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- **UNDERSTANDING & USING DUAL-TRACE OSCILLOSCOPES**
- **RESTORE LIFE IN ANY SIZE NICKEL-CADMIUM CELLS**


A Digital Tachometer Module for the DMS (p. 44)

Full Construction Plans:
- **Digital Tachometer Displays Car- & Boat-Engine rpm**
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- **Drive Away Car Thieves with Painful, Limited-Distance High-Pitch Audio Amplifier**

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- **Rejuvenating Computer Printer Ribbons**
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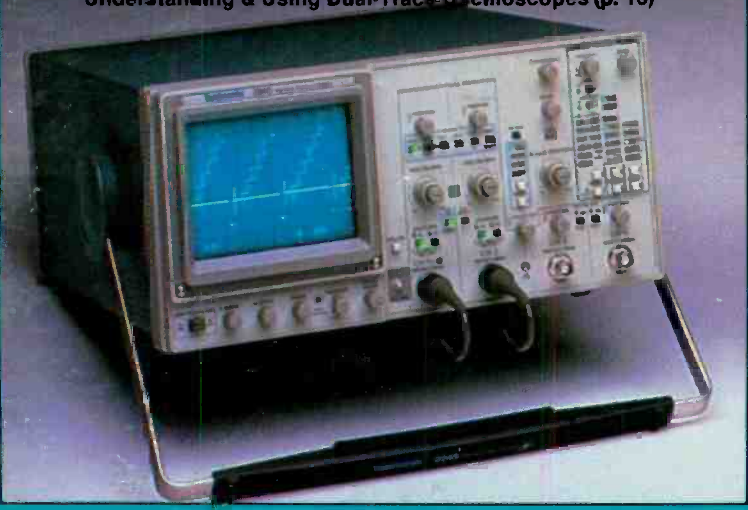
Understanding & Using Dual-Trace Oscilloscopes (p. 16)


The (Car) Thief Chaser (p. 34)


Plus: Forrest Mims experiments with NAND Gates ● Eric Grevstad reviews Leading Edge's Model D Computer . . . Ability and Able One Software ● Don Lancaster's "Hardware Hacker" ● Joe Carr's "Antenna Noise Bridge" ● Electronic & Computer News . . . and more.

ICOM 25-1000MHz Plus! IC-R7000

ICOM's commercial quality scanning receiver...Top quality at a gem of a price.

ICOM introduces the IC-R7000 advanced technology 25-2000MHz* continuous coverage communications receiver. With 99 owner programmable memories, the IC-R7000 covers low band, aircraft, marine, business, FM broadcast, amateur radio, emergency services, government and television bands.

Keyboard Entry. For simplified operation and quick tuning, the IC-R7000 features direct keyboard entry. Precise frequencies can be selected by pushing the digit keys in sequence of the frequency or by turning the main tuning knob.

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*Specifications guaranteed from 25-1000MHz and 1260-1300MHz. No coverage from 1000-1025MHz. No additional module required for coverage to approximately 2.0GHz.

See the IC-R7000 receiver at your local authorized ICOM dealer. Also available is the IC-R71A 0.1-30MHz general coverage receiver.

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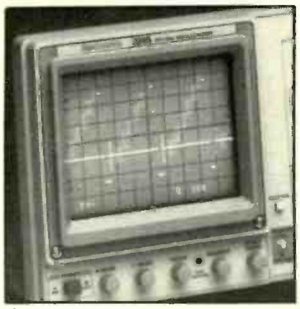
MODERN ELECTRONICS

THE MAGAZINE FOR ELECTRONICS & COMPUTER ENTHUSIASTS

OCTOBER 1986 **VOLUME 3, NUMBER 10**



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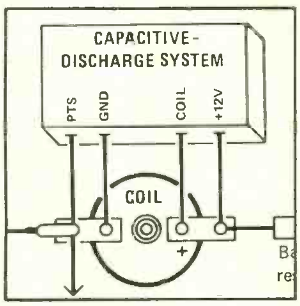

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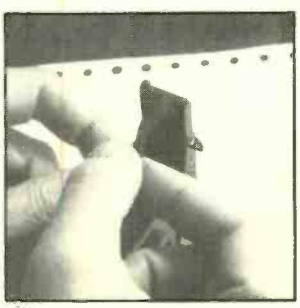

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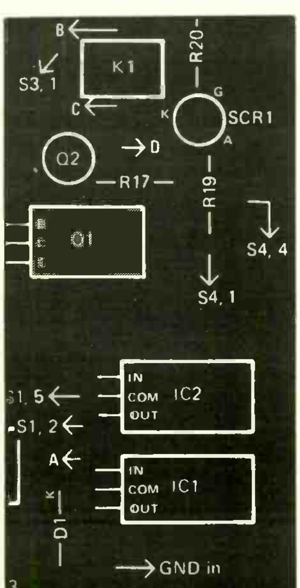

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FEATURES

COLUMNS

DEPARTMENTS

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EDITORIAL

Home Base

More and more people work at home. Full time, part time and as an adjunct to their main business-location work.

This might entail an independent work operation, say, a part-time electronic servicing business or a small mail-order sales; electronic design and prototyping work for one's self (perhaps a pet circuit you want to sell, manufacture, or submit to *Modern Electronics* as part of a construction-project article); writing a novel or whatever; doing research by tapping computer information services via telephone line; working on a spreadsheet or project schedule on a home-based computer that's compatible with an office computer system, and so on.

Whichever route(s) are taken for working at home, it's an endeavor that's expanding. In my case, it always required a bevy of test instruments, and appropriate tools for electronics work, and a typewriter (now a computer), all ensconced in a separate home room that serves as an office and shop away from company facilities.

I'm sure that many of you, like me, are continually upgrading and adding to your store of professional equipment. Thinking back to computers alone, I started with a MITS Altair machine, a Teletypewriter and BASIC on paper tape about ten years ago. This was supplemented by a Netronics Elf computer, followed by a Radio Shack TRS-80 Model I computer. I enhanced the latter to the point of an inherited high-speed digital tape system.

The foregoing equipment allowed me to enjoy a nice learning experience, but the tedium of working with tape limited their usefulness. It wasn't until I got a Heath H-89 all-in-one desktop computer with a single disk drive (hard sector) and a CP/M operating system disk that some computing in earnest could be achieved. After upgrading this system with a soft-sector floppy-disk drive/controller, I got a Kaypro computer with its separate keyboard and dual floppy drives. From there I went to an IBM PC that I upgraded to an XT with a hard-disk drive, and a Zenith IBM-compatible portable.

As you might imagine, each machine was constantly refined with internal modifications and a host of external devices, from various printers to modems, from one piece of software to another.

The point is that, though a full-time operation isn't met at home, there's plenty of merchandise bought for home business use. Many times this equipment is chosen to complement what's being used at one's main work station, of course. Our editors here are presently using a Tandy 1000 and an ITTXtra, for example, both IBM-compatible. Moreover, the additional experience garnered at home, aside from increasing productivity, helps in making equipment and material buying decisions in the office.

So reports that the home computer market is dead are premature. It's burgeoning (not for game-playing, though)! A study by *Computer Dealer* magazine reveals that 53% of computer dealers sold equipment to people with at-home businesses, which tied for third place out of 22 categories. Underscoring this, it's estimated that about 23-million people earn part or all of their living by working at home, and more than 200,000 people have arrangements with their employers for home telecomputing.

This is an interesting phenomenon, don't you think?

Art Salsberg

Pluses

• A note of thanks for Modern Electronics! I have enjoyed your mix of articles very much, especially those on construction, communications, and international broadcasting. Forrest Mims' articles are especially appreciated.

William T. Hole, M.D.
Barrington, RI

• I am a long time electronics hobbyist, as well as electronics engineer. I did not know of your publication until a few weeks ago when I ran across it on a newsstand in the Pentagon. I immediately sent in a subscription, and am happy with what I see.

I am particularly gratified that you have Forrest Mims as one of your contributors. He certainly has the ability to explain, relatively simply, some rather involved concepts and circuitry. I have attended some of his IEEE-sponsored classes here in the Washington area and have the highest regard of his ability as a teacher and "explainer."

William Winters
Bethesda, MD

And Minuses

• A couple of errors were made during printing of my "A Dual Video Amplifier" article (August 1986). Both are in the Parts List, which should read "LM359" for IC1 and "7806" for IC2. The Fig. 6 schematic diagram shows the correct component numbers.

Michael J. Keryan

• The schematic diagram in Fig. 1 of my "RS-232C Breakout Box" article (August 1986) shows LED2 connected in the circuit backwards. Proper wiring of the circuit is shown in Detail B of Fig. 3.

Cass Lewart

• With reference to the "Solar Cell Converter" (August 1986), please note that hot-carrier diode D2 should be number 5082-2835 and that the 1N4001 shown in Fig. 3 can be omitted. Also, the "P1" and "P2" labels for T1 should be transposed.

Dan Becker

• In "HF Op Amp" (June 1986), labeling of inputs to the voltage comparator in Fig. 7 is the reverse of what they should be. If V1 and V2 are swapped, the schematic and caption would be correct.

Duane M. Perkins

"WELL, I SPECIALIZED IN GROCERY STORE 'HEISTS' EXCLUSIVELY—"

MODERN ELECTRONICS NEWS

AUDIO ROYALTY TAX ATTACKED. A proposed royalty for record companies on audio tape recorders was attacked by Tandy Corp. chairman John V. Roach before a Senate panel. He said that "A subsidy to the recording industry...is absurd." The record companies, he noted, are asking for a subsidy from the industry that contributed to its sales growth.

FORREST MIMS' DOINGS. Modern Electronics columnist Forrest Mims got an award for his book on computer projects from the Computer Press Association this past spring. At the same time, he was informed that his application for the Space Shuttle Journalist-in-Space Projects was turned down. He was among 1,700 applicants. Walter Cronkite got the nod. Following the good news and bad news (though the latter might be deemed good by many) comes good news again. The prominent author just finished a taping session with a major cable TV company, HBO, in which he displayed electronic surveillence equipment. Expected showing is February 1987.

FCC PROPOSES NOVICE VOICE PRIVILEGES. Though pressured to turn down a proposal for a no-code Novice license a while back, the FCC now has proposed giving Novices voice privileges. Hopefully, this would stem the tide of declining numbers of Novices. As of year-end 1985 there were a total of about 76,000, which represents an attrition of more than 10,000 in a three-year period.

MULTILINGUAL WORD PROCESSOR. According to Computers Anywhere, McLean, VA, its new "Interword: The International Word Processor" for IBM-PC and compatibles permits switching from one language to another with a single keystroke. One version provides word processing in English and a second language (Arabic, Farsi or Russian), while two other versions let one write in up to either 5 or 11 languages and combine two or more on one page. The five-language set (Latin Languages) will likely be the most popular. An EPROM chip that accompanies software must be installed in the computer.

FREE 8-MM VIDEO INFO. A hot line for anyone interested in getting information about 8-mm VCRs has been announced by the recently organized 8MM Video Council, New York City. It's 1-800-843-8645, 8 a.m. to 6 p.m. Eastern Time, The New York state number is 212-986-3978.

CHEAPER ELECTRONICS LABOR. While the dust is still settling on a semiconductor trade agreement with Japan, and griped about Korea, Taiwan and Sigapore chip makers with too-low prices for the U.S. to remain competitive, Japan's Fujitsu is trying to work a deal with the People's Republic of China to manufacture their products for export to the U.S., including refrigerators and color-TV sets.

ELECTRONICS EMPLOYMENT TOPS ALL. The American Electronics Association reports that the electronics industry in the U.S. employed more people in 1985 than any other manufacturing segment--more than 2½-million. Transportation-product employment was next with 2.03-million employees. California dominated the industry with almost 600,000 employees in electronics companies. Next was New York with 226,000, followed by Massachusettes with 214,000 and Texas with 157,000 electronics workers.

SHOCK ABSORBER.

RCA's Power Safe surge suppressors absorb voltage surges before your customers' electronics get damaged.

Now you can help your customers protect their expensive electronic equipment from sudden shock with two new surge suppressors from RCA.

The Power Safe (SK406) protects TVs, computers, microwaves and more by absorbing transient voltage surges resulting from nearby lightning strikes, load switching and other causes before the surge hits the equipment. Handsomely designed and easy to install, this handy six-outlet strip simply plugs into any grounded wall outlet.

The Power Safe Plus (SKF406) protects every way the Power Safe does, plus it filters out electronic noise interference. The suppressor's high-frequency bi-directional filter senses, absorbs, and dissipates noise interference before it can reach the equipment.

Together, they have the potential to become powerful profit builders for you.

To learn more about this shock-absorbing team, see your RCA Distributor. Or contact RCA Distributor and Special Products Division, Deptford, NJ 08096-2088.

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CIRCLE 50 ON FREE INFORMATION CARD

NEW

Only NRI gives you a 27" high-resolution stereo color TV you build to prepare you for today's video servicing careers.

Become one of America's most sought-after technicians . . . put your talents and spare time to work for you in the "explosive-growth" world of home entertainment electronics.

Train in state-of-the-art video/audio servicing and become a fully qualified service professional the uniquely successful NRI way. It's hands-on training, at home . . . designed around the latest electronic equipment you build and keep as part of your training. You start from scratch and "discover by doing." You conduct key experiments . . . perform vital tests . . . build your own systems . . . and do it all at the pace that suits you best.

There's no stopping the incredible boom in consumer electronics. Soaring sales, new and improved video products, entirely new technologies have opened up new opportunities for the trained technician as never before.

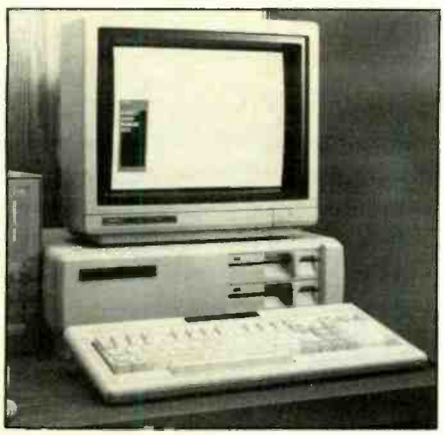
Now at $26 billion in annual sales, the consumer electronics industry is creating a whole new servicing, installation, and repair market. This year, TV sales alone are expected to hit 16.2 *million* units. Every day, sales of home VCRs, a product barely conceived of 10 years ago, reach 20,000 units. Every day!

And the revolution has spread to the business sector as tens of thousands of companies are purchasing expensive high-tech video equipment used for employee training, data storage, even video conferencing.

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.

PC-Compatible Computer

Tandy Corp.'s Model 1000 SX (replaces the popular 1000) business computer is said to run 50% faster than the IBM PC with which it is compatible. Built around the 8088 microprocessor, it runs most MS-DOS software at 7.16 MHz and is software switchable to 4.77 MHz. The 1000 SX features two disk drives and comes with more memory and 10″-maximum expansion slots than the 1000. The keyboard has 90 keys with 12 programmable function keys.



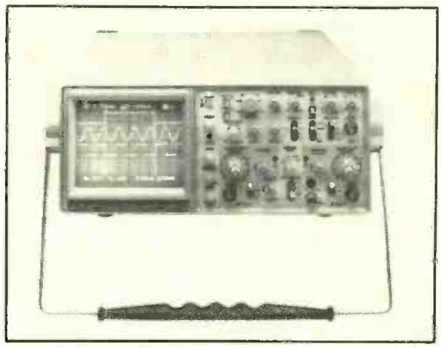
Standard features include: 384K of RAM, expandable to 640K on the main board; two 360K 5.25-in. floppy drives; printer and joystick ports; and monochrome and color (composite and RGBI) video capability. It also supports the ViaNet™, Network 4 and PC Net® networks. There's a socket for an 8087 math coprocessor.

Included with the computer are MS-DOS 3.2, GW-BASIC and DeskMate® II. DeskMate II software is an updated version of Tandy's six-in-one applications package, which consists of word processing, spreadsheet analysis, electronic filing, calendar/alarm, telecommunications and electronic mail functions. A new task-switching feature permits exiting from DeskMate II, entering a different applications program and returning to DeskMate II with just a few keystrokes. $1,199.

CIRCLE 43 ON FREE INFORMATION CARD

Real-Time Oscilloscope

Gould Electronics' new Model 3060 60-MHz oscilloscope offers 3-channel, 6-trace delayed sweep and diagnostic self-check in a bench-top/portable instrument.

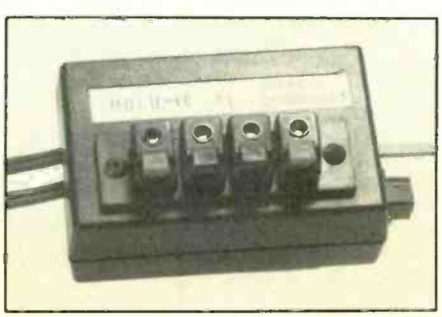


Its auto/normal triggering modes include TV-V/TV-H. cursor measurements include voltage difference, time difference, and frequency. Displayed on-screen vertical deflection settings include V/div., MAG, UNCAL, INVERT (CH2), ADD and Probe Attenuator (×10). Displayed horizontal deflection settings are s/div, MAG, UNCAL and Delay Time. Featured is a square CRT with illuminated integral graticule. The adjustable carrying handle, with moulded plastic hand grip, doubles as a tilt stand on the bench. $1,490.

CIRCLE 44 ON FREE INFORMATION CARD

Audio Volume Reducer

Technetwork's (San Jose, CA) new Volume II accessory electronically reduces the sound level of any home stereo system when the telephone



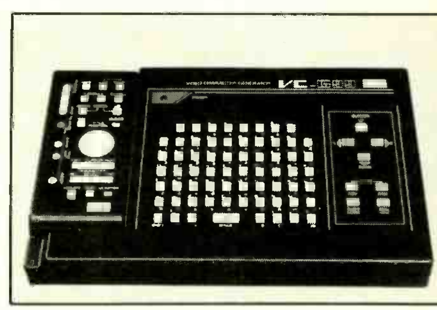
rings or is in use. With Volume II installed between the output of the stereo system and the speakers, with a connection to the telephone line, lifting the telephone's receiver automatically reduces the sound to a low level. The accessory also alerts the user to incoming calls by lowering and raising the volume in step with the ring of the telephone. Sound returns to its original level when the receiver is replaced on the telephone.

The Volume II accessory has two selectable volume levels that can bring the sound down to a whisper when used with amplifiers rated at up to 100 watts rms. $34.95.

CIRCLE 45 ON FREE INFORMATION CARD

Video Character Generator

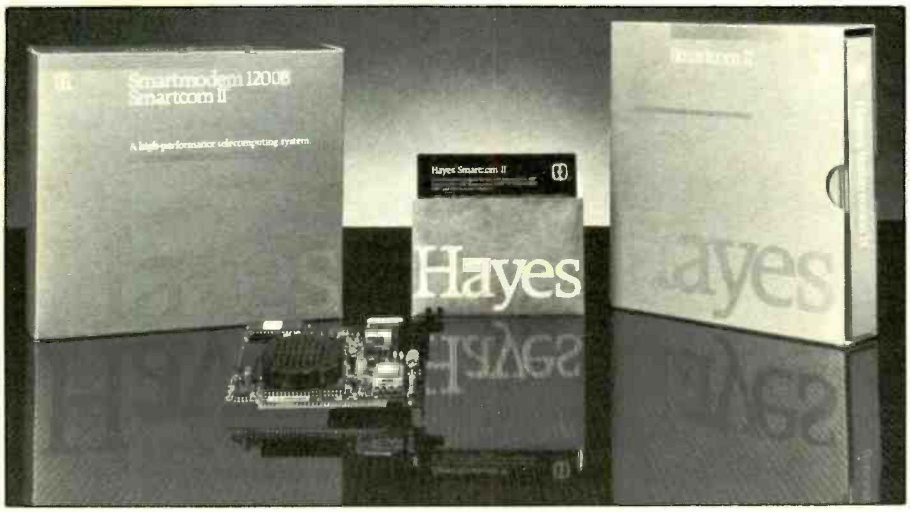
Sansui's Model VC-G99 portable video character generator professionally titles amateur and commercial video tapes. It has a typewriter-style keyboard that can be separated from the main character generator unit. The character generator itself provides 124 characters in English, French, German and Spanish. Character size is variable line-by-line with four sizes available. Up to eight pages can be stored in memory, each containing up to seven lines of 20 characters per line.



Portability and the VC-G99's ability to work directly with a video camera permit on-site titling as original video tapes are shot. Titling can be informational for future use in editing, or part of an on-the-spot production. Calendar date can be displayed along with lap time. Included are zoom and positioning functions for titling, cursor and scroll functions.

Power can be obtained from the camera with which the title generator is being used, an ac adapter (included) or six AA cells (not included). The character generator unit measures 5¼" × 2" × 1", the keyboard unit 9" × 6" × 2¾". $350.

CIRCLE 46 ON FREE INFORMATION CARD



Half-Slot 1200-Baud Modem

Hayes' Smartmodem 1200B™ internal auto-dial/answer modem board works in full- and half-card slots in IBM PCs and compatibles. It features: call progress monitoring, rotary and 16 DTMF or PABX dialing, built-in test modes, 1200- and 0-to-300-baud transmission rate, full Hayes Standard "AT" Command Set implementation, CCITT V.22 compatibility, voice/data transmission, two phone jacks, and redial.

Bundled with the Smartmodem 1200B is the Smartcom II communications software.

Four DIP switches (two fewer than in the previous model) are provided for configuring the modem. Internal uses controlled by the extra two switches in the previous version are implemented in the new modem using "AT" commands. The switches are accessible at the back panel without having to remove the computer's cover. $549.

CIRCLE 47 ON FREE INFORMATION CARD

Theft-Proof Car Radio

Denon's Model DCR-5420 receiver is designed for those people who want to prevent theft of their car stereo equipment. This receiver/cassette player easily slides out of the dashboard, leaving a conspicuous hole that informs thieves of lean pickings. Featured in the DIN E-size unit are: a frequency-synthesized AM/FM tuner with 18 FM and 6 AM presets; an auto-reverse cassette deck with Dolby B and C noise reduction; a flexible preamp/power amplifier; and the anti-theft slip-case.

The Denon Optimum Reception System (D.O.R.S.) in the tuner automatically adjusts muting, high-cut filtering and stereo separation according to signal strength. A Music Sensor in the auto-load/eject cassette deck automatically finds and plays the next or previous selection on tape. The 18-watt/channel internal amplifier can drive two pairs of speakers and features a front-to-rear fader control. The latter also balances between the internal amplifier and the line-level outputs to an external amplifier.

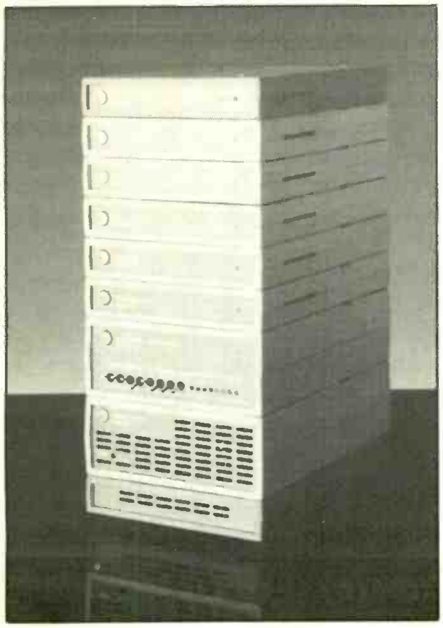
Tuned frequency and time appear in an LCD display, and front panel illumination is adjustable via the vehicle's dashboard instrument dimmer control. $429.95.

