit better, though the slight addition in mils breadth varied anywhere from 20% to 80%. Drive B performed similarly.

Checking out Head Alignment, which was indicated on a screen display with a sort of meter needle under a scale that had zero as its center with a +8 and −8 deviation in mils, revealed that all heads on both drives deviated from −1 to −3 mils. This still placed it in the "Good" category on the Quick Test, though.

The last test that did not require electronic test instruments was the Direction Seek one. This illustrates head radial alignment when it moves toward or away from the spindle and is displayed with two horizontal bars for "In" and "Out" movement. When the edges of both are square, it indicates perfect alignment; when they're not, it shows a deficiency, with a mils scale noting the degree. Again, the test illustrated that my drives were imperfectly aligned, but still fine.

Conclusions

The nice thing about the Memory Minder is that no technical knowledge is needed to perform most of the tests. Moreover, there is a wide variety of important disk-drive elements that can be quickly tested.

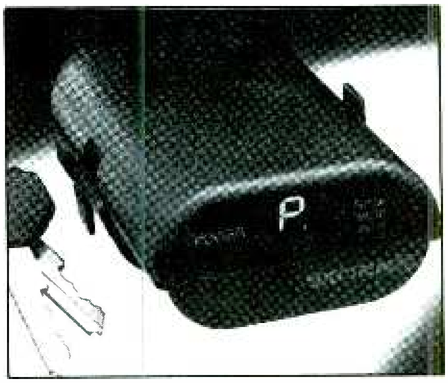
Testing one's drives with fair regularity, and recording the results in a log, can forewarn that something is deteriorating before data integrity is endangered.

However, many people will not be able to take corrective steps themselves. Though many drives have alignment screws for adjustment purposes, some drives have fixed servo circuits that cannot be adjusted. Nonetheless, data integrity is of the utmost importance.

The cost, $110, is rather low for acquiring the means to test disk drives in such a thorough and meaningful manner. I'd be hard pressed to recommend that one buy the program for use with a computer that's not used for business or professional purposes, though. But if you do any computer servicing at all or are involved with heavy computer usage, it's a very worthwhile tool to have and to use for repair or maintenance work. ME

NEW PRODUCTS • • • *(from page 10)*

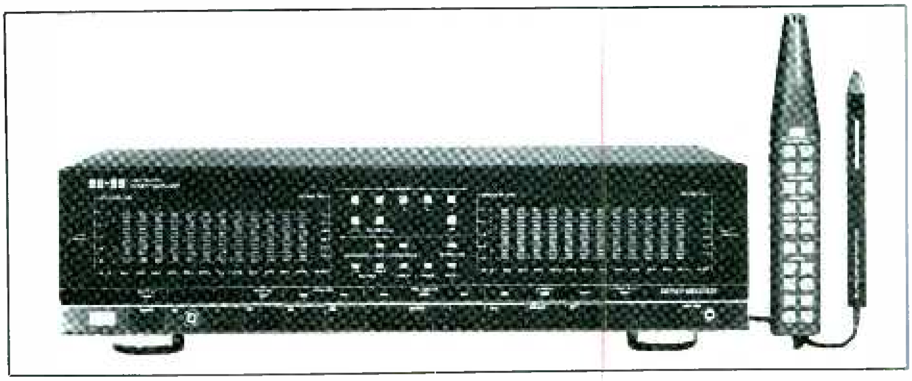
Pulse Protection Radar Detector



Whistler (Westford, MA) claims that its new Spectrum 2 is the only radar detector to feature pulse protection that provides a unique audible alarm and visual warning when receiving instant-on or pulse radar transmissions. This is in addition to the detector's X- and K-band signal differentiation. Spectrum 2 sounds an "ambulance-like" audible signal, as well as flashing a "P" on its digital display when a pulsed radar signal is detected.

Features include: a digital display that shows signal strength on a 0-to-9 scale; X- and K-band differentiation with separate audible and visible alerts; variable filter setting with preset function; a mute mode that silences the audible alarm but maintains the visible alarm; and a dark mode that eliminates the visible alarm but maintains the audible alarm. Included with the detector is a carrying case for transporting the Spectrum 2 between vehicles. The compact (4.875″ × 2.375″ × 1.180″) detector mounts on a dashboard, sun visor or windshield. $289.95.