CIRCLE 48 ON FREE INFORMATION CARD

Personal Control Computer System

The A-II Personal Control Computer System from DataBlocks, Inc. (Alamo, GA) is designed for real-time personal "process" control and measurement of real-world devices. The minimum system consists of stacking power-supply and central-processing unit "blocks." The latter interfaces with the real world through a variety of different user-selected stackable blocks. CMOS technology in all circuitry makes it possible to battery power or back up the CPU block.

Each block is designed to provide a separate function, such as PROM/RAM memory, parallel I/O, serial I/O, disk drive, drive control, voice synthesis, voice recognition, CRT control, A/D and D/A control, etc. The Central Processor block uses the NSC-800 CMOS microprocessor that includes the complete 8080 and Z80 instruction sets (making it fully CP/M compatible) and operates at 8 MHz. Twin 60-pin connectors on each block directly plug into the other blocks, eliminating the need for cables. Any combination of the more than 30 different special-purpose blocks currently available can be implemented in a single system, depending on the needs of the system, with an upper control limit of 65,000 different devices. Hence, each system's configuration can be unique.



The software is designed for control and robotic applications. ARTDOS (A-II Real-time Disk Operating System, resident in the CPU system PROM) specifically handles personal control applications. SB-80- and CP/M-based software will operate under ARTDOS. The A-II also supports a variety of languages, including XYBASIC, C, Assembler and PCL (A-II Process Control Language).

CIRCLE 49 ON FREE INFORMATION CARD

Home Security System

General Electric's Door Monitor™ closed-circuit TV surveillance system is designed primarily for installation in new construction. It allows homeowners to answer the door using a built-in camera/intercom that works in concert with an existing TV receiver. The system can be expanded to cover up to three camera and three TV control locations.

In operation, the homeowner can switch from a TV program to view a visitor at an entrance covered by the camera/intercom by pressing a button on the Master Controller. Pushing a second button then activates the intercom function.

GE's Door Monitor system consists of three units. The one-piece Door Camera incorporates camera, intercom, bell button and light. The Door Monitor Control is used to switch between closed-circuit and TV program viewing and includes the intercom function for two-way conversation. The master Controller is a central processing unit that mounts anywhere and acts as the distribution point for a master antenna or cable TV hookup. An optional high-sensitivity Mini Cam™ camera is available.

CIRCLE 50 ON FREE INFORMATION CARD

Variable DC Power Supplies

A new family of low-power laboratory and industrial variable dc power supplies featuring user selectable constant-voltage/constant-current and constant-voltage/current-limiting operation with full line and load regulation has been announced by VIZ Test equipment. Each of the six models is IEEE-488 bus-compatible with the WP-790 interface. CV/CC and CV/CL operation selection is via a recessed front-panel switch that prevents inadvertent changing from mode to mode. Two models each are available with outputs of 25, 40 and 50 watts. Line and load regulation are specified at 0.015% + 2 mV.

Featured are: 3½-digit LCD display that can be switched to separately indicate voltage and current; separate voltage and current setting controls; 5-way binding-post output connectors; a reset button; an overload LED; and a lighted power switch. All models are rack-mountable and comply with UL and CSA safety specifications.

CIRCLE 51 ON FREE INFORMATION CARD

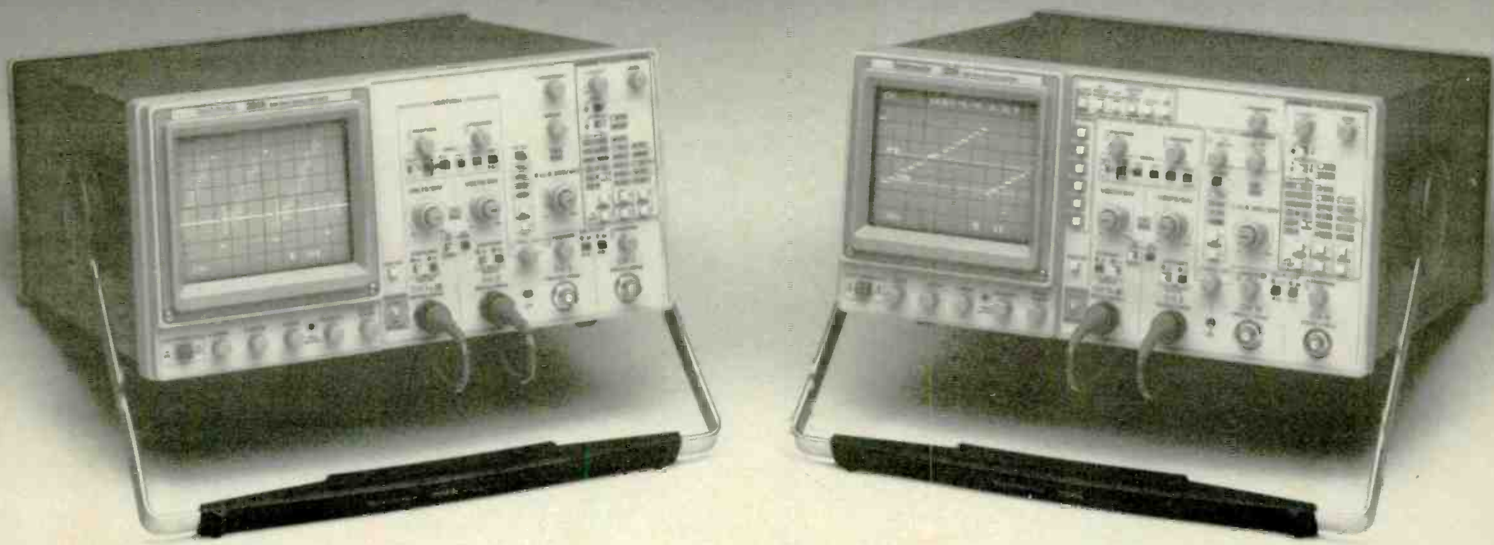
Security Device

Technalock from Business Security Systems Corp. (St. Louis, MO) offers a low-cost way to secure moveable equipment from theft. Pressure-sensitive adhesive bonding

(Continued on page 75)

CIRCLE 29 ON FREE INFORMATION CARD

Understanding and Using Dual-Trace Oscilloscopes



The basics, comparing two waveforms and a primer on probes

By TJ Byers

Modern waveform measurements are so critical that they often exceed the capabilities of the conventional oscilloscope, particularly in digital electronics. Accurate time comparisons between two waveforms is possible only when the two events can be observed simultaneously in real time. For most of us, this means using a dual-trace oscilloscope.

True dual-beam scopes exist, but the vast majority of the scopes in use employ digital switching techniques to display two traces on a conventional single-beam CRT. To obtain two or more traces from a single beam, two switching methods are used. These are identified as the alternate and chopped modes.

Switching Modes

Both the alternate and chopped modes use an electronic switch with two vertical preamplifiers and one vertical driver amplifier, as shown in Fig. 1. The electronic switch, which is sometimes called a chopper, is akin to an ultrafast relay that toggles between the outputs of the vertical preamplifiers, alternately feeding the two input signals to the vertical driver amplifier.

In the alternate mode, the electronic switch toggles between the preamplifier outputs following subsequent sweep periods. For example, the switch feeds the channel A signal to the vertical driver during the first sweep period. (The vertical driver displays the signal on the screen.) This gives the first waveform.

During retrace, the electronic switch flips position and feeds the signal on channel B through the vertical driver amplifier for the next sweep period. This gives the second waveform. Because the phosphor on the CRT screen has a persistence that is longer than the sweep time, both images appear to be on the screen simultaneously.

To keep the images separate, each preamplifier has an offset voltage that forces the trace above or below the center line of the screen. Individual panel adjustments control the

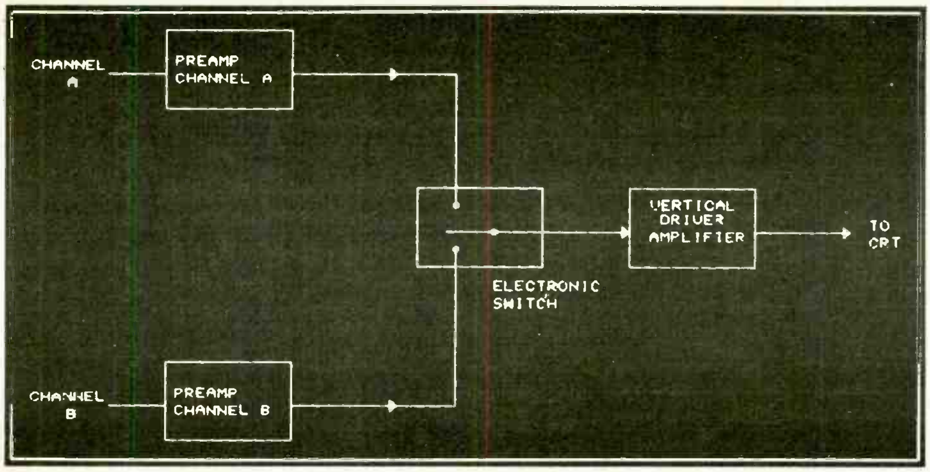


Fig. 1. Most dual-trace oscilloscopes use digital switches to display two traces on a single-beam CRT. An electronic switch alternates between outputs of vertical preamplifiers and feeds signals to a vertical driver amplifier for display.

offset voltage and subsequent screen positions of the traces.

In the chopped mode, the electronic switch alternates between channels A and B at a rate considerably faster than the sweep frequency (generally 100 kHz or better). This technique is known as sampling.

As the sweep begins, the switch first takes a sample from channel A and passes it through the vertical driver amplifier. Quickly, the electronic switch toggles to take a sample of the signal on channel B, passing this along, with a corresponding offset voltage, to the vertical driver for display. Another sample is then taken from channel A, another from channel B, etc. A typical display looks like that shown in Fig. 2.

When the samples are displayed on the screen, though, the human eye is tricked into believing that two solid traces exist—one above the other. The missing portions of each trace, which actually amount to 50% of the total information, are so small that the brain's integration system fills in the blanks so that the waveform appears to be solid and continuous. This same filling is what makes viewing a television picture a success.

The disadvantage of the chopped display is that short-lived transients may be cut out of the picture entirely during the switching period, which can lead to a false impression of the waveform. This problem does not occur in the alternate mode because each sweep is carried to the finish before transfer between channels.

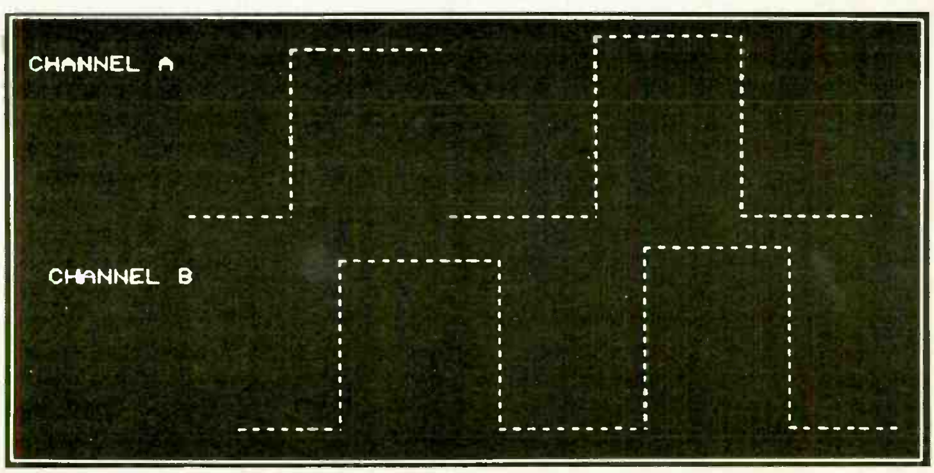
The only limitations to the number of traces that can be simultaneously displayed in the alternate mode are the persistence of the phosphor and screen area. Many oscilloscopes boast eight traces, and some digital scopes offer as many as 16 traces.

Chopped displays, on the other hand, are limited in number. As more and more time is devoted to sampling alternate inputs, less time is available for each input. In a dual-trace system, a full 50% of the waveform is lost on each trace. Displaying four traces causes 75% of the information to be lost, leaving only 25% of the waveform to be sampled and displayed per input. Hence, a lot of the waveform is unaccounted for. As input frequency increases, fewer samples are taken per cycle, and the image becomes coarser and more difficult to distinguish. The trick is to run the sampling oscillator much faster than the input signal frequency so that samplings are closer together and the display is more representative of the waveform.

There is a limit to how fast the switch can sweep the input preamplifiers and still return a true display of the input. Factors like slew rate and settling time place an upper frequency limit on the sample rate, which limits the number of traces the chopped mode can faithfully display. At the present time, four seems to be the practical limit.

Which display mode is best for an application? The answer depends on the complexity of the waveforms involved and the accuracy of the measurement required. Chopped images

Fig. 2. In chopped mode, electronic switch alternates between channels A and B at a rate considerably faster than sweep frequency, producing a broken waveform. the eye is tricked into seeing solid traces.



are less faithful because portions of the waveforms are missing. Alternate displays, on the other hand, produce objectionable flicker when the sweep rate is too slow.

Generally, it is a good idea to use the chopped mode for sweep rates of 1 millisecond or more and the alternate mode for anything faster than that. In some instruments, you make the choice. By and large, though, selection is made automatically by the oscilloscope as sweep rate is adjusted.

Sweep Triggering

As with any display, the sweep must begin at a precisely defined time for a stable waveform to appear on the screen. When working with more than one trace, this can get tricky.

Sweep triggering is handled by a trigger generator that is responsive to several trigger input sources. Typical trigger sources include internal, external and line, each designed to suit its own range of applications.

On internal triggering, the trigger generator obtains its drive from the vertical input amplifier. On external, the trigger pulse comes from an external source. Line sync triggering is unique in that it receives its trigger from the 60-Hz ac line, a source that is used when the waveform conforms to ac line timing.

Most scopes offer automatic (auto) and normal synchronization modes. Automatic triggering is the most frequently used. In this mode, a trigger signal is generated whenever the vertical input passes through an imaginary baseline reference, usually zero volt, set by the horizontal sweep. With this arrangement, a trace is displayed whether or not a vertical input is present. It is most useful when the signal amplitude is too low for triggering.

In normal triggering, the trigger pulse is generated after the input signal passes through a preset voltage. Because this mode does not have the imaginary baseline reference of the auto mode, it is important that the vertical waveform does cross this preset level or the circuit will not trigger. Most scopes have a level control that shifts the voltage of the triggering point above or below zero volt so that even negatively-biased waveforms can enable the sweep.

Generally, the trigger is taken from the channel A input. Just where on the signal the sweep is to begin is determined by the trigger control settings and the triggering mode selected. Alternatively, the trigger can be taken from channel B. Since the trigger input is independent of the electronic sampling switch, trigger selection is simply a matter of monitoring one channel or the other.

Finally, the trigger can be taken alternately from channels A and B. In this mode, the trigger is derived from the output of the electronic switch. This mode is most often used when two unrelated waveforms are simultaneously displayed.

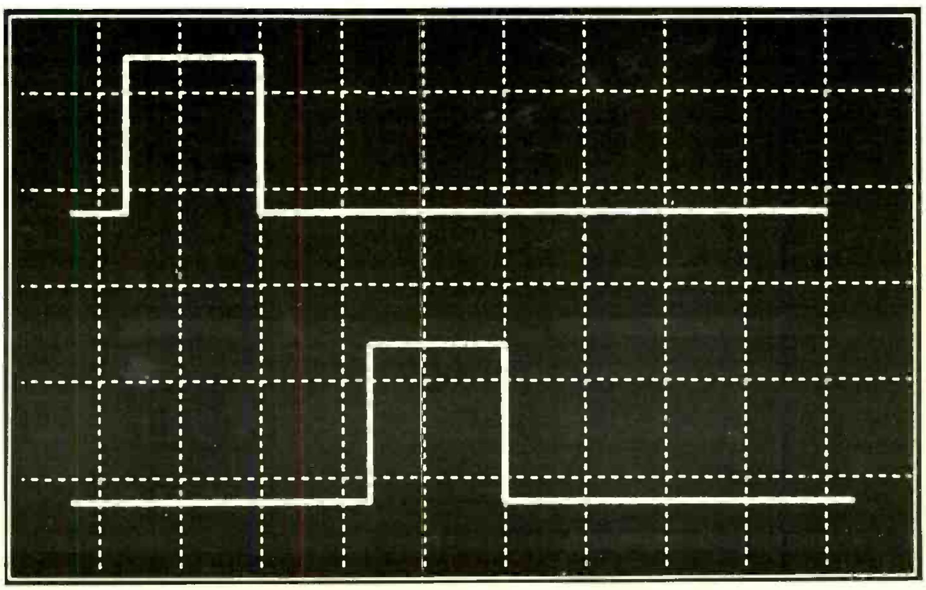
As an example of alternate channel A/B triggering, say you wish to view the ac line voltage going into a TV receiver and the receiver's vertical sweep on the two channels. Since these frequencies are similar but unrelated, there is no common denominator. Therefore, one or the other signal will appear to drift on the screen. To eliminate this drift, place the oscilloscope in the alternate-trace mode and initiate alternate triggering. Here the trigger is first taken from channel A, then channel B. Each trace is synchronized with its representative input, so both images appear stable even though they are unrelated.

Time/Phase Measurements

Dual-trace scopes are at their best when comparing two waveforms in real time. In many applications, it is important to know either the time or phase relationship between two signals, especially in digital circuits where clock pulses must fall within specific timing slots with reference to other events.

Time relationships between two waveforms can be viewed directly on a dual-trace oscilloscope simply by adjusting the vertical and sweep controls to obtain a stable display on the CRT screen. Best results are obtained when the sweep is triggered from the leading edge of the signal on channel A.

Fig. 3. With a scale factor of 1 microsecond per division, events depicted here are 3 microseconds apart.



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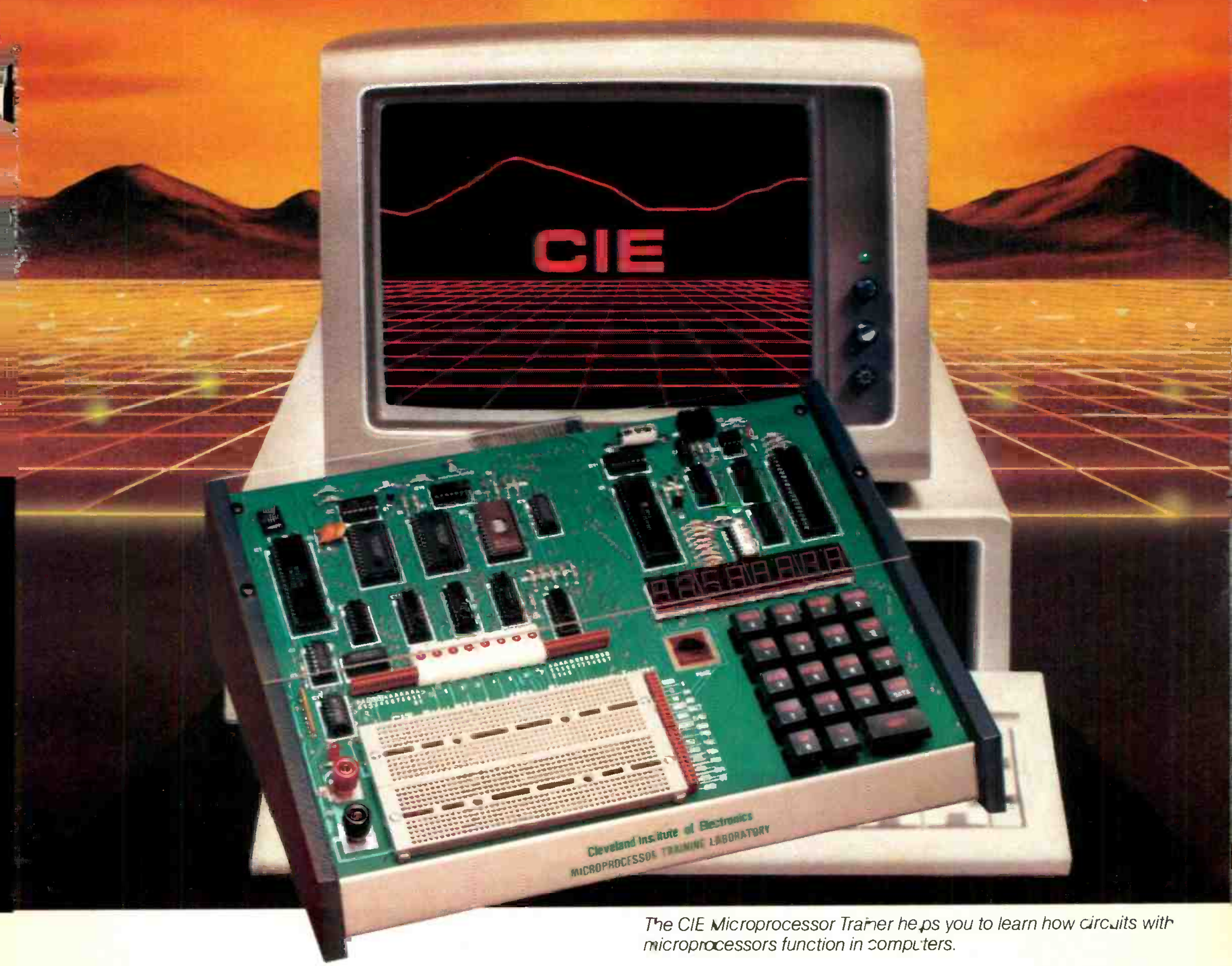

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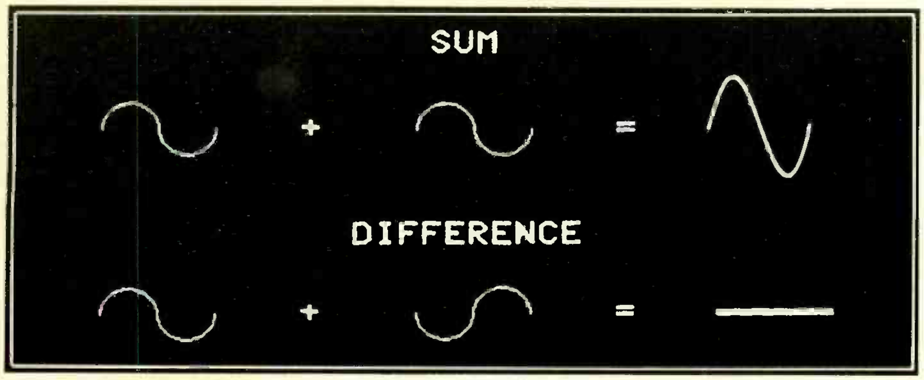


Fig. 4. Outputs of preamps can be combined to produce unique results. In sum mode, inputs are mixed in-phase and complement each other. In difference mode, inputs are 180° out-of-phase and cancel. This can be used to emphasize differences between apparently identical signals.

Once the display has been stabilized, you count the number of graticule lines between identical points on the waveforms and multiply by the scale factor. In Fig. 3, for example, the leading edge of input B begins three divisions after channel A has started. If the scale factor is 1 microsecond per division, the two events are separated by 3 microseconds.

Phase angle, on the other hand, is a calculated value determined by the duration of the clock cycle as it relates to time displacement. For example, if a shift of 250 nanoseconds is noted between two 1-MHz signals, the displacement is 0.25 times the whole, or 90 degrees, 360 degrees being the whole. A shift of 0.5 (expressed as 1:2) is 180 degrees; 3:4 is 270 degrees; and so forth.

Digital phase measurements are not as confusing as they may at first appear. A simple way to relate two waveforms is to look for phase inversions in which signals are 180 degrees out-of-phase and leading or lagging clock pulses in which the signals are generally 90 degrees out-of-phase. These are the most prominent. It is seldom that digital clocks use oddball phase angles.

Sum and Difference

Another interesting aspect of dual inputs occurs when the two signals are mixed together rather than viewed separately. In this mode, the outputs of the preamplifiers are combined in a mixer circuit. The phase shift of the two signals is precisely controlled so that predictable results are obtained.

In the sum or add mode, for instance, the inputs are in-phase and complement each other (upper portion of Fig. 4). Two sine waves of the exact same frequency, for example, reinforce to produce an output that has twice as much voltage swing as either does individually. The sum mode can be used to produce suitable displays of signals otherwise too low in amplitude for regular viewing.

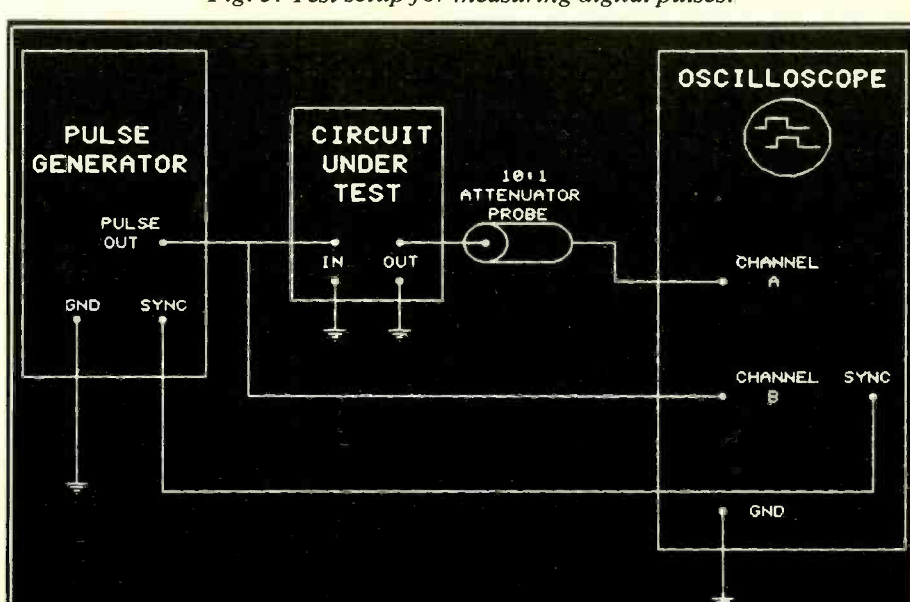
The difference (or sub) mode places the two inputs 180 degrees out-of-phase with each other (lower portion of Fig. 4). This is done inside the preamplifier by sending the signal through an inverter before routing it to the mixer. In this mode, like voltages cancel. If identical sine waves are applied to the inputs, the voltages oppose each other, causing a straight line to be displayed on the oscilloscope's screen.

The difference mode is most useful for detecting small differences in a processed signal, as would be the case if you were comparing the input of an amplifier to its output. Since the original waveform cancels itself out, small amounts of distortion and phase shift are readily visible—and are, in fact, the only images seen on the screen.

Pulse Measurements

A digital pulse contains five important parameters: pulse rate, duty cycle, pulse width, rise time and fall time. The test setup for measuring digital pulses is shown in Fig. 5. Rise

Fig. 5. Test setup for measuring digital pulses.



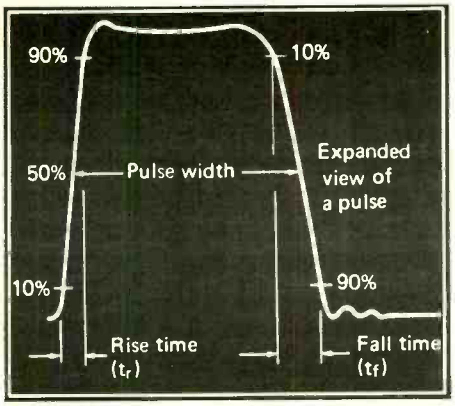


Fig. 6. Rise and fall times are measured between 10% and 90% points on vertical axis; pulse width is measured between the 50% marks.

and fall times are measured between the 10% and 90% points along the vertical axis, as shown in Fig. 6. Pulse width is measured between the 50% marks, and duty cycle is calculated as pulse width divided by the time required to complete a cycle.

In most digital and computer circuits, rise and fall times are the most important pulse parameters. When measuring rise and fall times with an oscilloscope, it is desirable to adjust sweep rate and triggering controls so that the leading (or trailing) edge fills a large part of the screen.

For rise time measurements, the trigger is set to begin on the rising edge of the waveform. Sweep rate is then adjusted so that the slope of the leading edge fills as much of the screen from left to right as possible without overscanning. The 10% and 90% points are identified on the vertical axis and a time measurement is made along the horizontal axis between these two points.

A similar method is used to measure fall time. Fall times are generally longer than are rise times by a factor of about three and vary considerably, depending on the load placed on the output of the device under test. Hence, fall times are measured using a slower sweep rate.

Unfortunately, waveform aberrations make it difficult to trigger the sweep on the falling edge, which is a critical requirement for displaying the parameter. The delayed sweep feature found on most dual-trace oscilloscopes offers a simple method for measuring fall time with very good results. You simply stabilize the image by triggering on the leading edge and activate the delay function. Using the horizontal positioning control, you then position the waveform on the screen so that the trailing edge of the pulse is visible.

In some cases, though, the width of the pulse may be too large for the time delay. When this occurs, it is possible to trigger the sweep from another source. This is where the dual-trace oscilloscope has an advantage over the single-trace scope.

Single-trace scopes require an external trigger source when operating in this mode—which includes additional external circuitry. A dual-trace oscilloscope, though, can take its cue from an alternate input. To do this, you simply search through the various waveforms available in the circuit and select one that allows you to trigger your sweep from channel B at the time desired.

Probes

Probes are critical to the proper measurement of pulses with an oscilloscope. In fact, the probe can very well be the most critical component in the system because it interacts with both the scope and the signal source. Choosing the wrong test probe can lead to false readings, and may even damage the circuit under test.

The need for a probe arises from the need to combat the electromagnetic noise pollution that is constantly with us. Unless the vertical input is insulated from this external "interference," whatever noise that may be in the vicinity, including stray 60-Hz ac-line hum, will be fed into the scope's input along with the signal. The obvious result is inaccuracies in the displayed waveform's shape, amplitude, etc.

One effective solution to the pollution problem is to shield the scope's input from external radiation by encasing its input wire in a metal shroud. Common coaxial cable offers the simplest approach. Coaxial cable consists of a single conductor surrounded by a wire braid or metal foil shield. Grounding the shield, which intercepts any electrical noise in the vicinity, routes to ground the noise before it can reach the signal-carrying inner conductor.

Several types of coaxial cable are used for scope probes, the most popular being RG58/U, RG59/U, and RG188A/U. Unfortunately, coax suffers from noticeable attenuation that is both frequency and length sensitive. As the frequency of the input signal increases, so too does the cable's attenuation characteristic. Similarly, the longer the cable, regardless of frequency, the greater the attenuation. Figure 7 shows the relationship between attenuation, length and frequency for three types of coaxial cable.

Part of the coaxial cable's attenuation is due to dielectric absorption, the remainder to capacitive loading. Capacitive loading gives the oscilloscope the most problems. Dielectric absorption can be compensated for

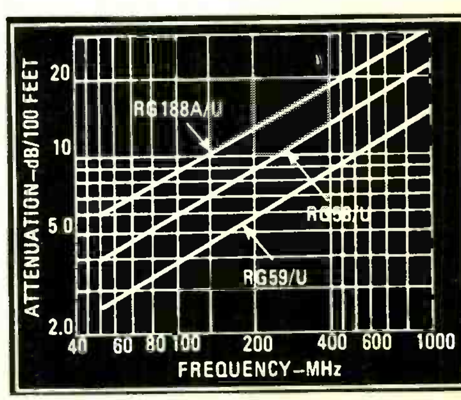


Fig. 7. Coaxial cable suffers from noticeable attenuation of signal as input frequency increases. Cable length is also a cable-loss factor.

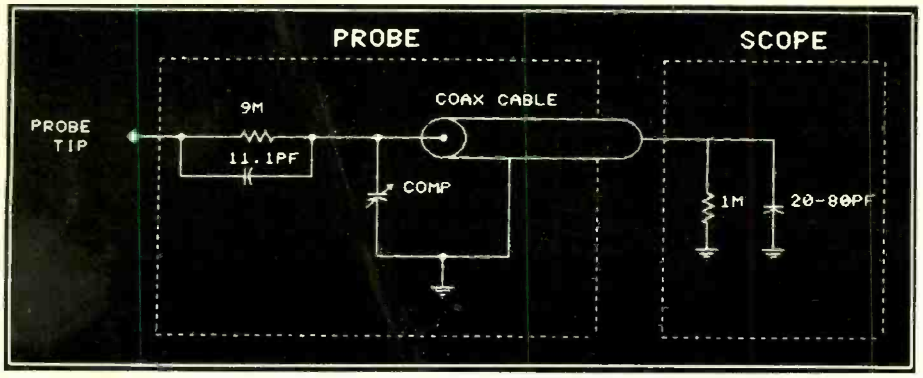


Fig. 8. Attenuator probe has series resistor that isolates cable capacitance from device under test. Series capacitor compensates for frequency attenuation.

The Bandwidth Issue

The quality of a digital pulse measurement depends heavily on the bandwidth of the oscilloscope and the probe(s) used with it. The frequency response of the vertical amplifier determines the bandwidth.

Oscilloscopes fall into two general categories: low frequency and high frequency. Low-frequency scopes have a frequency response from dc up to 10 MHz and are generally used in service applications, such as TV repair. Generally, these scopes are low-budget instruments with few features.

High-frequency scopes, on the other hand, have bandwidths as wide as 350 MHz and are used primarily in laboratory environments. These instruments normally include many features that enhance the performance, including delayed sweep and sweep magnification.

Every increase in bandwidth and added frill adds to the cost of the instrument. Even so, high-frequency scopes are being increasingly used in digital testing because of their quick rise-time response.

with standard calibration measures. The effect of capacitance loading, which affects the shape of the waveform, however, is a bit more difficult to deal with.

A good example of the problems encountered in dealing with digital measurements can be found in a square wave. The square wave, by definition, consists of the summation of an infinite number of odd-harmonic frequencies. The lowest frequency determines the oscillation period, the highest the sharpness of the corners of the waveform.

As a signal passes through a length of coax, the cable attenuates the higher frequencies more than it does the lower frequencies. If a perfectly square waveform were fed into the input end of the cable, it would have rounded corners when it exited the output end. This is obviously unacceptable for critical scope work. The problem is compounded by the cable capacitance, which loads the circuit under test and causes further distortion the waveform.

Isolating the Load

To solve the distortion problem, a two-fold approach is used. Firstly, the circuit must be isolated from the capacitive loads imposed by the coaxial cable and the oscilloscope. This is done by inserting a resistor in series with the cable's center conductor, as shown in Fig. 8. The resistor is placed at the very tip of the probe, where it has the most effect. The load now appears to the oscilloscope to be resistive rather than capacitive.

Selection of a value for the resistor is based on a compromise between isolation characteristics, signal attenuation, and bandwidth. The larger the value, the greater the isolation. On the other hand, signal attenuation, increases as resistance increases, while bandwidth decreases. Obviously, then, the value selected must provide a compromise that will provide acceptable overall performance results.

Probe bandwidth is closely related to rise time response. It is calculated using the formula: $BW = 0.35/(t_r)$, where BW is bandwidth in Hz and (t_r) is rise time in seconds.

Rise time response is a factor of isolation resistance and cable capacitance and is defined as the amount of time it takes to charge the RC (resistive and capacitive) components of the test probe to the nominal voltage value. The resistive component consists largely of the series resistor, while the capacitive component consists of the combination of distributed cable capacitance and oscilloscope input impedance.

As input resistance increases, the RC time constant also increases. This reduces bandwidth, evidenced by rounding of the corners of square waves, and attenuates high-frequency sine waves. Both situations lead to an inaccurate representation of the waveform under test.

A compromise value of 9 megohms is typical for the series resistance. An input impedance of 10 megohms effectively reduces the shunt capacitance to a low 10 pF while maintaining a respectable 10:1 attenuation ratio.

Equalizing the Bandwidth

Effects of frequency-selective signal attenuation within the coaxial cable must be dealt with next. In essence, you want to accentuate the highs while maintaining the lows. This is accomplished with a high-frequency boost to overcome the losses caused by the coaxial cable. Ideally, the boost should increase with frequency to offset the frequency-sensitive attenuation characteristic of the cable.

A series capacitor offers a virtually ideal solution. Capacitive reac-

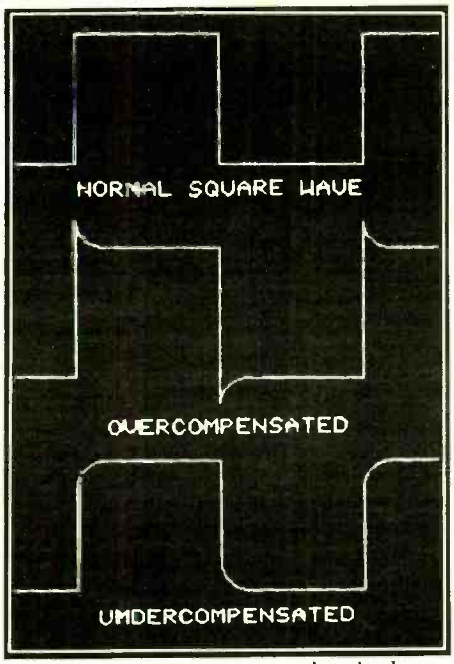


Fig. 9. Probe compensation is done using square waves. At top is example of perfect compensation, center and bottom show distortion that results with too much and too little compensation, respectively.

tance (the amount of effective resistance a capacitor exhibits to the passage of an ac current) is an inverse function of frequency. That is, the higher the frequency, the less resistance a capacitor represents. By providing a capacitive path for the signal, the high frequencies can be proportionally boosted.

Compensation is most effective when the capacitor is placed across the isolation resistor, as shown in Fig. 8. Because the compensating capacitor is typically very low in value (on the order of 10 pF), it has little effect on the lower frequencies that must make their way through the isolating resistor. Higher frequencies, however, find the capacitive path easier going and bypass the isolation resistor altogether. The higher the frequency, the less the resistance encountered. By the time both components reach the input of the scope, though, the high-frequencies have been attenuated to the level of the low frequencies and the waveform appears in its original form.

Cable length complicates the picture. For the compensating capacitor to put all frequencies back in balance, the exact distributed capacitance of the scope probe must remain constant from unit to unit. Standard manufacturing practices, however, prohibit such precision. A variable capacitor is placed across the line to allow the user to compensate for differences in cable capacitance.

Before the probe can be used, therefore, the trimmer capacitor must be adjusted. Not surprisingly, adjustment is done using a square wave. Most quality oscilloscopes provide an internal square-wave calibrator for such purposes. With the probe attached to the voltage calibrator output, you adjust the capacitor until the waveform is as square in appearance as you can get it. What you are actually looking for is a very square corner at the leading edge of the waveform.

If a probe is undercompensated, the leading-edge corner will appear rounded; while too much compensation causes the signal to overshoot and result in leading-edge ringing. Figure 9 shows typical waveforms for a properly compensated probe, along with those for an over- and an undercompensated probe.

After a probe has been adjusted, it is ready to use. Just keep in mind that the probe's internal network is in series with the input and, thus, attenuates the signal by a factor of 10. Hence, always remember to make the appropriate mental adjustment.

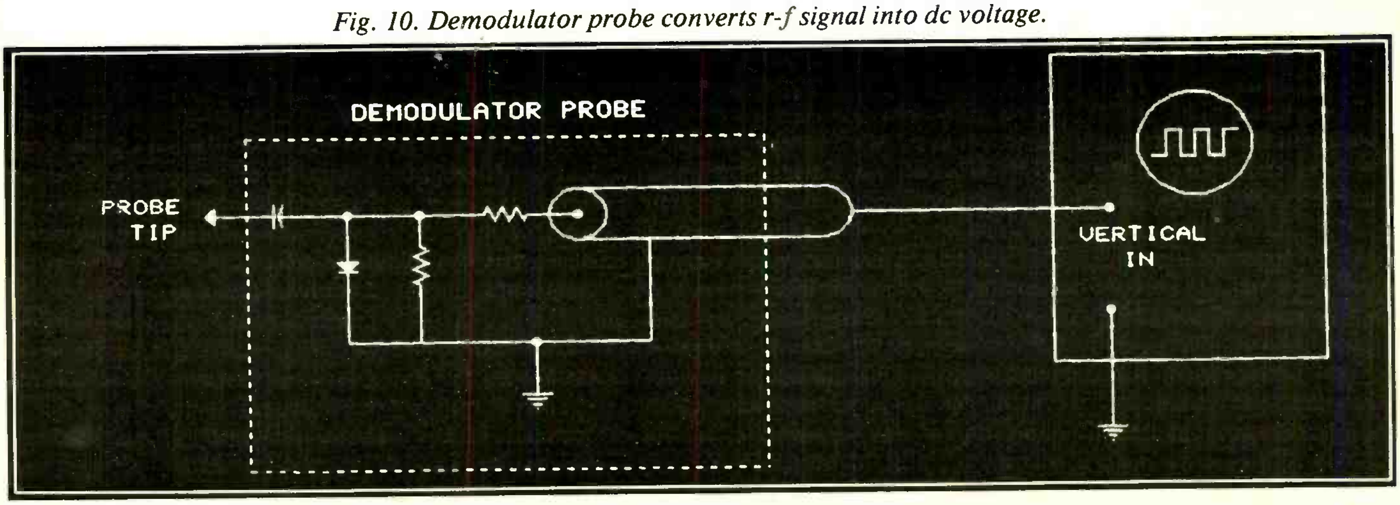
Special-Purpose Probes

In addition to the low-capacitance probe, the oscilloscope has a rather large family of special-purpose test probes. These are designed to enhance the versatility of the oscilloscope. The most popular is the demodulator probe, which is used to convert an r-f signal into dc voltage.

Inside the demodulator probe is a small-signal diode that converts the r-f input to a voltage that is proportional to the peak r-f signal. An RC network inside the probe, shown in

(Continued on page 92)

Fig. 10. Demodulator probe converts r-f signal into dc voltage.



A Programmable Ni-Cd Recycler

Safely recharges and reconditions nickel-cadmium batteries and up to 10 cells of any capacity

By Peter A. Lovelock

So many articles have been written about the care and feeding of rechargeable nickel-cadmium batteries that it is probably difficult to imagine anything new in this subject. As a heavy user of Ni-Cd batteries and cells, however, two

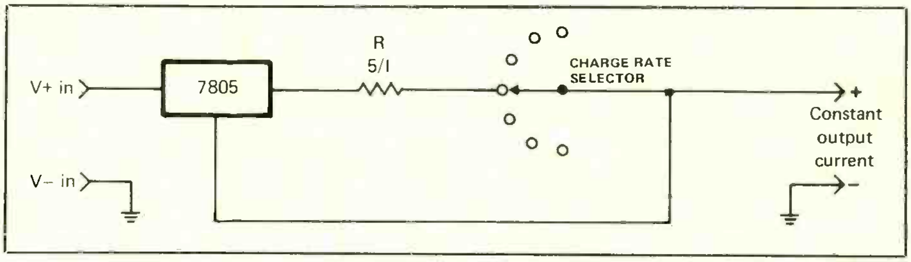
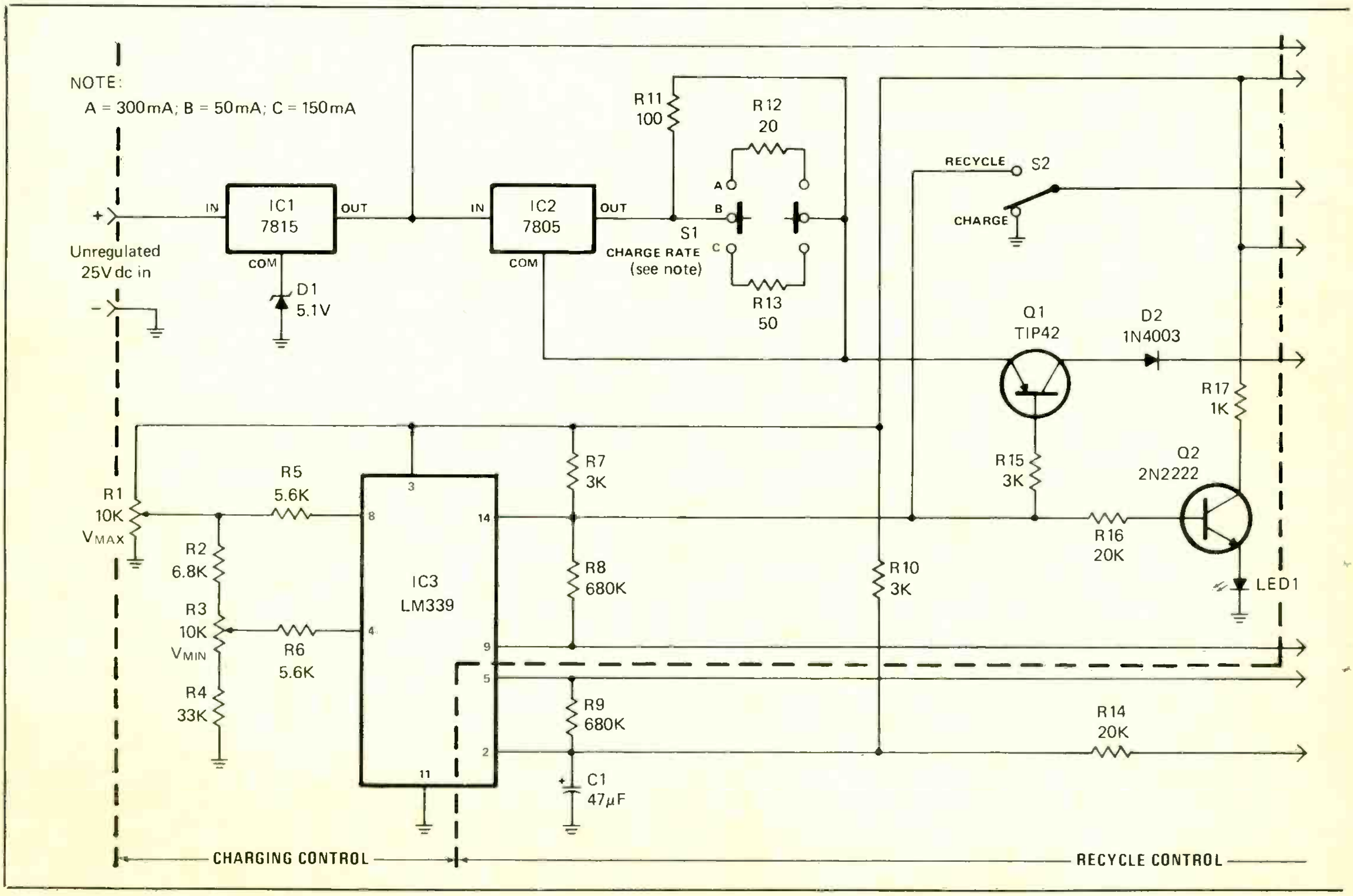


Fig. 1. The basic constant-current charger circuit.

Fig. 2. Overall schematic diagram minus power supply.



problems have always plagued me. One was the need to have a number of chargers around for the various voltage/capacity power packs I use. The other was the need to regularly "exercise" my Ni-Cd cells and batteries to eliminate the "memory" phenomenon that affects them when their charges are constantly "topped up" after partial discharge.