CIRCLE 79 ON FREE INFORMATION CARD



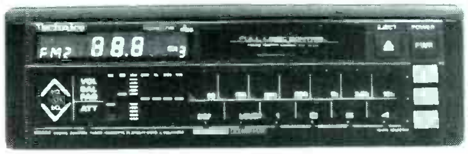
Stereo Graphic Equalizer

Sansui's new Model SE-99 electronic stereo graphic equalizer has automated functions that allow the user to optimize tape recording and listening room equalization. On the front panel are separate left- and right-channel displays. Equalization can be set for each channel independently or for both simultaneously. There are 11 memories, including a sound menu with five settings for enhancing various types of recordings. There are also five user-settable memories and a special flat setting that automatically memorizes the latest flat compensation curve. The memories can be activated with either a light pen (included) or with the supplied remote controller.

Among the equalizer's many features are: a built-in pink-noise generator; a wireless remote controller with built-in condenser microphone; ability to measure reverberation time; and bidirectional taping facilities. Center frequencies are at 16, 32, 64, 125, 250, 500, 1,000, 2,000, 4,000, 8,000, 16,000 and 32,000 Hz. Rated frequency response is 10 Hz to 100 kHz +1/−2 dB; THD is 0.003%; and S/N is 120 dB, $699.

CIRCLE 80 ON FREE INFORMATION CARD

Tuner Mode



Equalizer Mode

Tape Mode

Chameleon-Like Car Stereo

Tri-color panel lighting allows Technics' Model CQ-H9600 in-dash stereo unit to appear as a tuner (red) or cassette player (green) or graphic equalizer (white). The LED front panel display serves as a visual aid for setting volume, balance and fader controls and shows the EQ curve and acts as a spectrum analyzer. The analyzer mode displays real-time indication of the energy level in each of seven bands. In the EQ mode, the display shows one of four preset equalization curves (each can be recalled, changed and/or stored at the touch of a button).

The tuner section provides 12 AM and 12 FM station presets plus seek, scan, preset scan and auto preset scan tuning.

The logic-controlled cassette player features dbx and Dolby B and C noise reduction, double-cut narrow-gap head and two-way azimuth mechanism that automatically aligns the head according to tape direction. Features include scan, blank skip, repeat and programmable TPS to take the user to the blank spot preceding any recorded selection up to nine ahead or eight behind the current position before automatically going into play. Frequency response is 30 Hz to 30 kHz ±3 dB with metal tape, and wow and flutter are rated at 0.09% wrms.

Equalizer center frequencies are at 63, 125, 250, 500, 1k, 3.5k and 10k Hz and boost/cut range is ±12 dB. Available here is independent front/rear defeat that allows for equalization of rear speakers only, front speakers only or both front and rear speakers.

Other features include a sound image position memory, which allows for presetting up to four volume, balance and fader combinations, a built-in preamp and a CD player input. The unit measures 7"W × 5⅞"D × 1$^{15}/_{16}$"H. $1,200.

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Part No	Description	1	10	100
C8908	8 pin solder tail, tin	13	1.15	10.50
C8914	14 pin solder tail, tin	15	1.45	12.00
C8916	16 pin solder tail, tin	17	1.60	13.00
C8918	18 pin solder tail, tin	20	1.90	17.00
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C8924	24 pin solder tail, tin	28	2.50	24.00
C8928	28 pin solder tail, tin	32	2.90	27.00
C8940	40 pin solder tail, tin	46	4.20	39.00

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Part No	Description	1	10	100
C9808	8 pin solder tail, gold	34	3.20	30.00
C9814	14 pin solder tail, gold	44	4.20	40.00
C9816	16 pin solder tail, gold	50	4.70	45.00
C9818	18 pin solder tail, gold	57	5.40	52.00
C9820	20 pin solder tail, gold	63	5.90	57.00
C9822	22 pin solder tail, gold	70	6.60	64.00
C9824	24 pin solder tail, gold	76	7.20	70.00
C9828	28 pin solder tail, gold	79	7.50	73.00
C9840	40 pin solder tail, gold	1.12	9.90	97.00

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C8116	16 pin wire wrap, tin	57	5.60	56.00
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C8120	20 pin wire wrap, tin	76	7.50	74.00
C8122	22 pin wire wrap, tin	83	8.20	81.00
C8124	24 pin wire wrap, tin	91	8.90	88.00
C8128	28 pin wire wrap, tin	1.04	10.30	102.00
C8140	40 pin wire wrap, tin	1.42	13.90	138.00