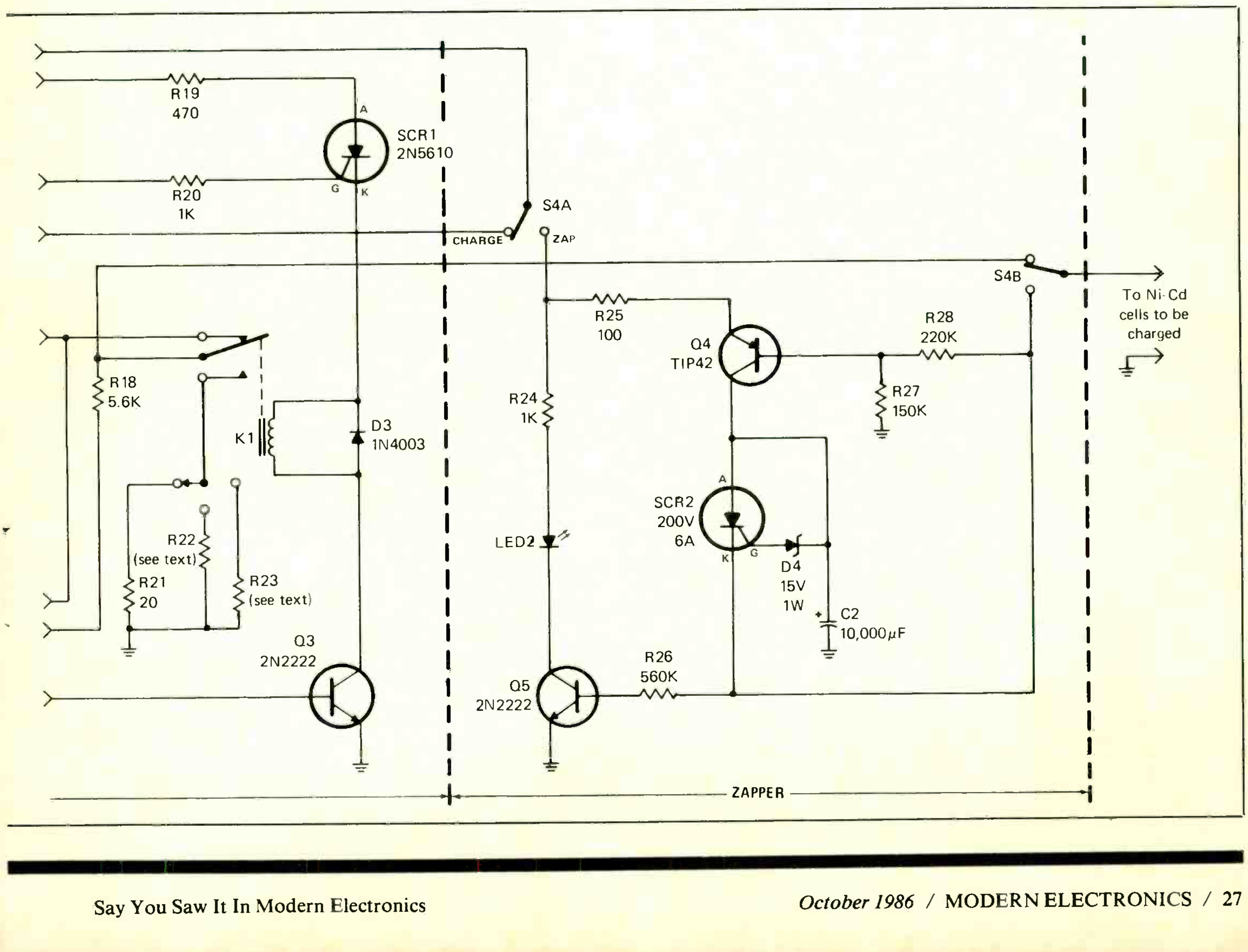
What I needed was a charger that could be programmed to the desired charge rate and a maximum voltage shutdown equal to one to ten cells. The solution was the Programmable Ni-Cd Recycler described here. Recharging Ni-Cd cells and batteries was only one of the design objectives. Another was a switch that could be used to discharge the Ni-Cds after completing a full-charge cycle to reduce and eliminate the dreaded memory effect. In this project, the battery can be switched back to charge when its discharge voltage drops to a preset 1 volt per cell and automatically recycles between charge and discharge within controlled limits. One cycle keeps Ni-Cds healthy. Repeated cycling eliminates the memory effect.

A final design objective was to incorporate into the project a "zapper" mode. The zapper clears internal "whiskers" that cause Ni-Cds to short circuit between their terminals and prevent them from taking on a charge. It also allows cells that have become reverse-charged to be restored to normal polarity. Though the zapper circuit is part of the project, it can be assembled and used separately as a stand-alone reconditioning device.

Problems & Solutions

A number of effects can result in failure of nickel-cadmium cells and batteries. Chief among these are the following:

- Frequent shallow discharge before recharging that results in the dreaded "memory phenomenon," manifested as an apparent loss in a Ni-Cd's ampere-hour capacity;
- Charging to less than 1.4 volts per cell (not replacing the required 30% more energy than was discharged while the Ni-Cd was in service), which contributes to the memory phenomenon;
- Short circuiting, caused by chemi-



PARTS LIST

Semiconductors

D1—5.1-volt, 1-watt zener diode
D2,D3—1N4003 rectifier diode
D4—volt, 1-watt zener diode
D5 thru D8—1N4001 rectifier diode or 50-volt, 1-ampere bridge rectifier
IC1—7815 +15-volt regulator
IC2—7805 +5-volt regulator
IC3—LM339 low-power quad comparator
LED1—5 volt flashing light-emitting diode (Radio Shack Cat. No. 276-036 or similar)
LED2—Panel-mount light-emitting diode
Q1, Q4—TIP42 pnp transistor
Q2,Q3,Q5—2N2222 npn transistor
SCR1—2N5610 1-ampere (50-volt or more) silicon controlled rectifier
SCR2—6-ampere, 200-volt silicon controlled rectifier (Radio Shack Cat. No. 276-1027 or similar)

Capacitors

C1—47-μF, 50-volt electrolytic
C2—10,000-μF, 50-volt computer-grade electrolytic
C3—1,000-μF, 50-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R2—6,800 ohms
R4—33,000 ohms
R5,R6,R18—5,600 ohms
R7,R10,R15—3,000 ohms
R8,R9—680,000 ohms
R14,R16—20,000 ohms
R17,R20,R24—1,000 ohms
R26—560,000 ohms
R27—150,000 ohms
R28—220,000 ohms
R11—100 ohms, 1 watt (10% tolerance)
R19—470 ohms, 1 watt (10% tolerance)
R25—100 ohms, 1 watt (10% tolerance)
R12—20 ohms, 5 watts (10% tolerance)
R13—50 ohms, 5 watts (10% tolerance)
R21—20 ohms, 10 watt (10% tolerance)
R22,R23—See text
R1—10,000-ohm, 10-turn otentiometer with vernier dial
R3—10,000-ohm flat-mount pc trimmer potentiometer

Miscellaneous

F1—0.5-ampere slow-blow fuse
K1—12-volt dc relay with 1-ampere contacts (Radio Shack Cat. No. 275-241 or equivalent)
S1—DP3T, center-off toggle switch (Radio Shack Cat. No. 275-1545 or similar)
S2—SPDT toggle or slide switch
S3—3-position nonshorting rotary switch
S4—DPDT slide or toggle switch
S5—SPST slide or toggle switch
T1—25-volt power transformer
Suitable enclosure (see text); printed-circuit board or perforated board and soldering hardware; socket for IC3 (optional); bayonet fuse holder for F1; 4-lug terminal strip (see text); ac line cord with plug; rubber grommets; control knobs for R1 and S3; 9-volt battery snap and cell holders (see text); lettering kit; clear acrylic spray; insulating tubing; No. 6 ground lug; spacers; machine hardware; hookup wire; solder; etc.

Note: An etched and drilled pc board is available for $8.00 ppd from: R&R Associates, 3106 Glendon, Los Angeles, CA 90034. California residents, add state sales tax.

cal "whiskers" growing inside Ni-Cd cells that prevent the cells from taking on a charge;

• Reversed polarity of a cell in a series string, which is fully discharged first and then reverse charged by current flowing from the other cells in the string.

Fortunately, these effects are usually curable, allowing most Ni-Cds to be restored to full health. A cell or battery that has dried out due to a ruptured internal seal resulting from overheating, though, can not be cured by any known means. (The small crystals visible around their terminals easily identify a cell that has been ruptured and is beyond salvage.)

Solutions to the above effects as well as the ability to recharge Ni-Cds are provided in the Ni-Cd Recycler. The basic element of this project is its charge mode whose programmable charger can accommodate from one to ten cells. It charges each cell with a sufficient voltage to assure restoration of 30% more energy than was drained from it while in service.

A recycle mode can automatically switch fully charged cells and batteries to a discharge load, draining them until their charge drops to 1.0 volt per cell and then back to the charge mode to restore full charge. In the recycle mode, Ni-Cds are recycled continuously between full charge and discharge over their full capacity range to eliminate the memory effect. Recycling can be done just once every so often to keep Ni-Cds healthy, or it can be allowed to run as many times as needed to eliminate the memory condition.

Finally, the zapper function's high-current pulses are applied to shorted cells to burn away internal shorts and to repolarize reverse-charged cells.

About the Circuit

Constant-current charging was chosen over constant-voltage charging as the fastest means of restoring the charge on a spent battery or cell without the attendant heat generated by an initial higher current. The circuit shown in Fig. 1 is the heart of the constant-current charger. Built around the common 7805 5-volt regulator, this circuit shows a single resistor, *R*, between the chip's output and common pins. The resistor sets a constant-current output that is determined by the equation: $R = 5/I$. For example, for a 50-mA charge rate, $R = 5/0.05 = 100$ ohms. Using a rotary switch as shown, different-value resistors can be connected to the various switch positions to provide different charge rates.

Supply voltage to the 7805's input terminal must be at least 5 volts

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Standard Equipment
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	73	75, 21	77, 23
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AC Voltage	3% + 2	2% + 2	2% + 2
Ohms	1% + 1	0.7% + 1	0.5% + 1
DC Current	2% + 2	1.5% + 2*	1.5% + 2*
AC Current	3% + 2	3% + 2	3% + 2

*2% + 2 on 21 and 23

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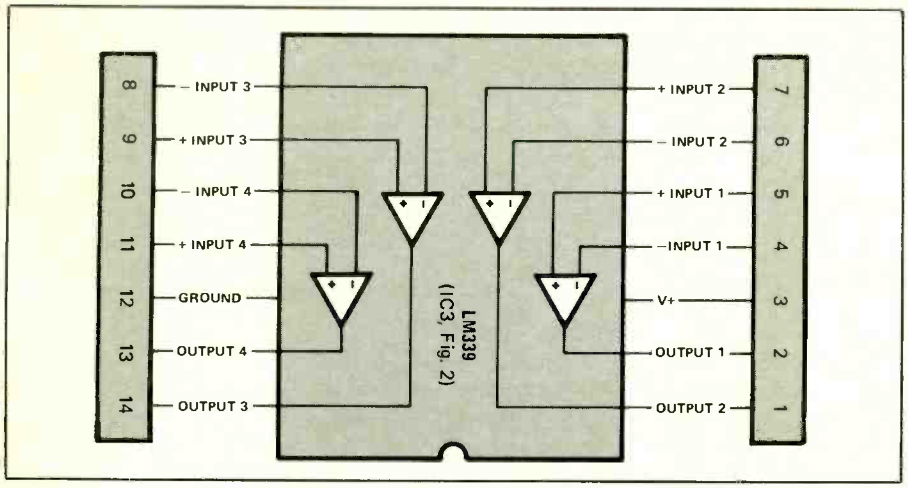


Fig. 3. Internal details and pinouts for LM339 quad comparator.

greater than the highest voltage required. To avoid life-reducing undercharging, the circuit should be designed to put back 30% more energy than was drawn by the cell or battery while it was in service. Therefore, the voltage on each cell must rise to 1.4 volts under charging conditions. For a 10-cell, 12.5-volt battery pack, maximum charge must be 14 volts. Therefore, minimum supply voltage to the regulator chip must be $(10 \times 1.4) + 5 = 19$ volts. To be on the safe side, it is best to use 20 to 25 volts dc.

Figure 2 shows the final design of the charger circuit. Here, +15-volt regulator *IC1* is referenced 5.1 volts above ground by zener diode *D1* to supply a regulated 20 volts dc to 5-volt regulator *IC2*. The 20-volt output from *IC1* also supplies power to the control circuitry. Cells and batteries to be charged connect to the circuit via the + and – BATTERY terminals shown at the far right.

Only three current-control resistors are switched in this circuit to provide 50, 150 and 300 mA via *R11*, *R12* and *R13*, respectively. Any number of current-control resistors can be switched to furnish a range of currents up to the 1-ampere ratings of *IC1* and *IC2* (Fig. 1). These resistors should have a wattage rating determined by the I^2R formula; for a 100-ohm resistor at 50 mA charge, which actually calls for a ¼-watt resistor, use a 1-watt rating.

In Fig. 2, *R11* is always in the circuit, regardless of the position to which CHARGE RATE switch *S1* is set. To obtain the 300- and 150-mA charge rates, *R12* and *R13* are switched in parallel with *R11*.

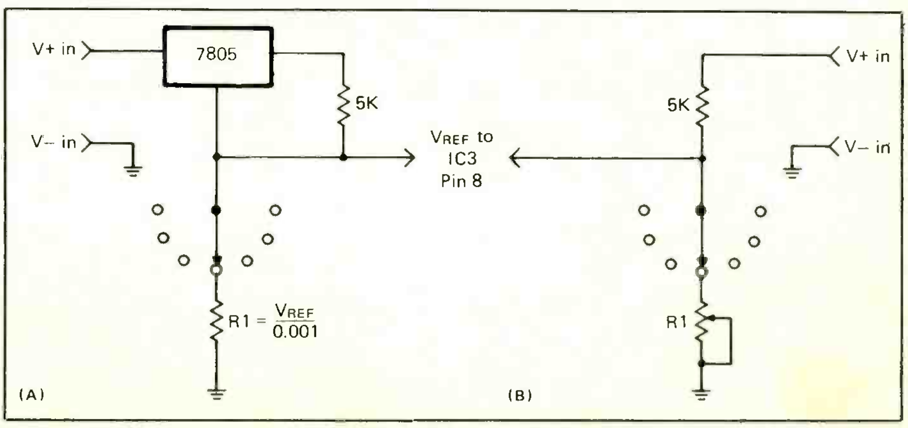
In the charge/discharge control circuit, two sections of quad comparator *IC3* (see Fig. 3 for internal details and pinouts for this quad comparator) separately detect the programmed full charge and full discharge voltage limits. In the charge mode, V MAX control *R1* sets a reference voltage on the inverting (–) input of the first comparator in *IC3* at pin 8. This reference voltage is equal to 1.4 times the number of cells. The noninverting (+) input at pin 9 of this comparator monitors the output voltage across the cell or battery being charged. When the charge exceeds the reference set by *R1*, the comparator's output at pin 14 goes high, producing 20 volts that biases off *Q1* and disables the charge current to the cells. The 20 volts also turns on *Q2* and END OF CHARGE light-emitting diode *LED1*.

A 10-turn precision potentiometer with vernier dial is recommended for *R1*. However, a single-pole rotary switch and a number of fixed-value resistors can be substituted for the voltage reference portion of the circuit (Fig. 4). Figure 4A employs another 7805 to supply a constant 1 mA to resistors of selected fixed values. The values of these resistors are calculated according to the formula $R = V_{ref}/0.001$. For example, for $V_{ref} = 8.4$ volts, $R = 8{,}400$ ohms.

If you have a problem finding resistors of the exact calculated values, various standard values can be wired in series or/and parallel configurations as needed. Alternatively, you can wire into the circuit separate 10,000-ohm trimmer potentiometers for each switch position, as in Fig. 4B, and set them for the desired reference voltages.

Returning to Fig. 2, resistor *R8* sets up conditions so that when the battery (off charge) drops down about 0.2 volt, output pin 14 of *IC3*

Fig. 4. Alternative voltage references.



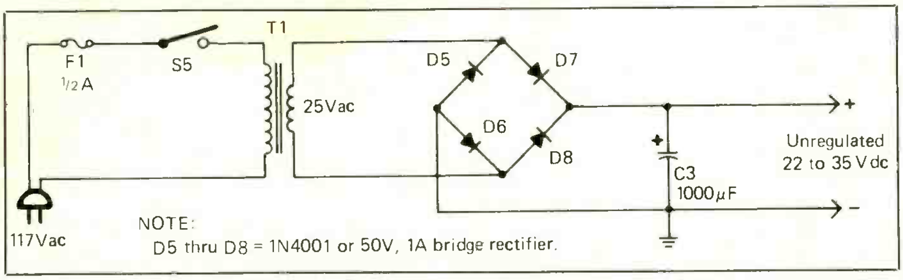


Fig. 5. Power supply for Fig. 2.

goes low, *Q1* switches on the charging current, cutting off *Q2* and extinguishing *LED1*. Circuit status then remains unchanged until the voltage across the cells or battery being charged rises above the reference level set by *R1*. This cycle then repeats, with the charge pulsed on and off, rather than tapering down, with decreasing charge pulses as the battery tops off. The pulsing final charge is very effective in bringing the battery to full charge without creating an overvoltage condition.

In operation, even when cells are left for several hours on pulsating charge, there will be no discernible heating of the cells. With *S2* set to CHARGE, *LED1* will flash when the battery is fully charged.

With *S2* set to RECYCLE, the first time the battery voltage causes *IC3* to switch to a high output at pin 14, *SCR1* turns on. This closes *K1*'s lower contacts, completing a circuit from the battery or cell to ground through *R17*. This resistor then discharges the battery until the voltage drops below the reference at the pin 4 inverting input of the second comparator in *IC3*, set by V MIN control *R3* (V MIN is equal to 1 volt times the number of cells being charged).

When output pin 2 of *IC3* is high, *Q3* conducts. When battery voltage monitored by the noninverting input at pin 5 of *IC3* drops below the V MIN reference at pin 4, output pin 2 goes low. This deenergizes *K1* and switches the battery back to the charge output. Interruption of relay coil current also switches off *SCR1*.

Trimmer *R3* and resistors *R2* and *R4* can set the discharge limit to 70% of the charge limit. Since *R3* is supplied from the wiper of *R1*, the discharge limit will always track the charge limit set by *R1*. Hence, *R3* must be adjusted only once and is, therefore, a hidden set-and-forget trimmer control.

Shown in Fig. 5 is the simple ac-line-operated power supply for the Fig. 2 circuit. This circuit delivers an unregulated 22 to 35 volts to the charger circuit. Regulation is accomplished by *IC1* and *IC2* in Fig. 2.

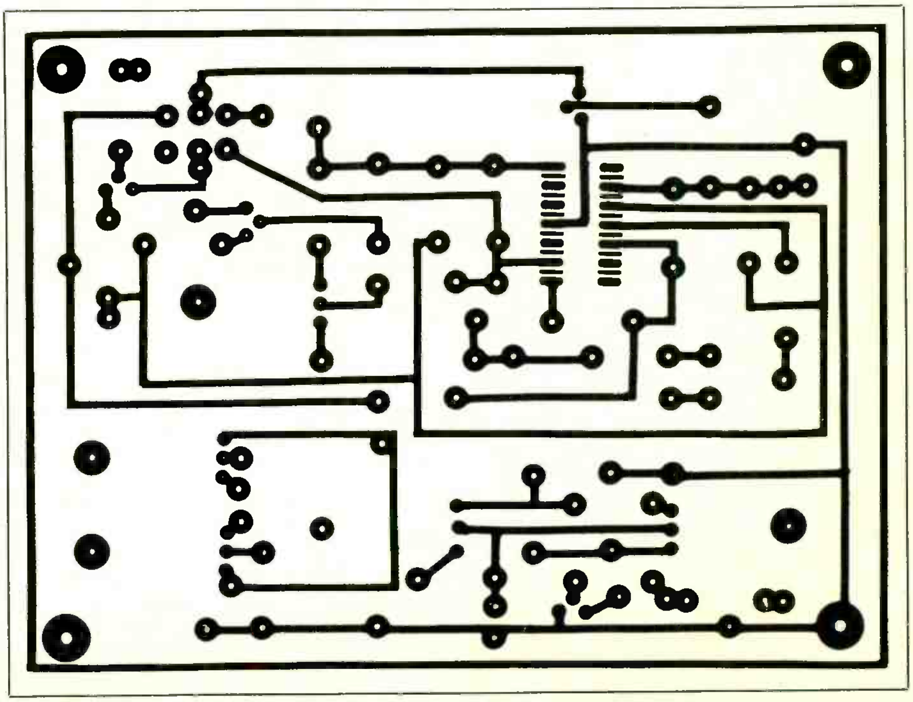
Burning away internal whiskers by discharging a large capacitor like the 10,000 μF specified for *C2* in Fig. 2 through the "bad" cell is effective, though it can require a considerable number of discharges to fully clear a short. Connecting one or more good Ni-Cd cells across the shorted cell may work but could result in destructive venting if a heavy current is sustained for too long a time.

Repeated short-duration, high-energy pulses delivered to a shorted cell clears whiskers without attendant potential damage to the cell being treated. Short clearing in this project is accomplished with the automatic zapper circuit consisting of *C2*, *R4*, *Q5* and *SCR2* in Fig. 2. (*Warning*: Be sure to use the zapper function with only *one* Ni-Cd cell at a time!)

With *S4* set to ZAP, regulated 20 volts dc charges *C2* through *Q5*. When the charge reaches 15 volts, zener diode *D4* conducts and triggers on *SCR2*, causing *C1* to discharge through the cell connected to the output terminals of the project in a short burst of high energy.

Feedback to the base of *Q5* causes this transistor to disable the charging current until *C2* is fully discharged and *SCR1* stops conducting. Then

Fig. 6. Actual-size etching-and-drilling guide.



when *Q5* conducts again, *C2* charges once more. The cycle repeats as long as needed to restore the shorted cell.

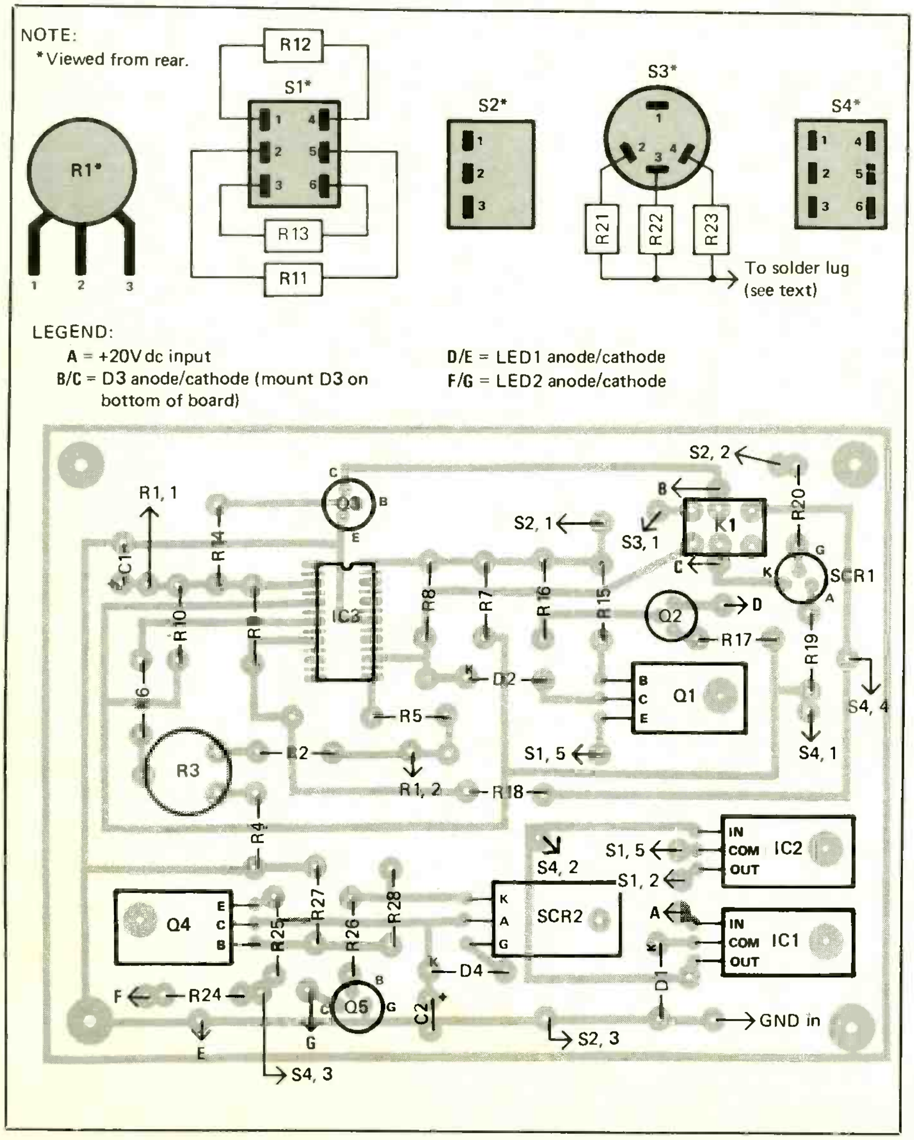
CONDITION light-emitting diode *LED2* is normally off, since the cell is a direct short circuit across it, but it flashes each time a pulse is applied to the cell. When the cell's internal short is cleared, *LED2* lights continuously to signal that the cell has been cleared of whiskers.