GOLD INLAY WIRE WRAP Min. 50 Microinches Gold

Part No	Description	1	10	100
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Silicon Transistors

Digi-Key Part No.	1	10	100	1,000
[illegible]				

1 AMP SILICON RECTIFIERS

Part No.	Description	Pkg.	10	100	1,000	10,000
[illegible]						

3 AMP SILICON RECTIFIERS

Part No.	Description	Pkg.	1	10	100	1,000
[illegible]						

5% Carbon Film Resistors

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

Wattage Rating	1/8W	1/4W	1/2W
Max. Working Voltage	200V	250V	350V
Rated Ambient Temp.	70°C		
Operating Temp. Range	55°C to +155°C		
Dimension "L"	3.80	6.50	9.50
Dimension "D"	1.50	2.30	3.20
Dimension "d"	0.45	0.60	0.60

5% Carbon Film Resistor Values in Ohms: 1.0 to 4.7M

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

Pricing	5	200	1000
1/8 Watt	25	6.40	25.00
1/4 Watt	25	3.40	13.00
1/2 Watt	25	3.50	16.00

For large quantities and prices as low as $2.85/M call Digi-Key.

1/8 Watt Carbon Film Assortments

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- **RS125** 5 each of the 73 standard values in series 1.0, 1.2, 1.5, 1.8, 2.2, etc. through 1.0M (365 total pcs.) — $9.90
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- **RS150** 5 each of the 73 standard values in series 1.0, 1.2, 1.5, 1.8, 2.2, etc. through 1.0M (365 total pcs.) — $9.90
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1% Metal Film Fixed Resistors

Available in 1/4 Watt

Wattage Rating	1/4 Watt
Max. Working Voltage	150V
Rated Ambient Temp.	70°C
Operating Temp. Range	65°C to +150°C
Dimension "L"	6.5
Dimension "D"	2.3
Dimension "d"	0.6

1% Metal Film Values in Ohms: 10.0 to 1.00M

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

Pricing	5	10	1000
1/4 Watt	50	3.90	30.00

For large quantities and prices as low as $8.15/M call Digi-Key.

1/4 Watt Metal Film Assortments

- **RSX1** 5 each of values 10Ω to 97.6Ω (480 total pcs.) — $29.95
- **RSX2** 5 each of values 100Ω to 976Ω (480 total pcs.) — $29.95
- **RSX3** 5 each of values 1.00KΩ to 9.76KΩ (480 total pcs.) — $29.95
- **RSX4** 5 each of values 10.0KΩ to 97.6KΩ (480 total pcs.) — $29.95
- **RSX5** 5 each of values 100KΩ to 1.00MΩ (480 total pcs.) — $29.95

5% Metal Oxide Film Resistors

Available in 1 & 2 Watt

Wattage Rating	1 Watt	2 Watt
Max. Working Voltage	350V	350V
Rated Ambient Temp.	70°C	70°C
Operating Temp. Range	55°C to +200°C	
Dimension "L"	13.0	17.0
Dimension "D"	4.5	5.5
Dimension "d"	0.8	0.8

5% Metal Oxide Film Values in Ohms: 0.47 to 1.0M

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

Pricing	1	5	100	500	1,000
1 Watt	15	70	9.00	40.00	72.50
2 Watt	18	85	10.50	47.50	87.50

1 Watt Resistor Assortments

- **RS101** 5 each of values 0.47Ω to 56Ω (255 total pcs.) — $29.95
- **RS201** 5 each of values 62Ω to 7.5KΩ (255 total pcs.) — $29.95
- **RS301** 5 each of values 8.2KΩ to 1.0MΩ (255 total pcs.) — $29.95

2 Watt Resistor Assortments

- **RS102** 5 each of values 0.47Ω to 56Ω (255 total pcs.) — $29.95
- **RS202** 5 each of values 62Ω to 7.5KΩ (255 total pcs.) — $29.95
- **RS302** 5 each of values 8.2KΩ to 1.0MΩ (255 total pcs.) — $29.95