In addition to clearing internal short circuits, the zapper function will repolarize cells that have become reverse charged. Bear in mind, though, that not all such cells can be rejuvenated in this manner. Some are just plain worn out from use. Just connect the cell across the project's output terminals in proper polarity and run the zap function until *LED3* lights continuously and then switch over to normal charging until the cell's potential on charge measures the full 1.4 volts.

Construction

Most of the circuitry shown in Fig. 2 can be assembled on a small printed-circuit board you can make yourself using the actual-size etching-and-drilling guide shown in Fig. 6. If you wish, you can purchase a ready-to-wire board from the source given in the Note at the end of the Parts List. Alternatively, you can assemble the circuit on perforated board with the aid of suitable soldering hardware.

Fig. 7. Wiring details for pc board and potentiometer R1 and switches.



Light-emitting diodes *LED1* and *LED2*, 10-turn potentiometer *R1* and the various switches mount on the front panel of the box in which the project is housed. Wire the Fig. 2 circuit exactly as shown in Fig. 7, starting with the resistors and diodes and working up to the largest components. Note that *D3* mounts on the bottom of the board, *after* installing *K1*. A socket for *IC3* is optional but recommended. Make sure as you install *C1*, the diodes, transistors and ICs that they are properly oriented before soldering their leads into place.

Mount all power resistors with 1-watt or higher rating so that there is ⅛" to ¼" of space between them and the board's surface to allow for air circulation. Finish board wiring by installing and soldering into place suitable lengths of prepared hookup wire at the locations that are to interconnect with off-the-board components. Use heavy-duty color-coded stranded hookup wires for the lines to the power supply and output terminals and for the wiring between *S4B* and *K1*'s toggle contact.

For convenience, it is a good idea to use a pair of front-panel-mounted color-coded jacks or 5-way binding posts, connected to the project's output terminals, to allow you to monitor battery voltage during charging with an external meter. The battery connectors and holders can be installed in the project case, along with the rest of the circuitry. If you decide to use a separate box in which to house the battery connectors and holders, mount a suitable jack on the rear panel of the main project to provide a means for connecting the external box to it.

Drill all required mounting holes,

(Continued on page 86)

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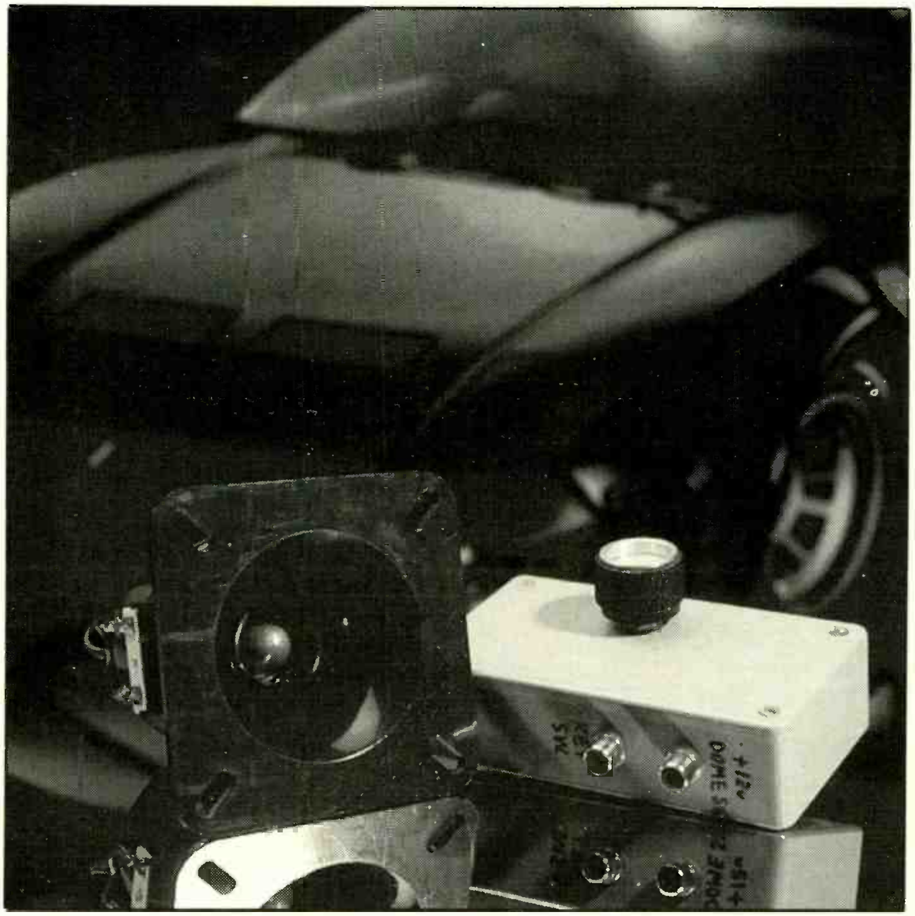
The (Car) Thief Chaser

System emits painfully loud high-pitched sound that drives off thieves before they can steal anything of value

By Desi Stelling



With the high cost of cars and high insurance premiums for them, installing a theft alarm system in them is a necessity nowadays. Unfortunately even a high-priced deluxe alarm system won't always prevent your car or anything in it from being stolen with today's savvy thieves. Even if a thief does trip an ordinary alarm, passersby are likely to ignore it. If the foregoing makes you feel helpless, you're just one of millions of worried car owners in the same predicament. A solution to this problem is installing the (Car) Thief Chaser described here. This simple device actually drives thieves away before they can rip you off.

It does this by pumping out 40 watts of raw 10-15-kHz sound that's likely to drive away any but a deaf thief when he's inside the car. It's the combination of high-power, high-frequency sound and the car's small interior that does the trick, even if one plugs up his ears. (Only ten feet away outside the car the sound becomes bearable.)

About the Circuit

As shown in Fig. 1, a state-of-the-art power MOSFET, *Q1*, is switched on and off to deliver a large amount of power to the supertweeter connected to terminals A and B. The choice for the particular power MOSFET for *Q1* was dictated by the need for the source-to-drain resistance to switch a 4-ohm load consisting of two 8-ohm supertweeters. If only one supertweeter is used, 20 watts of 15-kHz sound power is generated by the circuit, which is adequate to protect an average-size car. The ability of the circuit to deliver 40 watts to two supertweeters adds a wide margin of safety to the system.

Timer *IC1* is operated at 15 kHz, with a 50% duty cycle. The frequency controlling RC network for the 555 timer IC is comprised of *R1*, *R2*, *R3* and *C2*, with *R2* used as a trimmer control that fine tunes the circuit for the most effective sound.

Zener diode *D4* prevents transients at the gate of *Q1* that exceed approximately 14 volts from appearing at the pin 1 output of *IC1*. (These transients occur as a result of the drain-to-gate capacitance of the MOSFET.) Diode *D3* clamps *Q1*'s drain to prevent the MOSFET from exceeding its maximum drain-to-source voltage. The need for *D3* is dictated by the inductive nature of the supertweeter(s). Switching an inductor tends to build current that must be discharged back to the battery. The discharge path that pro-

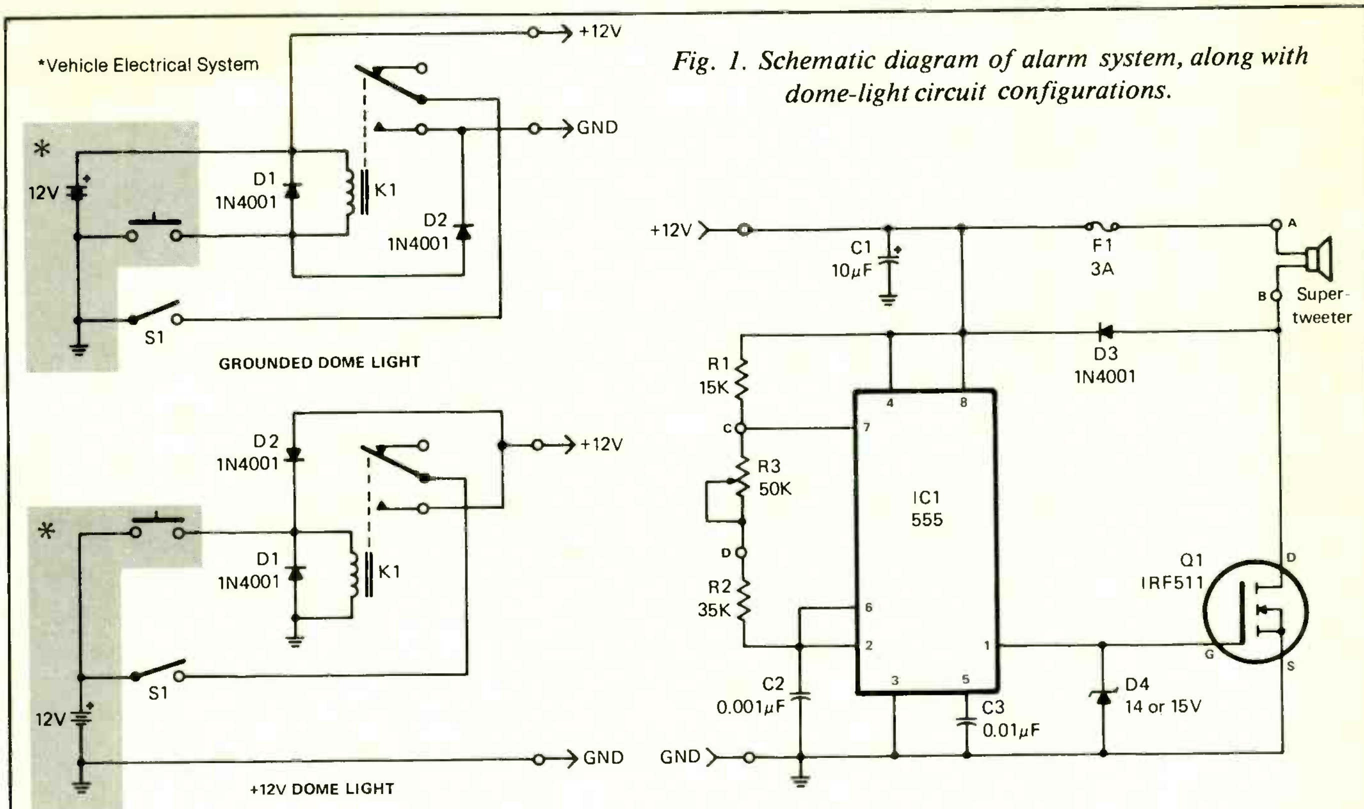


Fig. 1. Schematic diagram of alarm system, along with dome-light circuit configurations.

PARTS LIST

C1—10-μF, 50-volt electrolytic capacitor
C2—0.001-μF disc capacitor
C3—0.01-μF disc capacitor
D1,D2,D3—1N4001 rectifier diode
D4—14- or 15-volt zener diode
F1—3-ampere fuse
IC1—555 timer
K1—Dpdt 12-volt dc relay
Q1—IFR511 power MOSFET
R1—15,000-ohm, ¼-watt, 5% tolerance resistor
R2—35,000-ohm, ¼-watt, 5% tolerance resistor
R3—50,000-ohm linear-taper potentiometer
S1—Spst keyswitch

Misc.—8-ohm supertweeter (see text); printed-circuit board or perforated board and soldering hardware; 4.5" × 2.5" × 1.125" plastic project box; phono jacks and plugs (3 sets); control knob for R3; pc-mount fuse holder; two-conductor cable (see text); machine hardware and plastic cement or double-sided foam tape; stranded hookup wire; solder; etc.

Note: The following items are available from DDS Systems, P.O. Box 5715, Glendale, AZ 85312: Complete kit (less enclosure, supertweeter and keyswitch) for $19.95; pc board for $4.95; warning decal for $1.50 plus $3.50 P&H. Arizona residents, please add 6% sales tax.

tects *Q1* from being damaged by excessive current is provided by *D3*.

Power for the system is provided by your car's electrical system. It's taken from the dome-light circuit as shown in the drawings at the left in Fig. 1. Note that there are two different wiring arrangements for the dome-light circuit in modern cars.

The circuit is armed by closing keyswitch *S1*. It is tripped by closing the unlabeled switch, which is the pin switch that normally turns on the car's dome light when a door is opened. With *S1* closed, if a door is opened and the other switch is closed even momentarily, current from the car's 12-volt battery energizes *K1*.

With *K1* energized, its armature is pulled down to the lower contact. This simultaneously latches *K1* in the closed position by current flowing back to its coil through *D2* and delivers 12 volts dc to the Chaser's circuit. Diode *D1* protects the circuit from voltage spikes generated by the collapsing magnetic field when *K1* deenergizes. As long as keyswitch *S1* is closed and the circuit has been triggered, *K1* will be latched and the supertweeter will sound until *S1* is opened with a key.

Construction

The best way to assemble the circuit is on a printed-circuit board and housing it in a small plastic or metal project box. You can fabricate your own pc board using the actual-size etching-and-drilling guide shown in Fig. 2, or you can purchase a ready-to-wire board from the source given

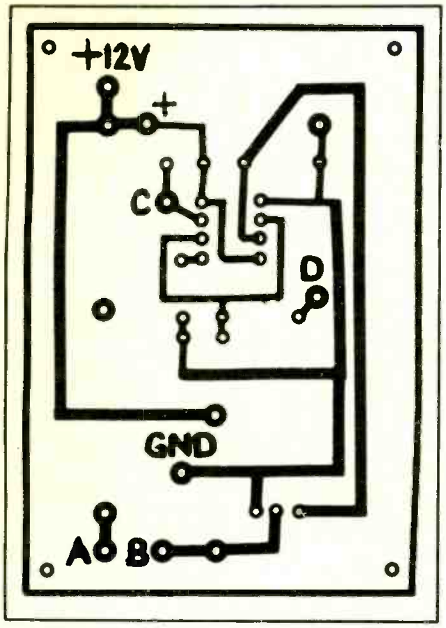


Fig. 2. Actual-size etching-and-drilling guide for pc board.

in the Note at the end of the Parts List. Wiring of the board is simple and straightforward, as shown in Fig. 3. Just be sure to properly orient *C1*, *D3*, *D4* and *IC1* before soldering their leads and pins to the copper pads on the board. Do not forget to solder short wires from the lugs on the fuse holder to the *F1* holes in the board. Use of a socket is not recommended in this project because road vibration might work the IC loose.

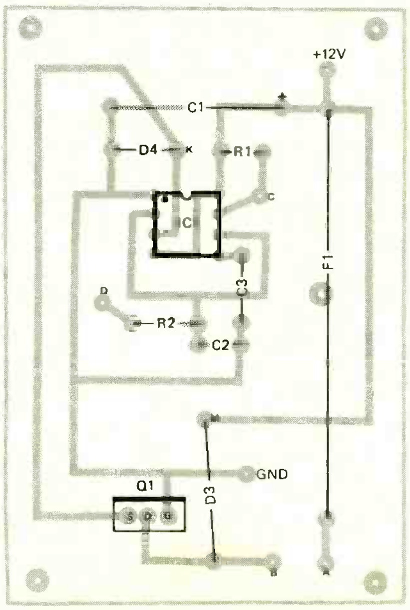
After the circuit board is wired as shown in Fig. 3, solder 2″ lengths of hookup wire to points A and B. Similarly, solder 5″ lengths of wire in the holes labeled C, D, +12V and GND. Use only *stranded* hookup wire throughout to wire the project.

Components that do not mount on the board include *D1*, *D2*, *K1*, *R3* and *S1*. Diodes *D1* and *D2* wire directly across the appropriate lugs on the relay. These diodes must be wired to the relay lugs according to the type of dome-light circuit in your car. For cars with grounded dome-light circuit, as in circuit A in Fig. 1, wire the diodes anode to anode. Those with +12-volt dome-light circuits, as in circuit B, wire cathode to cathode. Then connect and solder 2″ lengths of stranded hookup wire to the lug to which both diodes are connected and the lug that goes to the relay's armature contact.

Because ordinary phono jacks are used for the dc power input, connection of the *S1* keyswitch and the output to the supertweeter, it is important that you use a plastic—*not* metal—project box to house the project. Drill holes in the box to accommodate control *R3* and the jacks. Then mount the jacks and control in their respective locations. Label the jacks according to function) TWEETER, KEYSWITCH and +12V DOME LIGHT SWITCH).

Strip an extra ½″ of insulation from the wire coming from hole D on the pc board. Twist together the fine wires and lightly tin them with solder. Now loop this wire from the left to the center lugs (viewed from the rear) of the potentiometer and solder both connections. Then connect and solder the free end of the wire coming from hole C to the potentiometer's right lug.

Fig. 3. Wiring guide for pc board.



Connect and solder the wires coming from the pc board to the appropriate points in the circuit. Refer to Fig. 1 for details for your particular dome-light circuit configuration.

You can mount the relay and pc board assembly with plastic cement and machine hardware, respectively. Alternatively, you can use double-sided foam tape to secure the two into place. Then mount the jacks in their respective holes. Connect and solder the free ends of the wires coming from the holes labeled A and B on the circuit board to the TWEETER jack. Locate the wire coming from the armature contact of the relay and connect and solder its free end to one lug on the KEYSWITCH jack. Wire the other lug of this jack to the point in the system that corresponds to your type of dome-light circuit.

Assemble the project's case.

Installation

Mount the keyswitch in an external front-end location where it will be relatively well hidden from view and protected from the elements. Route a two-conductor cable from inside your car through the firewall to the keyswitch. Dress the cable neatly around the engine compartment, and use plastic cable ties to hold it in place. Connect the cable's conductors to the switch's lugs.

Select a location for mounting the project box where it will be invisible and relatively difficult to get at inside the passenger compartment. Once you have selected an appropriate location for the project box, determine how long the cable from the keyswitch must be, cut to length, and terminate with a phono plug.

Now find a suitable location in which to mount the supertweeter(s). Keep in mind that high-frequency sound energy tends to be quite directional. Therefore, select a mounting location that beams the sound energy to cover the front seat, particularly the driver's area. Under the dashboard is a good location. If your car is a compact sport model, one supertweeter may be enough to assure adequate coverage. However, if your car is a full-size model, it may be better to use two supertweeters, mounted on opposite sides of the passenger compartment and angled inward to cover the front-seat area.

Select unobtrusive mounting locations for the supertweeters. Then connect and solder two-conductor cable to the lugs of each. If you are using two supertweeters, wire them in parallel with each other, properly phased. That is, tie together the cable conductors that go to the "hot" (may be identified with a + sign or a painted dot or both). Similarly, tie together the conductors that go to the "neutral" (identified with a − sign). Then run a two-conductor from the junction to the project box. Terminate the other end of the cable in a phono plug.

Connect another cable into your car's dome-light circuit (see Fig. 1) and terminate it with a phono plug at the project box end.

As you route the cables inside the passenger compartment, hide them from view as much as possible.

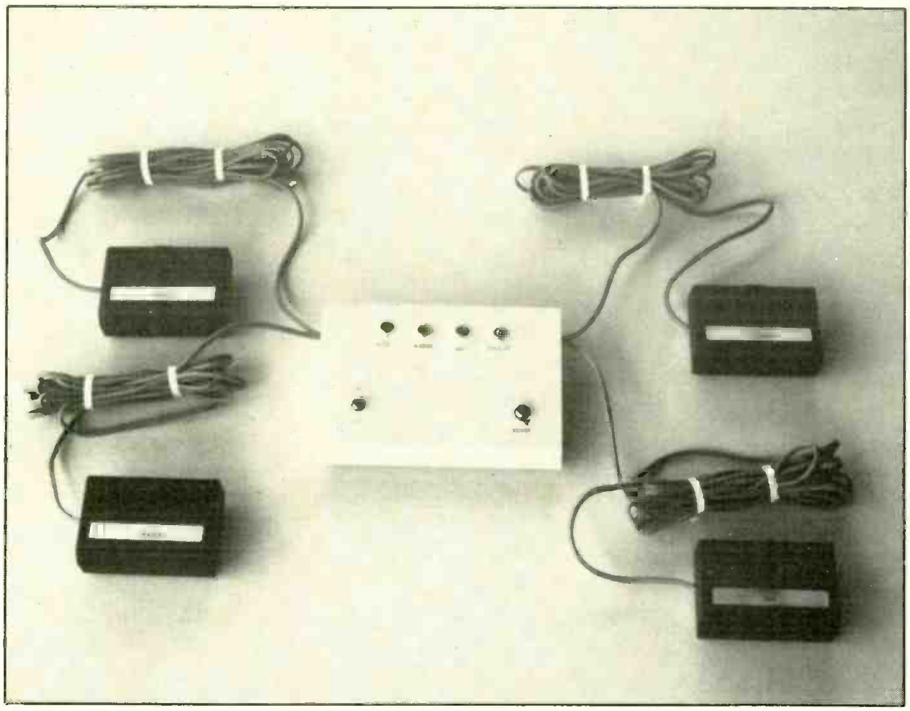
Once the system is completely installed, arm it by closing the keyswitch and trigger it by opening a door. If everything is okay, you should immediately hear a painfully high-pitched sound. Closing the door should not silence the sound. Disarm the system with the keyswitch. Repeat the procedure to make sure everything is okay. Then trigger the system once again and adjust the setting of the control for the most unpleasant sound. Disarm the system and mount the project box in its final location.

To use the (Car) Thief Chaser, all you do is get out of your car, lock the doors and arm it with your keyswitch. When you return, disarm it with your keyswitch—before opening any doors! **ME**

First-Answer Selector

A games-playing "judge" whose decisions are impartial and totally accurate

By Mike Rigsby



Trivia-style and other types of games have become very popular. In such a game, players are asked a question and are required to respond as fast as possible with the answer. The first player to respond correctly wins the round. If two or more players claim to have responded first, there can be an argument. The judge must decide who was the first to respond. If the judge is a person, his decision is frequently questioned by the players who lost the decision. So the solution is to use a totally impartial judge whose decision is impossible to question.

Enter the First Answer Selector, an electronic "judge" whose decision is impartial and totally accurate. Similar to those devices used on TV game shows, the First Answer Selector responds to only the first player to press a button. Even if two or more players press their buttons within a fraction of a second of each other, only the first response will register by lighting that player's LED indicator and sounding a buzzer. Other players can press their buttons as much as they like without affecting the play decision. With no arguments to slow things down, games proceed at a faster pace and with more competitive spirit on the part of the players.

About the Circuit

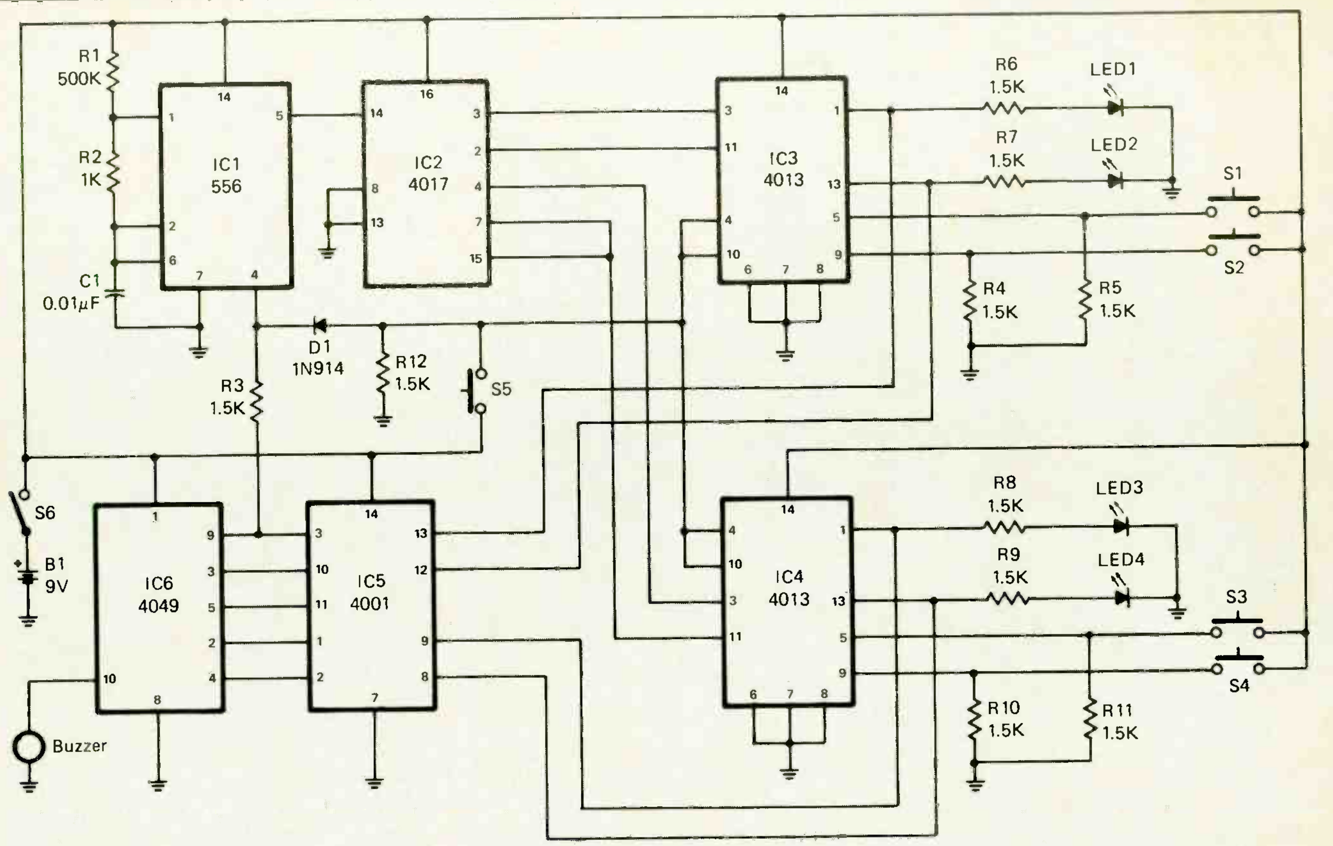
In Fig. 1, timer *IC1* operates as an astable multivibrator that serves as the clock pulse generator for the system. Its pulse repetition rate is determined by the values of *R1*, *R2*, and *C1*. Oscillator frequency is not critical; it just has to be greater than a few hundred pulses per second.

When reset pin 4 is brought high, *IC1* oscillates and delivers a train of pulses to pin 14 of decade counter/divider *IC2*. (With pin 14 high and low, *IC1* oscillates and stops oscillating, respectively.) As *IC2* counts the pulses, its output lines are sequentially brought high, one at a time. When pin 7 of *IC2* makes a transition from high to low, reset pin 15 is activated. Thereafter, the next clock pulse causes pin 3 to go high to initiate a new cycle.

Output pin 3 of *IC2* provides the clock pulse for one of the two flip-flops in *IC3*. When the Set1 line at pin 6 of *IC3* is low and the Reset1 line at pin 4—which is normally held low by *R12*—is low, the flip-flop is prepared for normal action. The status of the D1 input at pin 3 of *IC3*, normally held low by *R5*, is passed to the Q1 output at pin 1 when a clock signal appears at the pin 3 clock1 input. This puts a low on both sides of *LED1* so that it does not light.

Since none of the *S1* through *S4* switches has been pressed, all Q lines in *IC3* and *IC4* are maintained at a low level. Therefore, no LEDs will light, and pins 10 and 11 of *IC5* will be high because pins 8, 9, 12 and 13 are all low.

Outputs at pins 10 and 11 of *IC5* are inverted by *IC6* and are passed to input pins 1 and 2 of *IC5* at low



PARTS LIST

Semiconductors

D1—1N914 switching diode
LED1 thru LED4—Light-emitting diode (Radio Shack Cat. No. 276-068 in chrome holder or plain LED mounted in rubber grommet—see text)
IC1—556 timer
IC2—4017 decade counter/divider
IC3,IC4—4013 dual D flip-flop
IC5—4001 quad 2-input NOR gate
IC6—4049 hex inverter

Capacitors

C1—0.01-μF metal-film

Resistors (¼-watt, 5% tolerance)

R1—500,000 ohms
R2—1,000 ohms
R3 thru R12—1,500 ohms

Miscellaneous

B1—9-volt battery
S1 thru S5—Spst momentary action normally open pushbutton switch
S6—Miniature spst slide or toggle switch
Perforated board and Wire Wrap hardware or printed-circuit board (see text); 4-to-28-volt dc (5-mA at 12 V) buzzer (Radio Shack Cat. No. 273-060); suitable enclosure (see text); separate boxes for S1 thru S4 (see text); connector for B1; 14-pin (5) and 16-pin (1) sockets for ICs; flexible 2-conductor cable; rubber grommets; small-diameter heat-shrinkable tubing; dry-transfer lettering kit; clear spray acrylic; machine hardware; hookup wire; solder; etc.

Fig. 1. Overall schematic diagram of the First Answer Selector.

levels. Therefore, pin 3 of *IC5* will deliver a high to *IC1* pin 4, which continues to generate clock pulses. Pin 3 of *IC5* is also tied to pin 9 of *IC6*, resulting in a low at pin 10 of *IC6*; the buzzer will not sound.

Pressing *S1* (we will use this switch to explain circuit operation, though any of the *S1* through *S4* switches could be used in like manner) changes operating conditions. Pin 1 of *IC3* is pulled high, resulting in a high output at Q1 output pin 1 and causing *LED1* to light. The high signal on pin 1 of *IC3* travels to pin 13 of *IC5* and causes pin 11 to go low.

The low at pin 11 of *IC5* goes to pin 4 of *IC1*, where it stops the timer from generating clock pulses. With no more pulses being generated, there can be no further effect on the circuit by pressing any of the *S1* through *S4* switches. Because the low on pin 3 of *IC5* creates a high at pin 10 of *IC6*, the low-current buzzer is powered and sounds.

At this point, the moderator

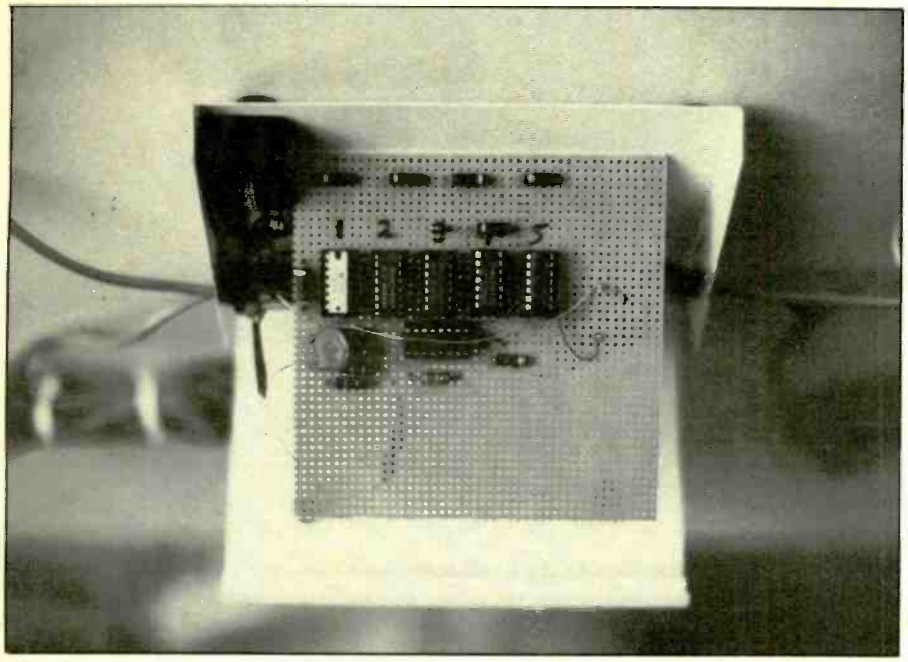


Fig. 2. Perforated board and suitable Wire Wrap hardware were used in prototype. A home-made pc board can be designed and used if desired.

knows that someone has pressed a button by the sound of the audible alert. Furthermore, he knows which person has pushed the button by the fact that that person's LED is lit (*LED1* in this example). Conditions remain in this state until RESET switch *S5* is pressed and released.

Whenever *S1* is pressed and released, a high is applied to pin 4 of *IC1*. This starts the clock pulse generator operating. Simultaneously, the high delivered to the reset lines at pins 4 and 10 of both *IC3* and *IC4* causes Q output pins 1 and 13 of both ICs to go low and turn off all LEDs. The circuit is now ready to capture the response of the first person to press his switch.

Diode *D1* is included in the circuit to assure proper operation. Under normal operating conditions (none of the *S1* through *S4* switches pressed), pin 4 of *IC1* is high and the reset lines of *IC3* and *IC4* are low.

Use of CMOS ICs makes it possible for the project to run for a long time on a single 9-volt battery (*B1*). The only time the circuit is drawing more than a few milliamperes is when any of the LEDs is on and the buzzer is sounding.

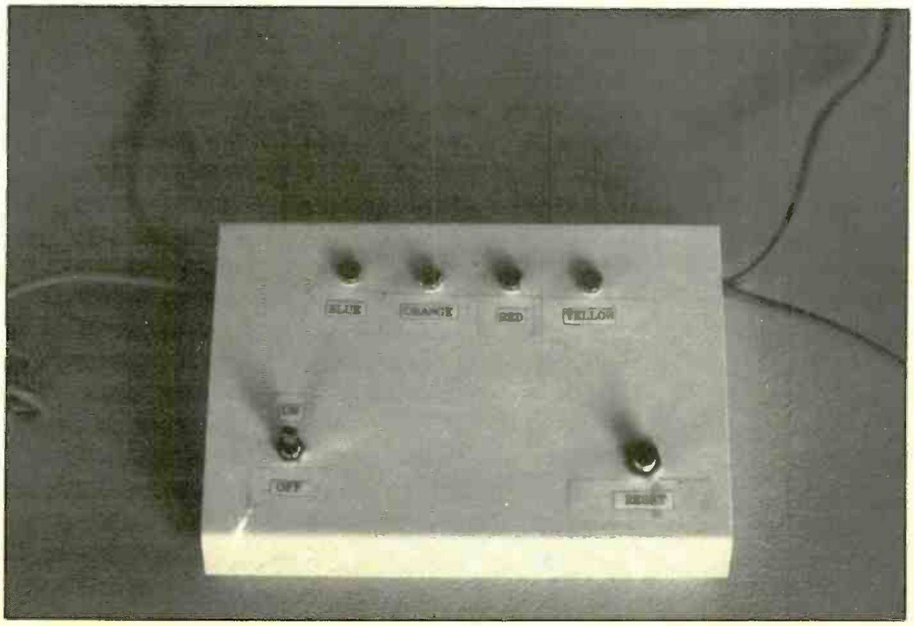
Construction

The prototype circuit for the First-Answer Selector was assembled using perforated board and Wire Wrap hardware (Fig. 2). However, if you wish, you can design and fabricate a printed-circuit board on which to mount the components that make up the circuit.

Wire the board as shown in Fig. 1. Keep in mind that the LEDs and switches all mount off the board, with *S1* through *S4* completely external to the box in which the main project is housed. Use sockets for the ICs, and make sure you properly index the ICs and diode. Also, mark the cathode connection points for the LEDs with the letter "K" for easy identification when the time comes to wire them into the circuit.

Any type of enclosure that will accommodate the circuit board and battery with its holder will serve well for the project, though one with a sloping panel will probably look most attractive (Fig. 3). Machine the enclosure to permit mounting the board in place and to accommodate the RESET switch and the chrome holders or the small rubber grommets in which the LEDs mount. Additionally, drill holes for the cables to the player switchboxes and line

Fig. 3. Project is best housed inside enclosure with a sloping front panel.



them with rubber grommets. If you prefer, you can have the player switches interface to the project via phono jack/plug pairs. In this case, you might want to use a 4-jack strip mounted on the rear of the enclosure.

Before mounting any components in or on the enclosure, paint it if necessary. Otherwise, use a dry-transfer lettering kit to label the LED positions and POWER and RESET switches. (If you do paint the enclosure, wait until the paint has dried before labeling it.) Incidentally, one way to avoid having to label the enclosure is to use a different-color LED for each player. Fortunately, there are four distinct LED colors: red, orange (or amber), yellow and green. Since POWER and RESET switches *S5* and *S6* are slide or toggle and pushbutton, respectively, there is really no need to identify each. Spray two or three *light* coats of clear acrylic over the lettering (if you go this route) to protect it.

Clip the leads of the LEDs to about ¾″ long and form each into a small hook. Carefully solder about 3″ lengths of hookup wires to the LED leads. Then slip over the cathode connection of each LED a 1″ length of small-diameter heat-shrinkable tubing. Push the tubing up against the bottom of the LED cases and gently shrink it.

Mount each LED on the front panel, either via its chrome holder or by pressing it into a rubber-grommet-lined hole, and connect and solder the trailing hookup wires to the appropriate points in the circuit. Trim the wires as needed and make sure the identified cathode leads connect to the K-identified points.

Mount RESET and POWER switches *S5* and *S6* in their respective holes and connect and solder to their lugs lengths of hookup wire. Then, if you are using the jack/plug arrangement for the cables to *S1* through *S4*, mount the individual jacks or 4-position jack strip in place and connect to it short lengths of hookup wire.

Connect and solder the free ends of the wires from *S1* and *S2* and the jacks to the appropriate points in the circuit (Fig. 1). Label each jack according to the player number to which it applies and spray on the clear acrylic to protect it. Then mount the circuit board in place with spacers and machine hardware. If you plan on wiring the player switches directly to the circuit board, pass the free ends of the four flexible cables (these should be about 10- to 12-feet long) through the rubber grommets, tie a knot about 6″ from the ends inside the enclosure, and connect and solder to the appropriate points in the circuit *before* mounting the board in place.

Player switches *S1* through *S4* can mount in any convenient boxes or cases that will comfortably fit in a hand. Typical boxes include the small hinged type plastic ones that are readily available in hardware and housewares stores; mini project boxes available from electronics parts stores; plastic 35-mm film cans; and even aluminum cigar tubes. The last are probably the most comfortable for players to handle, but you will have to use miniature pushbutton switches and line the tubes to insulate the switches.

Whichever housing you use for the player switches, be sure to tie a knot in the cables going to the switches to serve as strain reliefs. Also, identify each switch with a number or color. If you are using different-color LEDs to identify each player, use matching colors on the switch cases.

Additional player switches, up to a maximum of 10, can be incorporated into the project with relative ease, thanks to the fact that *IC2* has 10 separate output lines. When adding switches, each LED/resistor network must be connected to a flip-flop (half of a 4013). NOR and inverting circuits, some of which can be the spares in *IC5* and *IC6*, must be used to insure that a low signal appears on pins of *IC6* and pin 4 of *IC1* if any LED is on.

Checkout and Use

When the First Answer Selector is first powered up, one or more LEDs and/or the buzzer may come on. This is normal. Therefore, always follow a power-up with a quick operation of the RESET pushbutton switch to initiate play.

The improved response and motivation of players makes a useful games-playing tool. The first Answer Selector is completely impartial. Its only purpose is to indicate the first player to respond. It does this with the unerring accuracy of a machine whose decision is beyond question **ME**

Digital Tachometer Module

First of a series of add-on modules for the Digital Measuring System displays engine rpm in cars, vans and boats

By Charles R. Ball

Commercial precision digital tachometers for cars, RVs, boats or any other powered vehicle are usually expensive. "Digitach" is a versatile digital tachometer you build yourself for only a fraction of the cost for a commercial tachometer.

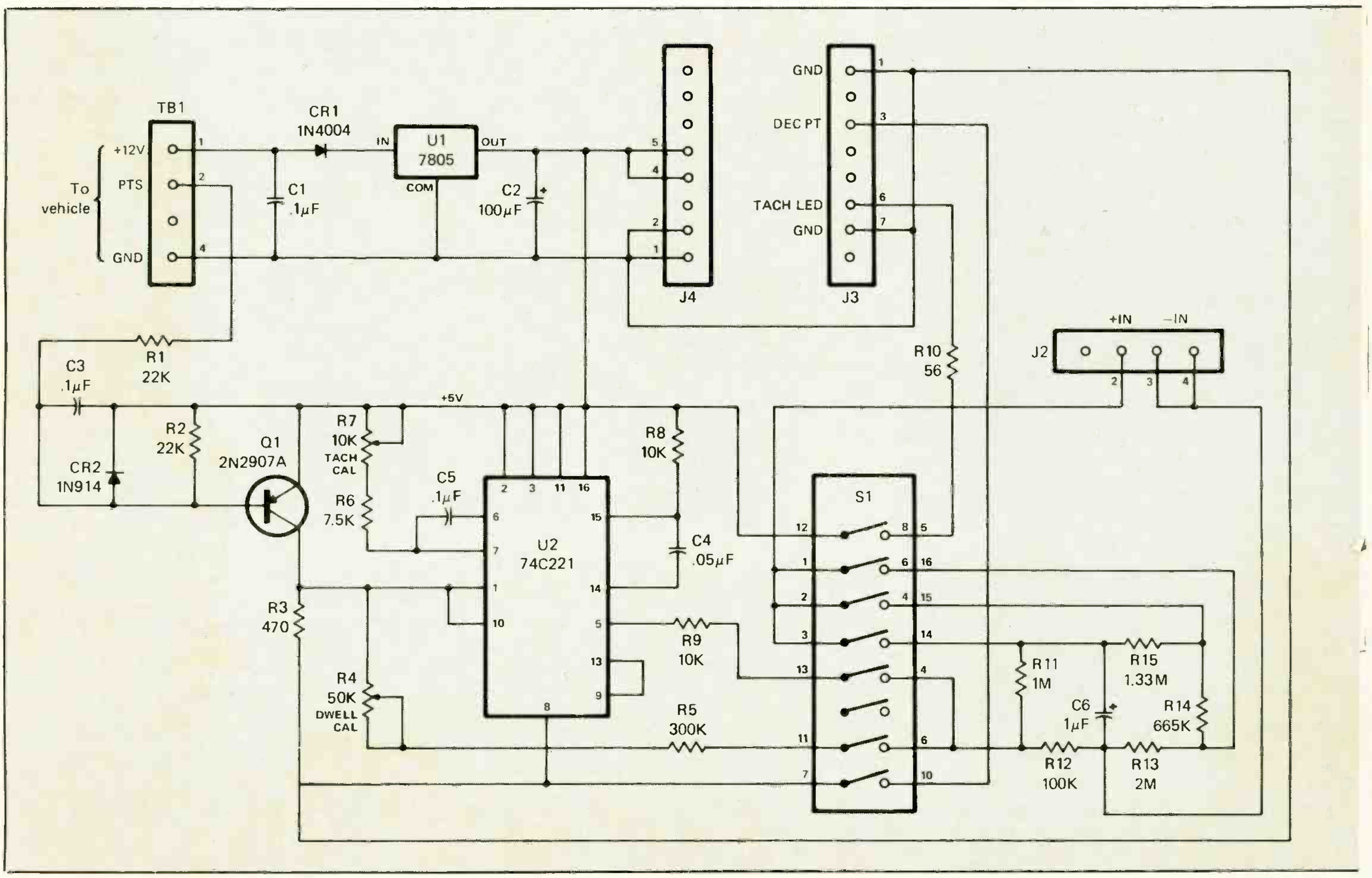
Designed to be used with the Digital Measuring System described last month, Digitach offers a range from 0 to 9999 rpm. With the proper sensor and scaling resistors, Digitach can also function as a digital speedometer, and internal switchable circuitry allows the project to be used as a dwell meter for tune-ups.

You can use Digitach with 4-, 6- and 8- cylinder, 2- and 4-stroke engines. Build the project into a case and add a battery pack, and you have a portable field-service instrument.

About the Circuit

This discussion is based on the premise that the Digitach is to be connected to and used with the Digital Measuring System's decoder/display and power supply modules described last month. However, it will also work with other basic digital panel meters that have the same input impedance and sensitivity as the DMS. If it is used with a DPM with different input impedance and sensitivity, the scaling network's accuracy will be adversely affected, throwing off the accuracy of the readings.

Though Digitach was designed primarily as a tachometer/speed-



ometer, it can also serve as a dwell meter to make it useful for tune-ups. The tachometer and dwell circuits share a common conditioning stage consisting of *C3*, *CR2*, *R1* and *R2* in Fig. 1. This stage filters and standardizes the height and shape of the electrical signals from the engine distributor or speedometer sensor.

In the tach/speedometer mode, the signal from *Q1*'s collector is sent to one half of dual nonretriggerable monostable (one-shot) multivibrator *U2*. This signal triggers *U2* with each input closure that brings the input low. Extraneous noise and point bouncing are eliminated with the second multivibrator in *U2*, which disables the first multivibrator when the points open to present a high input. A CMOS one-shot multivibrator is used in the Digitach because it does not have the inherent $V_{ce(sat)}$ offset that bipolar devices exhibit and, thus, permits true zeroing.

Output pulses from *U2* are routed via DIP switch *SW1* to the resistor scaling network for the cylinders selected. From here, the signal is routed to the DMS module through header *J2* to provide a numeric display of revolutions per second (rpm). The TACH LED is also selected with *SW1* and passed through *J3*.

In the dwell mode, *U2* is not used. Instead, the shaped and standardized waveform is routed to *SW1*, which is used to select the proper cylinder configuration via scaling resistors *R13*, *R14* and *R15*. The scaled signal is then averaged by *C6* for delivery to the DMS via *J2*.

Power for both the tach/dwell circuit and the DMS are provided by the vehicles's 12-volt battery. Rectifier *CR1* protects the system against accidental polarity reversal, and *U1* provides regulated 5-volt dc power for the system via *J4*.