5% Wirewound Rec. Resistors

Available in 5 & 10 Watt

Wattage Rating	5 Watt	10 Watt
Operating Temp. Range	55°C to +250°C	
Temp. Coefficient	+300 PPM/°C	
Dimension "L"	22.0	48.0

5% Wirewound Rectangular Resistors: 5 Watt Values 0.30Ω to 2.0KΩ; 10 Watt Values 1.0Ω to 3.0KΩ

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

Pricing	1	10	100	500	1,000
5 Watt	32	2.90	24.00	90.00	180.00
10 Watt	35	3.20	27.00	100.00	180.00

5 Watt Resistor Assortments

- **RS105** 5 each of values 0.30Ω to 9.1Ω (60 total pcs.) — $17.95
- **RS205** 4 each of values 10Ω to 91Ω (96 total pcs.) — $27.95
- **RS305** 4 each of values 100Ω to 910Ω (96 total pcs.) — $27.95
- **RS405** 3 each of values 100Ω to 2.0KΩ (96 total pcs.) — $27.95

10 Watt Resistor Assortment

- **R110** 2 each of all standard values (68 total pcs.) — $49.95

DISC CAPACITORS

Part No	Cap	Volt	Price 10	100	1,000
P4000	10 pf	500	75	6.49	48.71
P4002	15 pf	500	75	6.49	48.71
P4003	18 pf	500	75	6.49	48.71
P4004	22 pf	500	75	6.49	48.71
P4005	27 pf	500	75	6.49	48.71
P4006	33 pf	500	75	6.49	48.71
P4007	39 pf	500	75	6.49	48.71
P4008	47 pf	500	75	6.49	48.71
P4009	56 pf	500	75	6.49	48.71
P4010	68 pf	500	84	7.23	54.22
P4011	82 pf	500	84	7.23	54.22
P4100	100 pf	500	63	5.43	40.72
P4102	150 pf	500	63	5.43	40.72
P4103	180 pf	500	63	5.43	40.72
P4104	220 pf	500	63	5.43	40.72
P4105	270 pf	500	63	5.43	40.72
P4106	330 pf	500	63	5.43	40.72
P4107	390 pf	500	63	5.43	40.72
P4108	470 pf	500	80	6.91	51.86
P4109	560 pf	500	80	6.91	51.86
P4110	680 pf	500	80	6.91	51.86
P4111	820 pf	500	80	6.91	51.86
P4112	1000 pf	500	1.00	8.58	64.35
P4114	1500 pf	500	1.00	8.58	64.35
P4115	1800 pf	500	1.31	11.25	84.37
P4202	1500 pf	100	58	5.01	37.[illegible]
P4203	2200 pf	100	58	5.01	37.57
P4205	3300 pf	100	58	5.01	37.57
P4206	4700 pf	100	58	5.01	37.57
P4209	6800 pf	100	70	6.00	45.00
P4300	.01 uf	25	56	4.83	36.23
P4303	.022 uf	25	68	5.91	44.32
P4305	.033 uf	25	82	7.08	53.10
P4307	.047 uf	25	89	7.68	57.60
P4311	.1 uf	25	1.79	15.37	115.31

NPO NPO NPO NPO NPO NPO NPO NPO

Part No	Cap	Volt	10	100	1,000
P4400	10 pf	500	73	6.28	47.13
P4402	15 pf	500	81	6.97	52.31
P4403	18 pf	500	81	6.97	52.31
P4404	22 pf	500	81	6.97	52.31
P4406	33 pf	500	1.03	8.89	66.71
P4407	39 pf	500	1.03	8.89	66.71
P4408	47 pf	500	1.37	11.80	88.53
P4409	56 pf	500	1.37	11.80	88.53
P4410	68 pf	500	1.56	13.38	100.35
P4411	82 pf	500	2.05	17.59	131.96

For Complete Specs on Physical Size and Electrical Characteristics, consult your *FREE* DIGI-KEY Catalog.