Construction

Digitach's component count is low enough to permit perforated-board construction. However, if you plan to use the project with the Digital Measuring System's decoder/display module and power supply, it is best to assemble the circuit on a printed-circuit board. This will provide the compact dimensions required and precise mating between the DMS and Digitach.

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.

Wire the board exactly as shown in the component installation guide given in Fig. 3. Pay careful attention to the orientations of *C2*, *CR1*, *U1* and *U2*'s socket. (Do not install *U2* in the socket until instructed to do so later on.) Headers are not required in th *J1* and *J5* locations since they are not used in this circuit. Headers at *J2* through *J4* should be cut for the numbers of pins as needed. Install these from the component side of the board, with the longer pins going into the board's holes. Capacitor *C6* is large and oval shaped. To conserve board space, mount *C6* on edge.

Make sure to use a small heat sink on *U1*. Bend one fin of the heat sink slightly outward. A socket is recommended for *U2* to facilitate testing the system after assembly. A photo of the wired tachometer board is shown in Fig. 4.

Carefully recheck installation of all components and all soldered connections. If everything appears to be okay, thoroughly clean away all solder flux from the board with flux solvent or alcohol. Failure to do this will cause leakage that can result in

PARTS LIST

Semiconductors
CR1—1N4004 or equivalent rectifier diode
CR2—1N914 or 1N4148 switching diode
LED1,LED2—Light-emitting diode
Q1—2N2907A transistor
U1—7805 +5-volt regulator
U2—74C221

Capacitors
C1,C3—0.1-µF, 25-volt ceramic
C2—100-µF, 16-volt electrolytic
C4—0.05-µF, 50/100-volt Mylar
C5—0.1-µF, 50/100-volt Mylar
C6—1.0-µF, 100/200-volt metallized Mylar or polyester

Resistors (¼-watt)
R1,R2—22,000 ohms, 5%
R3—470 ohms, 5%
R5—300,000 ohms, 5%
R6—7,500 ohms, 5%
R8,R9—10,000 ohms, 5%
R10—56 ohms, 10%
R11—1 megohm, 1%
R12—100,000 ohms, 1%
R13—2 megohms, 1%
R14—665,000 ohms, 1%
R15—1.33 megohms, 1%
R4—50,000-ohm pc-type trimmer potentiometer (Bourns No. 3352H-1-503 or similar)
R7—10,000-ohm pc-type trimmer potentiometer (Bourns No. 3352H-1-103 or similar)

Miscellaneous
SW1—8-position DIP switch (see text)
Header (AP Products No. 929834-04—cut to size needed); Terminal board (OK Industries No. TS-4); socket for U2; heat sink for U1; printed-circuit board (see text); front panel (see text); ¼" spacers; machine hardware; solder; etc.

Note: The following items are available from Ballco Inc., P.O. Box 1022, Snellville, GA 30278-1022: Solder-plated silk-screened pc board No. DTH-PC for $8.95 ppd; complete kit (less headers and TB1) No. DTH-K for $22.95 plus $2.50 PH. Headers and TB1 are available from Digi-Key Corp., P.O. Box 677, Thief River Falls, MN 56701.

Fig. 1. Overall schematic diagram of tachometer module used with Digital Measuring System's decoder/display and power-supply modules.

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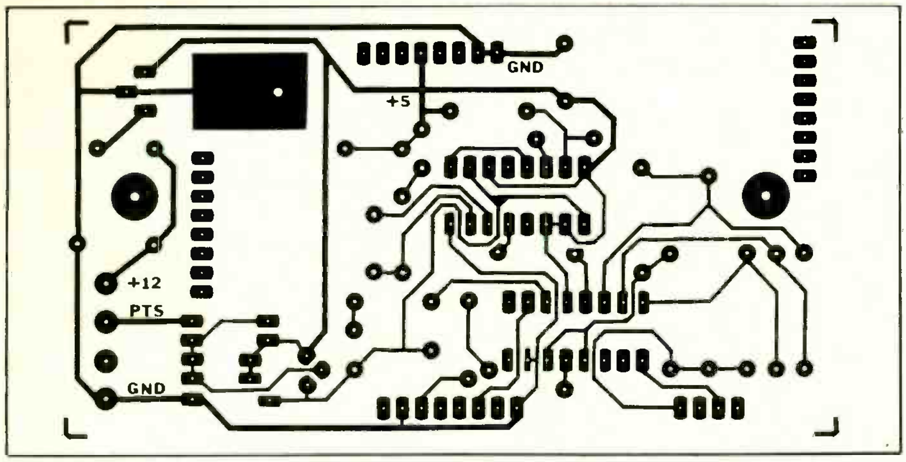


Fig. 2. Actual-size etching-and-drilling guide for basic tachometer.

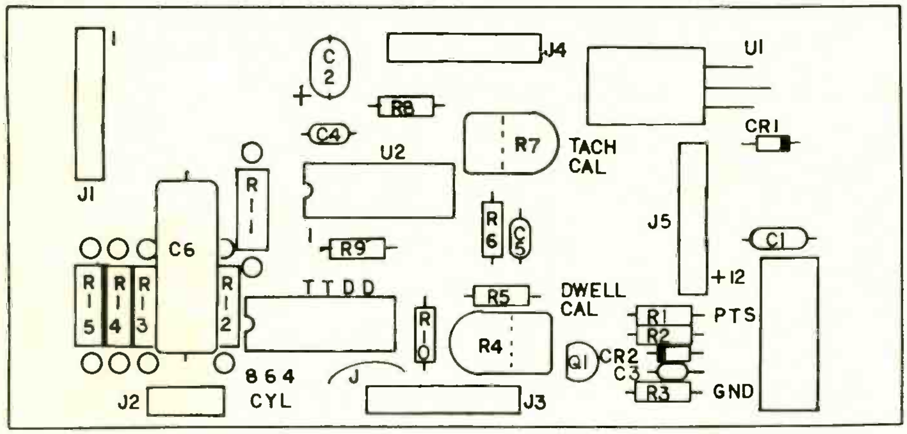


Fig. 3. Components location/orientation guide for basic tachometer.

severe errors in readings because of the tach's high input impedance.

When using Digitach with the DMS board, the latter requires a small LED board to be wired to it. The LED circuit is shown schematically in Fig. 5. The actual-size etching-and-drilling guide and components-placement diagram for this circuit's board are shown in Fig. 6. Note that the pc board is *very* small. If you plan to fabricate your own boards, it is best to etch and drill both on the same pc blank and then cut them apart. Otherwise, to simplify handling during construction, you might want to use a piece of perforated board the same size as the pc board for the LED circuit.

Install *LED1* and *LED2* with enough lead length to permit them to be bent flat against the board's surface and overhang the respective edges. Strip ¼" of insulation from both ends of three 2" lengths of hookup wire, preferably color coded for easy identification. Solder one end of each of these wires to the three pads on the LED board. Then, using machine hardware and a ¼" spacer, mount the LED board on the DMS board. Solder the free ends of the three wires to pins 6, 7 and 8 of *J3* on the DMS board, referring back to Fig. 5 for which to connect where. The finished assembly is shown mounted on the DMS in Fig. 7.

Test & Calibration

Before attaching Digitach to the DMS, and with *U2* still not in its socket, connect a 12- to 15-volt dc power source to the +12V and GND points of *TB1*. Use a voltmeter to check the voltage between pins 1 and 4 of *J4*. If you obtain a reading of 5 volts ±5%, remove the power source from Digitach. Install *U2* in its socket, making sure it is properly oriented before pushing it home. Then align the headers on Digitach with those on the DMS and use ¼" spacers and machine hardware to secure the two to each other.

Once again, connect the 12- to 15-volt dc power source to the +12V and GND points on *TB1*. With no connection to the POINTS terminal on *TB1*, the DMS display should indicate zero. Set *SW1* position 3 (4 cylinder) and positions 6 and 7 (dwell) to on. Temporarily jumper POINTS to GND at *TB1*. Adjust

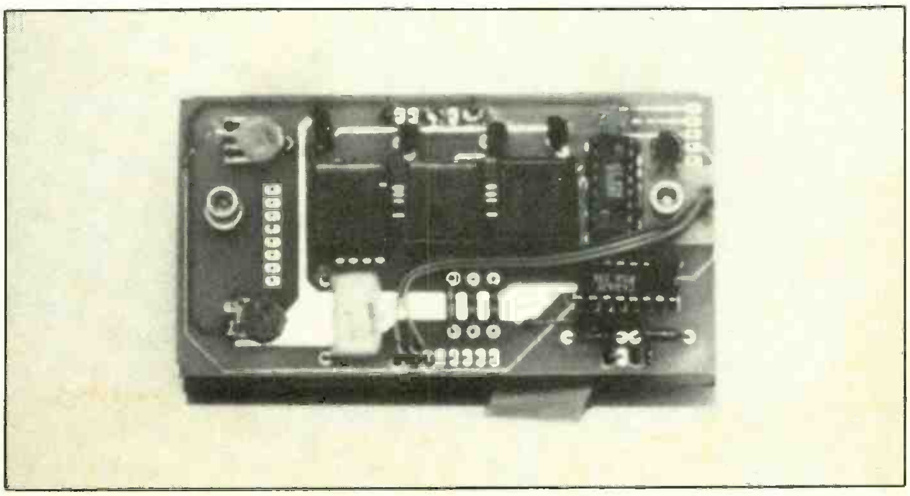


Fig. 4. Assembled tachometer module board.

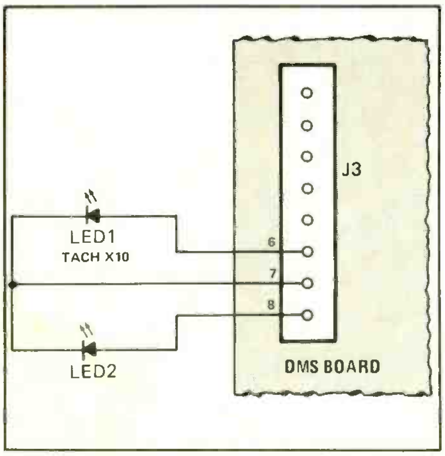


Fig. 5. LED display circuit.

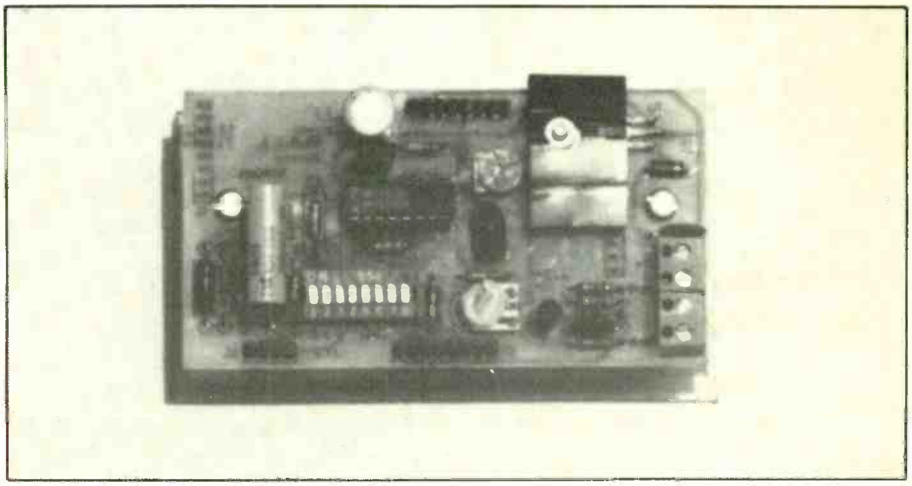


Fig. 7. LED board mounted on DMS board.

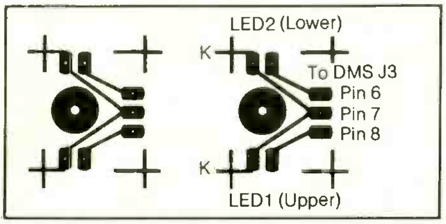


Fig. 6. Actual-size etching-and-drilling guide for LED circuit (left) and wiring diagram (right).

DWELL CAL trimmer *R4* for a display of 90.0 ± 1 count.

Disconnect the power source and set position 3 of *SW1* to off and position 2 (6 cylinder) to on. Reconnect the power source and observe that the DMS now displays 60.0 ±1 count. Power down once again and set position 2 of *SW1* to off and position 1 (8 cylinder) to on. Reconnect the power source and now note that the DMS displays 45.0 ± 1 count. Any deviation from these counts can be traced back to the *R13/15* divider network.

You need a square-wave signal to test the tachometer function of Digitach. If available, use a square-wave generator with 50-ohm output impedance to calibrate and check the circuit's linearity. Otherwise, you can put together the circuit shown in Fig. 8 to provide 60-Hz square waves. Make sure you connect the zener diodes back to back as shown and use a transformer with a 15- to 25-volt secondary.

Set all dwell switches in *SW1* (positions 4 through 7) to off. Then set position 1 to on to select 8 cylinders. (Positions 2 and 3 should be off at this time.) Apply a 60-Hz square-wave signal from the generator or Fig. 8 test circuit between the POINTS and GND terminals of *TB1*. Adjust TACH CAL trimmer *R7* for a display of 80 on the DMS.

Since all readings in the tach mode are multiplied by 10, indicated by the TACH ×10 (upper) LED coming on, actual rpm is 900. Displayed values are derived from the formula: display = (600 × test signal frequency)/sparks per second at 600 rpm for an 8-cylinder, 4-stroke engine. The Table shown elsewhere in this article gives pertinent engine ignition information.

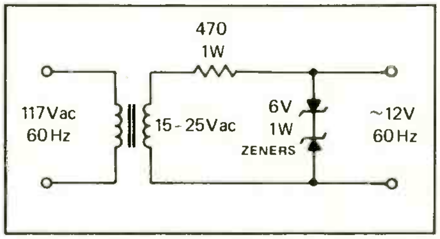


Fig. 8. Square-wave signal circuit used for testing tach function.

After calibrating Digitach, place a small drop of plastic cement or nail enamel on the adjust slots of trimmers *R4* and *R7* to prevent vibration from changing the settings.

Installation

Digitach lends itself well to a variety of installation options. For example, you can install the project in a box mounted under the dashboard or in place of your vehicle's present tachometer.

Digitach's electrical connections are relatively simple. The GND terminal of *TB1* connects to any convenient chassis point that is at ground

Ignition Information

Parameter	Two-Cycle			Four-Cycle			
Number of cylinders	2	4	6	2	4	6	8
Sparks/revolution	2	4	6	1	2	3	4
Sparks/second at							
600 rpm	20	40	60	10	20	30	40
6000 rpm	200	400	600	100	200	300	400
Cam degrees/spark	180	90	60	180	90	60	45
Crank degrees/spark	180	90	60	360	180	120	90

For 2-cylinder engines, multiply rpm displayed by 2.

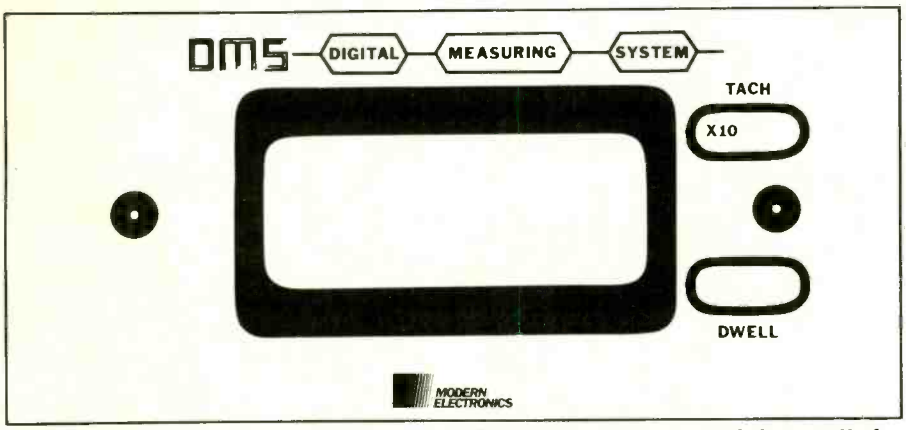


Fig. 9. Actual-size front-panel artwork for DMS with tach module installed.

potential. (Keep in mind that a metal piece on a Corvette or a boat is not necessarily at ground potential. To be certain that you have the proper ground in such situations, you must connect *TB1*'s GND terminal to the negative post of the battery.)

Connect the +12V terminal of *TB1* to any point in the electrical system that is powered only when the ignition is switched on. Consult your vehicle's shop manual or use a voltmeter to find an appropriate tie-in point. Connect the POINTS terminal of *TB1* to the points (or their electronic equivalent) terminal in your vehicle.

Three popular wiring schemes for Digitach are shown in Fig. 9. Select the one that matches your vehicles's electrical system.

If you decide to install your Digitach inside a box, you may want to equip it with the front panel shown actual-size in Fig. 10. You can make this panel from a piece of ⅛"-thick Lexan or Plexiglas with a nameplate overlay using the overlay procedure described in "Dress Up Your Projects" in the September 1985 issue of *Modern Electronics*. Of course, to do this, you must obtain a same-size film negative of the artwork from a print shop or lithographer.

A less expensive alternative is to cut out the Fig. 10 artwork and then the areas for the numberic displays and LEDs and cement it to the plastic sheet. If you go this route, protect the artwork with two or more coats of clear acrylic spray *before* you cement it to the plastic sheet. **ME**

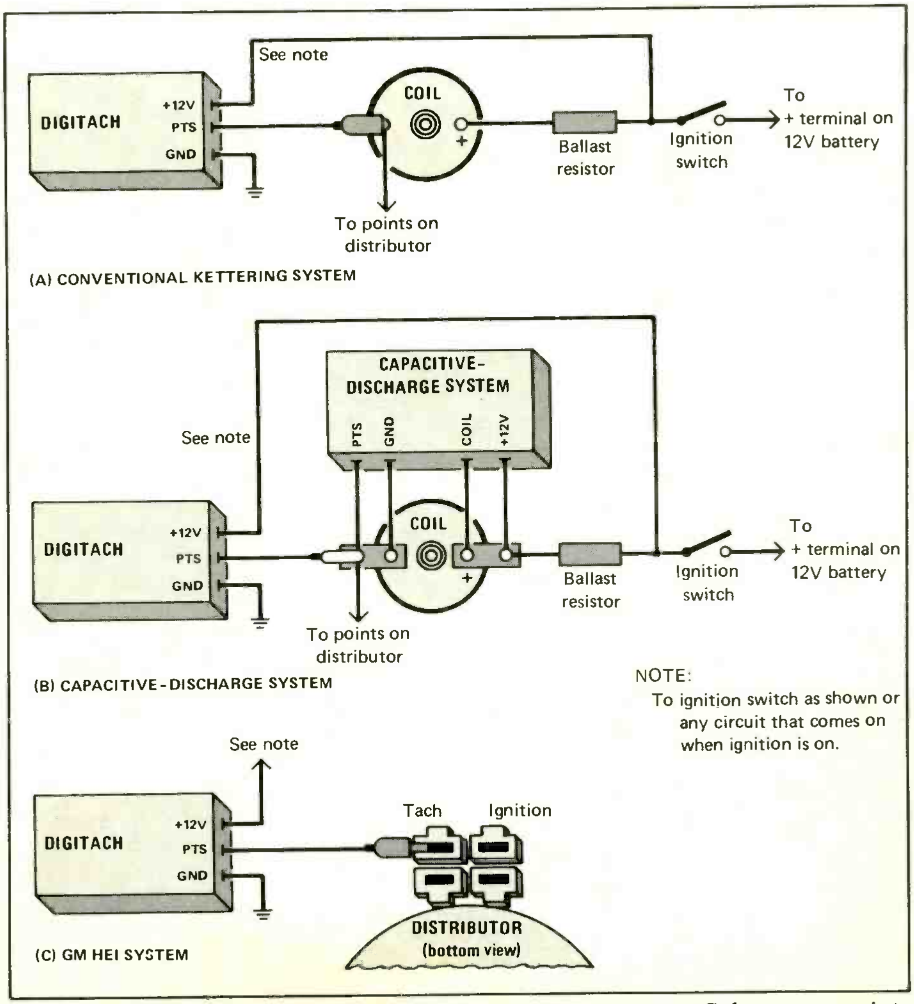


Fig. 10. Connect project to points indicated in your vehicle. Select appropriate arrangement for your vehicle's particular ignition system.

Speedometer Applications

Speedometer applications for Digitach require a bit more work than the tach/dwell applications do. You must first determine the number of revolutions of the speedometer cable at a given speed, say 60 mph. This information is usually available from shop manuals, or you can determine it experimentally using a hand tachometer and a dynamometer.

Once the rpm-to-mph ratio is derived, a transducer can be fabricated using magnets and Hall-effect devices or a small permanent-magnet dc motor. The output of the selected device is then fed to the scaling resistor network. Some scaling modification may be necessary. In the case of 60 mph, the DMS wants to "see" 600 mV at its input with the decimal point placed using the DIP switch.

How To Rejuvenate Printer Ribbons

Increase useful life of printer ribbons

By Ralph Tenny

Computer printer ribbons can be rejuvenated to save on the cost of replacements. There are at least two ways to do this. The most reliable one is to re-ink it. For the home computerist and low-volume user, however, this may not be the most economical solution. The typical commercial re-inker costs about $60, meaning that you would have to refresh 20 to 30 ribbons just to break even.

For the low-volume user, the cheaper alternative is to treat them with a solvent like common WD-40 spray lubricant. Though at least one manufacturer cautions against this, claiming it can damage printers, many people have used WD-40 with no ill effects. In this article, we will tell you how to rejuvenate worn computer printer ribbons using WD-40.

How Rejuvenation Works

Ribbons designed for use in Epson's MX-80 and similar printers are illustrated here in describing the rejuvenation procedure. This method can be adapted as necessary for other ribbon types.

Ribbons for computer printers are commonly used up along a "track" that measures only 3/32" wide, offset from the center of a 1/2"-wide fabric strip, as shown in Fig. 1. Normally, less than 20% of the ribbon's area is used; the other 80%-plus area is generally wasted, even though the full width of the ribbon is always inked at the factory.

As long as the ink does not dry out while a ribbon is in service, some of the ink in the areas outside the normal print track migrates to the track area. However, not all the ink on the ribbon will migrate to the track area before printed characters become too light for easy reading.

Since the print track is not centered on the ribbon, a second track area can be created by flipping over the fabric ribbon. This is accomplished with a half-twist of the ribbon as shown in Fig. 2. Put the half-twist in the ribbon just before it enters the takeup slot in the cartridge and then cycle the entire ribbon through the cartridge. Begin by slowly rotating the takeup knob until the ribbon enters the slot and is about 1" past it. Then use a variable-speed drill operated at low speed, a low-speed motor or a cassette rewinder

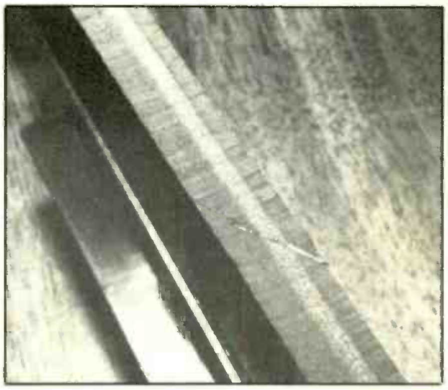


Fig. 1. Ribbons are "used up" along a narrow track (off-center lighter band). Note also diagonal splice that joins tape ends to create a continuous loop.

(Fig. 3) to finish cycling the ribbon at a higher speed.