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33	6.3	20	1.68	14.04	14	1.12	9.31
47	6.3	21	1.74	14.48	14	1.16	9.59
100	6.3	22	1.83	15.22	16	1.33	11.05
220	6.3	28	2.34	19.53	21	1.78	14.80
330	6.3	29	2.46	20.48	23	1.92	15.95
470	6.3	33	2.78	23.15	23	1.97	16.34
1000	6.3	49	4.20	35.00	36	3.08	25.67
2200	6.3	60	5.13	42.75	54	4.56	37.95
3300	6.3	81	6.94	57.83	75	6.38	53.10
4700	6.3	1.04	8.89	74.07	93	7.95	66.20
[illegible]							

150 CAPACITORS — ASSORTMENT OF 15 POPULAR CAPACITORS — Cat. No. P6200 Kit — *ONLY* **$39.95**

TANTALUM CAPACITORS

DIGI KEY Part No	Cap. (µf)	Volt DC	Price 1	10	100	1000
[illegible]						
P2067	0.1	50	32	2.70	22.50	202.50
P2068	0.15	50	32	2.70	22.50	202.50
P2069	0.22	50	32	2.70	22.50	202.50
P2070	0.33	50	32	2.70	22.50	202.50
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E2123	250	.012	19	1.64	13.68	123.08
E2153	250	.015	19	1.64	13.68	123.08
E2183	250	.018	19	1.64	13.68	123.08
E2223	250	.022	19	1.64	13.68	123.08
E2273	250	.027	19	1.64	13.68	123.08
E2333	250	.033	19	1.64	13.68	123.08
E2393	250	.039	19	1.64	13.68	123.08
E2473	250	.047	19	1.64	13.68	123.08
E2563	250	.056	22	1.85	15.43	138.83
E2683	250	.068	22	1.85	15.43	138.83
E2823	250	.082	22	1.85	15.43	138.83
E2104	250	.10	23	1.94	16.13	145.13
E2124	250	.12	25	2.12	17.63	158.63
E2154	250	.15	27	2.28	18.95	170.55
E2184	250	.18	29	2.49	20.73	186.53
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E2334	250	.33	37	3.18	26.47	238.17
E2394	250	.39	41	3.44	28.66	257.85
E2474	250	.47	43	3.68	30.65	275.85
E2564	250	.56	47	4.02	33.45	301.05
E2684	250	.68	52	4.43	36.93	332.33
E2824	250	.82	58	4.94	41.13	370.13
E2105	250	1.0	63	5.35	44.52	400.62
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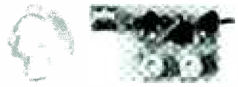

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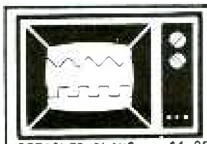

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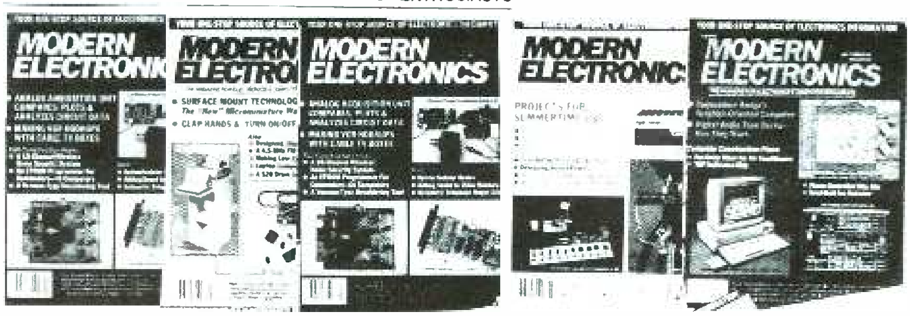

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EDITORIAL...

(from page 4)

their own, I think, and in many instances beat out CDs in sound quality, if they're kept clean as a whistle and you've got the room to store 'em all. CDs are the way of the future, there's no doubt. But just as early transistorized equipment couldn't match vacuum-tube equipment until designers got rid of crossover and other distortion-causing elements, and early stereophonic recordings took some time to capture its inherent advantages, so do compact discs have a way to go to equal the better LP recordings on the market in terms of sound quality when dust and wear aren't factors. Perhaps playing CDs on a $7,000 Accuphase compact disc player instead of a good $500 one would change my mind. We'll have to see about this.

Art Salsberg

Powerhouse *(from page 22)*

Besides these manuals, H-P offers a series of "Step-by-Step Booklets" for the calculator. I was able to examine the "Algebra and College Math" and "Vectors and Matrices" booklets and found each clear and easy to follow. Each page in these hundred-page-plus booklets provides illustrations of typical problems on a step-by-step basis. Additional booklets, including one on calculus, are either available or are in the works.

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