If you use an electric drill, you need a special "bit" made by hammering flat one end of a length of 5/32"

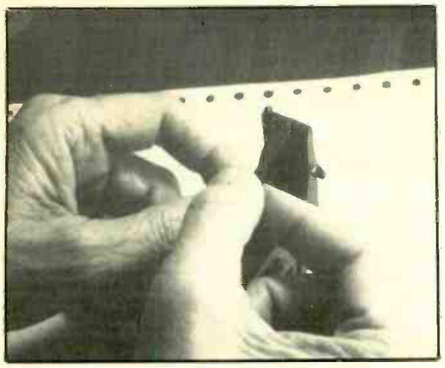


Fig. 2. A half-twist makes available a second life-stretching track.

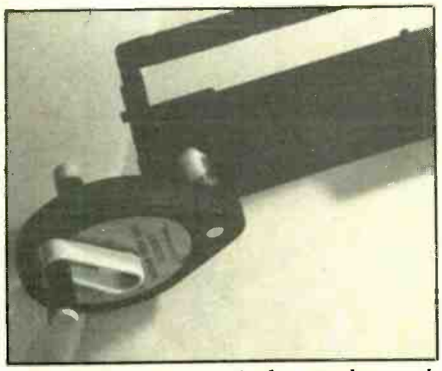


Fig. 3. Cassette rewinder can be used to cycle a ribbon from end to end.

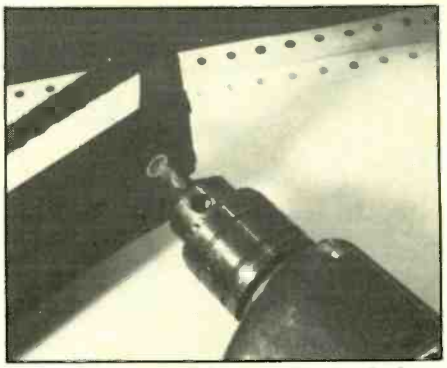


Fig. 4. Home-made "bit" and electric drill make short work of cycling.

hobby tubing. Chuck the bit into the drill and place the flattened end in the spindle splots at the bottom of the takeup assembly (Fig. 4). An electric motor or cassette rewinder requires a shaft adapter that you must fabricate yourself (Fig. 5).

To assure that the entire ribbon has been cycled through the cartridge assembly, start and end at the splice that joins the ends of the ribbon into a continuous loop (see Fig. 1).

Flipping can extend the useful life of a ribbon, but only if you do the flipping before the print quality becomes too low for legibility. However, even this will not let you take full advantage of the long-life potential inherent in a printer ribbon. Some 60% of the ribbon's surface still remains unused. If the ink in the unusued areas can be made to flow into the track area, you can obtain still longer ribbon life.

Thinning of the ink to make it flow into the track area is the task of the WD-40 lubricant. To do an effective job of it, two criteria must be met. One is that the ink must be made to flow evenly into the track area so that print density is uniform. The other is that absolutely all solvents in the WD-40 must be evaporated before putting the ribbon back into service. Failure to evaporate all solvents invites printhead damage. Keep in mind, too, that a moist ribbon attracts airborne dust and dirt that can clog a printhead and cause the driving circuitry to burn out.

Rejuvenation Procedure

It is pointless to rejuvenate a worn-through or torn ribbon or one that has frayed ends. If you try to use a damaged rejuvenated ribbon, printer damage may result. Therefore, it is important that you carefully inspect the entire lengths of all ribbons to be rejuvenated. Discard and replace any that show signs of tears, frays or pulled threads.

Ribbon inspection is most easily accomplished with an electric drill operated at low speed or the small electric motor or cassette rewinder, using the special bit or adapter described above. Always start and end at the splice to be sure that the entire length of each ribbon is inspected.

Treatment with WD-40 requires direct application to the entire length of the ribbon in one operation. To do this, you must open the cartridge.

There are several styles of ribbon cartridges on the market for Epson printers. In two popular ones, tiny slots under the lids are used as pry points to release the lids. Another type has molded latches that hold the cartridge closed. Except for releasing the latches on the cartridges that have them, opening either type of cartridge is a relatively simple but tedious operation.

Fig. 5. A slow motor is ideal for unattended continuous cycling of ribbon over the extended periods of time required for solvent evaporation.

To open a cartridge, insert the tip of a screwdriver with a thin, narrow blade into each slot in turn and gently pry until the latches release. Carefully lift off the lid, making sure you do not displace the gearing system in the takeup mechanism. Note how the gears are placed (Fig. 6) so that you can put them back if you should accidentally displace them.

When the driven gear is rotated, it takes up the ribbon in small folds that are then randomly fed into the open cavity in the cartridge. Also, if you look closely at the exit end of the cartridge, you will see a flat tentioning spring. Unless the ribbon is too slack or has excessive drag, leave this spring alone. Only if it needs it should this spring be adjusted.

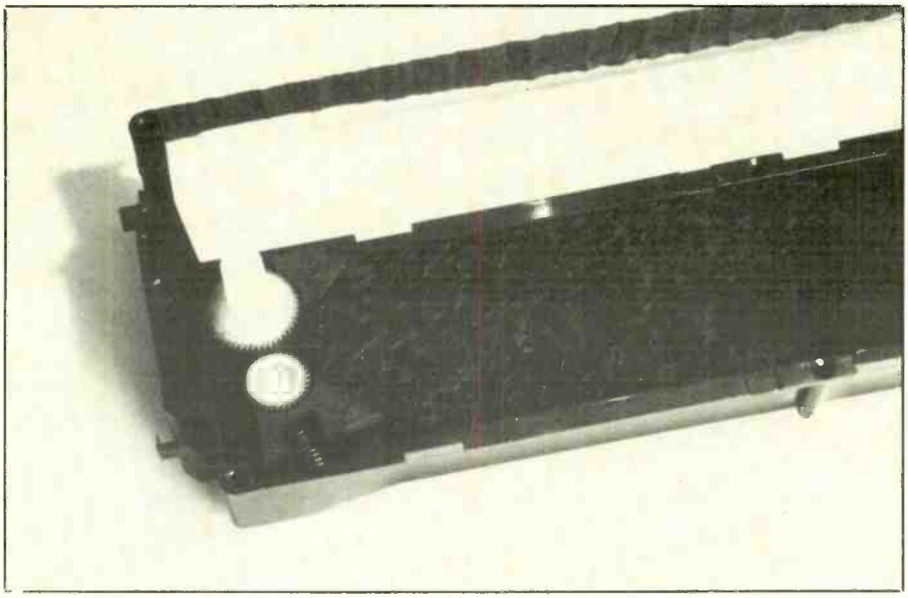


Fig. 6. The takeup drive gears at the left accordion fold the ribbon and force it to randomly bunch up inside the cartridge housing.

Rejuvenation is simple in concept but requires practice to assure consistent results. The ribbon inside the cartridge must be sprayed evenly with WD-40 as close as possible to the cartridge housing. After this, reassemble the cartridge and slowly cycle the ribbon continuously until all the solvent has evaporated.

Rejuvenation is performed as follows:

(1) Inspect the ribbon by slowly turning the takeup knob and examining the entire length of the ribbon.

(2) Carefully open the cartridge and make a note of how the ribbon drive gears are arranged.

(3) Spray WD-40 as uniformly as possible onto the ribbon for about 5 seconds. (Until you get the feel of things, it is better to spray too little than too much lubricant.)

(4) Reassemble the cartridge, making sure the drive gears are in their proper positions.

(5) Immediately cycle the ribbon at moderate speed, starting and ending at the splice. Repeat until the splice has passed through at least three times. You will see that WD-40's solvents cause the remaining ink to become more uniform across the width of the ribbon.

(6) Continuously cycle the ribbon at very low speed for at least 24 hours. Then inspect the entire length of the ribbon for shiny spots (unevaporated solvent). If you note any, continue to cycle the ribbon until all shiny shots disappear.

(7) Store the rejuvenated ribbon in an airtight plastic bag until ready to use.

Manual cycling of the ribbon in step 7 is impractical. It can also damage your printer, because ink and solvent will concentrate where the ribbon stops in contact with the cartridge at the entry and exit points. Therefore, some sort of motor-driven jig is recommended to cycle the ribbon. The best motor speed is between 1 and 10 revolutions per second, which can be obtained with an inexpensive synchronous timing motor (Fig. 5). Mount the motor on a frame that can hold the ribbon cartridge solidly in place during unattended cycling.

There is a limit to the number of times any given ribbon can be rejuvenated before results become unacceptable. At this point, you have no alternative but to replace the ribbon with a new one. ME

Solid-State Audio Circuits

Part 2 (Conclusion)

Analyzing audio preamplifiers and tone-control circuits

By Joseph J. Carr

Last month in Part 1 of this article, we discussed the various elementary circuits used in audio amplifier designs. This month, our focus is on detailed analyses of audio preamplifiers and tone-control circuits.

Audio Preamplifiers

The purpose of a preamplifier is to boost the minuscule output voltage from sources such as microphones, tape heads, phonograph cartridges, etc. In audio, the preamplifier might have a gain of as little as 2 or 3, and as great as 5000. The gain required of the preamplifier is a function of the input signal required by the power amplifier (or other load) and the voltage available from the source. Let us suppose that a microphone's output is 5 millivolts at normal speaking levels and that the power amplifier requires a 250-millivolt input to deliver maximum output power. This gives us the V_{in} and V_{out} potentials of the preamplifier. The required voltage gain can now be calculated from the formula $A = V_{out}/V_{in} = 250\ mV/5\ mV = 50$.

Several options are open when designing preamplifiers for audio use. One popular approach is the use of a special-purpose integrated circuit like the LM-381. Ordinary operational amplifiers, such as the 741 or LM-301 can also be used, as can special operational amplifiers designed for audio and stereo applications, such as the LM-1303. All

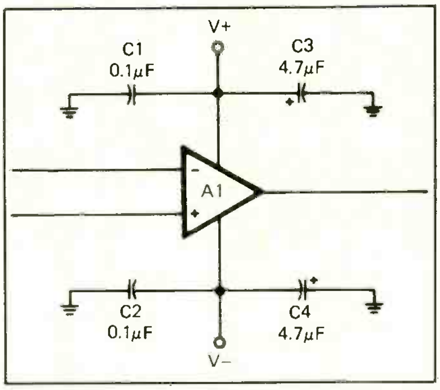


Fig. 1. To assure stable operation, it may be necessary to bypass each power-supply line with two capacitors to handle entire audio range.

these devices are easily obtained by hobbyists.

An IC audio preamplifier may have quite a bit of gain and could oscillate under some conditions. It also might easily influence, or be influenced by, other circuits because of signals passed between stages over the dc power lines. These potential problems make it necessary for the dc power lines of the IC preamplifier to be properly bypassed. Figure 1 shows correct bypassing of an operational amplifier, although the same decoupling methods apply to other audio integrated circuit devices

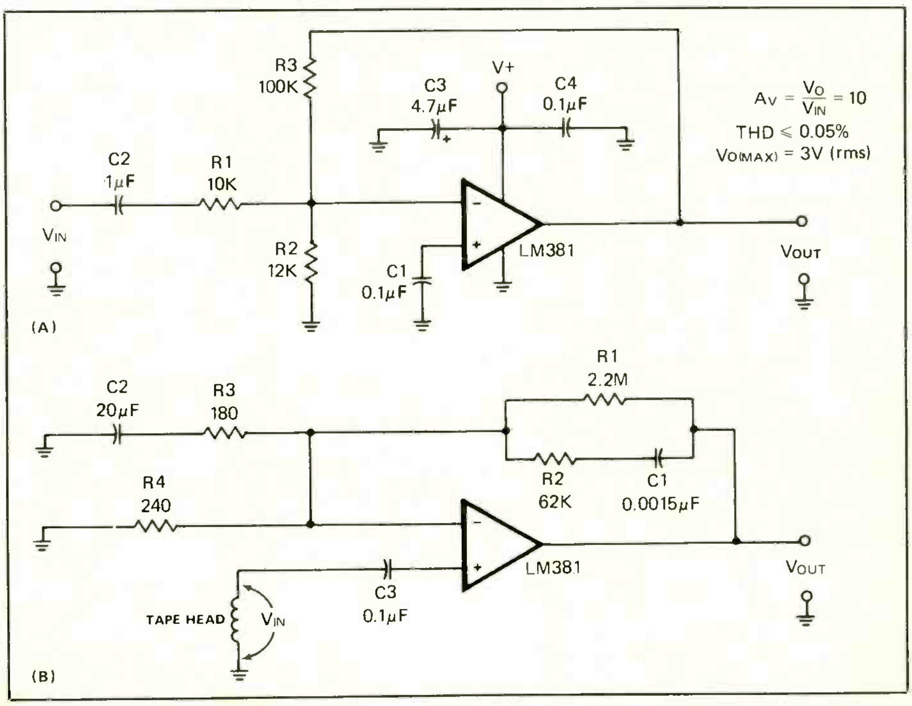


Fig. 2. Audio amplifier circuits based on the LM-381 IC amplifier. Circuit A is a common input preamp for phono cartridges, microphones, etc. Circuit B is generally used to preamplify the low-level signal from tape player heads.

whether single- or dual-polarity power supplies are used.

Each power supply line must be bypassed with at least one capacitor, and preferably two, as shown in Fig. 1. Capacitors *C1* and *C2* are 0.1 μF each and are used to decouple high-frequency signals. Capacitors *C3* and *C4* have larger values (typically 4.7 μF) and are used to decouple lower-frequency signals. Usually, *C3* and *C4* are tantalum electrolytics.

You may well ask why two capacitors are used in bypass circuits. The reason for this is that you want bypassing across the entire 20 kHz or so audio range. A relatively large value electrolytic will not work well at the higher-frequency extreme, and a small value capacitor is ineffective at the lower-frequency extreme. Therefore, we are forced to parallel a lower-value capacitor with a higher-value electrolytic capacitor to assure stable broad-spectrum preamplifier operation. In many cases, however, the single 0.1-μF capacitor on each dc power supply line is sufficient, so this "overkill" is not needed.

Several companies make IC preamplifiers especially for audio applications. Typical of these are the LM-381 and LM-382 from National Semiconductor (see the *Linear Data Book* for details). Two circuits based on the LM-381 are shown in Fig. 2.

Similar to a dual operational amplifier, the LM-381 differs in that it requires only a single-polarity dc power supply. With the values shown in the Fig. 2A wideband, low distortion audio preamplifier, the voltage gain is 10 at a total harmonic distortion (THD) of less than 0.05 percent. The frequency response of this circuit is essentially flat throughout the audio spectrum (up to the limit of the amplifier).

A large number of cassette tape players use the LM-381 as shown in Fig. 2B. The tape head is coupled to the noninverting (+) input of the LM-381 through a 0.1-μF capacitor. Because of its low input bias, the preamplifier does not require a resistor from the noninverting (+) input to ground. (Many versions of this circuit require a resistor to prevent charging of the capacitor by input bias currents.)

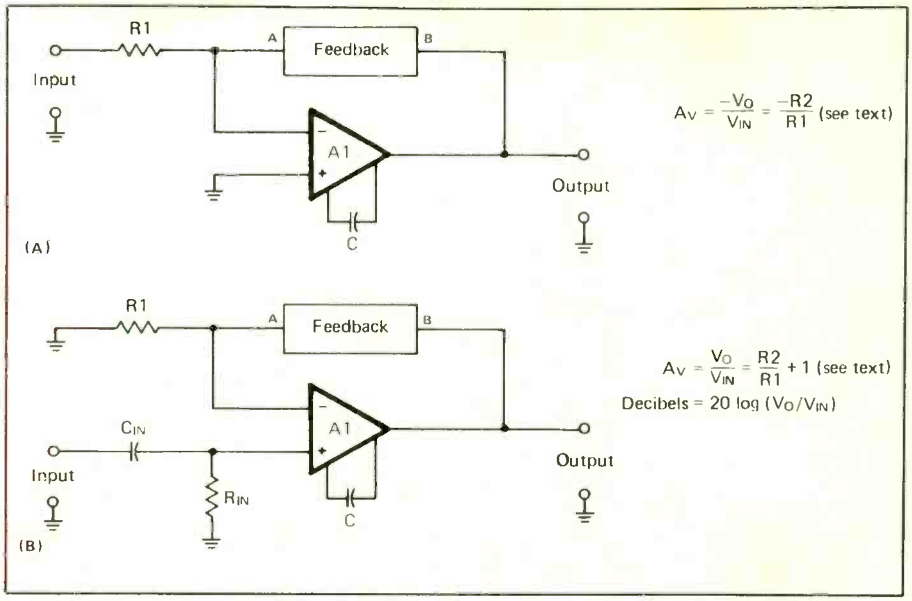


Fig. 3. Basic op amp inverting follower (A) and noninverting follower (B).

Figure 2B's low-frequency response is set by resistor *R3* and capacitor *C 2* and is calculated using the formula $F = 10^6/(6.28C2R3)$. Here, *F* is the low-end -3-dB frequency in hertz (Hz); *C2* is in microfarads; and *R3* is in ohms. Values shown for *R3* and *C2* yield a low-end frequency of about 45 Hz. The shape of the frequency response curve of this preamplifier is set to correspond to that required for the cassette tape equalization curve.

The classical operational amplifier is one of the most useful ICs available for audio amplificaion. The op amp is easy to use, usually well-behaved and low in cost. Designing circuits with the op amp is generally so easy that one wag was tempted to correctly claim that it makes ". . . the contriving of contrivances a game for all." Circuits that only very advanced hobbyists could tackle before the ubiquitous IC op amp became available are now open to even the newcomer.

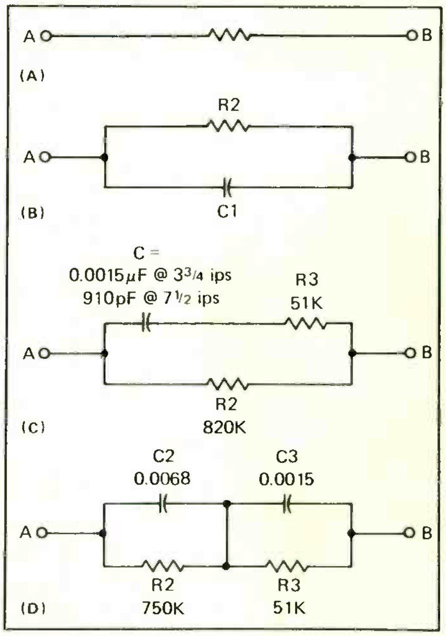


Fig. 4. Feedback networks commonly used in op amp circuits.

Figure 3 shows the basic operational amplifier configurations used in audio circuits. Figure 3A is the inverting follower, Fig. 3B is the noninverting follower. In the inverting circuit, the output signal will be 180 degrees out-of-phase with the input signal (reversed in polarity). In the noninveting circuits, the output signal is in-phase with the input signal.

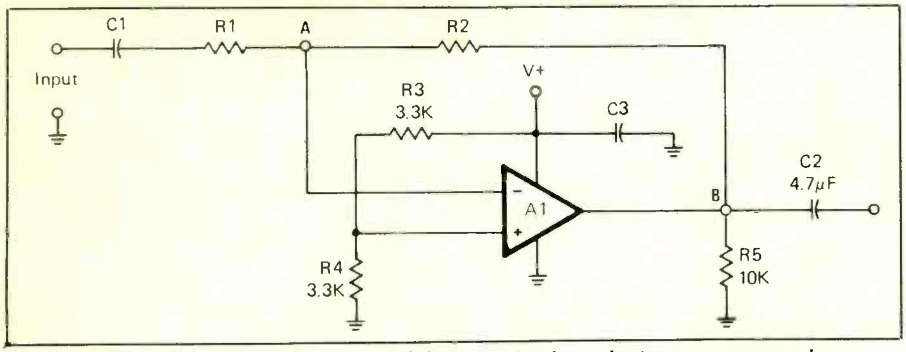


Fig. 5. Op amp circuit powered from a single-polarity power supply.

In both cases, gain is set by the values of the input resistor (*R1*) and a feedback network. The expressions for the special cases where the feedback network is a single resistor (see Fig. 4A) are shown with each circuit.

Several popular variations of the feedback network that find application in audio preamplifiers are shown in Fig. 4. Figure 4A is a wideband amplifier that has a frequency response with no tailoring except by the natural bandwidth of the amplifier. The approximate available bandwidth for this circuit is calculated from the gain-bandwidth product (F_t) of the device, which is the frequency at which gain drops to unity (1). The formula is F_t = gain × bandwidth.

One use of this formula is for determining which op amp is needed. For example, suppose a frequency response of 20,000 Hz is needed in an amplifier with a gain of 150. The required F_t is 150 × 20,000 = 3 MHz.

The formula can also be rearranged to provide the means for calculating the maximum frequency response of any given circuit where F_t is known. for example, suppose a 1-MHz op amp is to be used in a circuit with a gain of 100. Maximum frequency response will be F_t/Gain = 3 MHz/100 = 30 kHz.

Figure 3B's feedback network produces a flat gain at low frequencies equal to that of the resistor alone. At frequencies above a certain point, however, gain will roll off at −6-dB per octave. The "break-

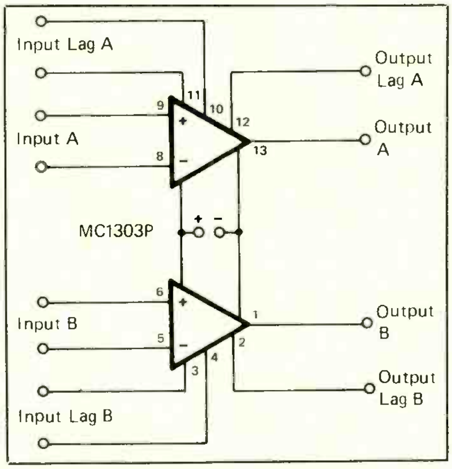


Fig. 6. Example of a stereo audio preamplifier based on the op amp.

point" between the low-frequency gain and the rolled off segment (high end − 3-dB point) is calculated using the formula F = $10^6/(6.28C1R2)$. Where: *F* is in hertz (Hz); *R2* is in ohms; and *C1* is in microfarads.

Remaining feedback networks in Fig. 4 are used in special preamplifiers. That in Fig. 4C is used for NAB-compensated tape preamplifiers, Fig. 4D for RIAA-compensated phonograph preamplifiers.

Operational amplifiers are normally used in dual-polarity power supply circuits. In cases where the op amp must be used in single-polarity supply circuits, a configuration like that shown in Fig. 5 can be used. In this type of circuit the V− power supply terminal is grounded and the V+ terminal is connected to the single power supply. The + input is biased to a point midway between V+ and ground by the *R3/R4* divider. The value of *R3/R4* can be any resistance between 2,000 and 100,000 ohms. The value shown, 3,300 ohms, is very common in audio preamplifiers.

A problem with this circuit is that the inverting input and the output terminals are also biased to a high dc potential. To prevent these voltages from affecting other circuits, capacitor coupling is required for this circuit. Capacitor *C1* couples the input signal to the amplifier while preventing the dc bias at point "A" from affecting the input source. Similarly, *C2* will pass the audio output signal while blocking the dc offset bias.

An example of a stereo audio preamplifier based on the op amp is shown in Fig. 6. Once called the MC-1303 when Motorola was the sole source of the chip, other manufacturers now offer it as the LM-1303. The chip contains two operational amplifiers that are completely independent of each other except for the V− and V+ dc power supply connections.

Tone Control Circuits

Tone controls allow the user to custom-tailor the frequency response of an audio preamplifier. The BASS control emphasizes the low frequencies, the TREBLE control the high frequencies. In some circuits a single TONE control serves both ends of the spectrum. Several varieties of tone control circuit are shown in Fig. 7.

A simple roll-off tone control found in low-cost equipment is shown in Fig. 7A. Consisting of just two components series-connected across the audio line, this is the simplest and least-desirable type of tone control. These components form a treble roll-off circuit that mimics the effect of "bass boost" (poorly) by rolling off the high frequencies. Unfortunately, while simple, this type of tone control reduces the amplitude of the signal.

Another variety of tone control is

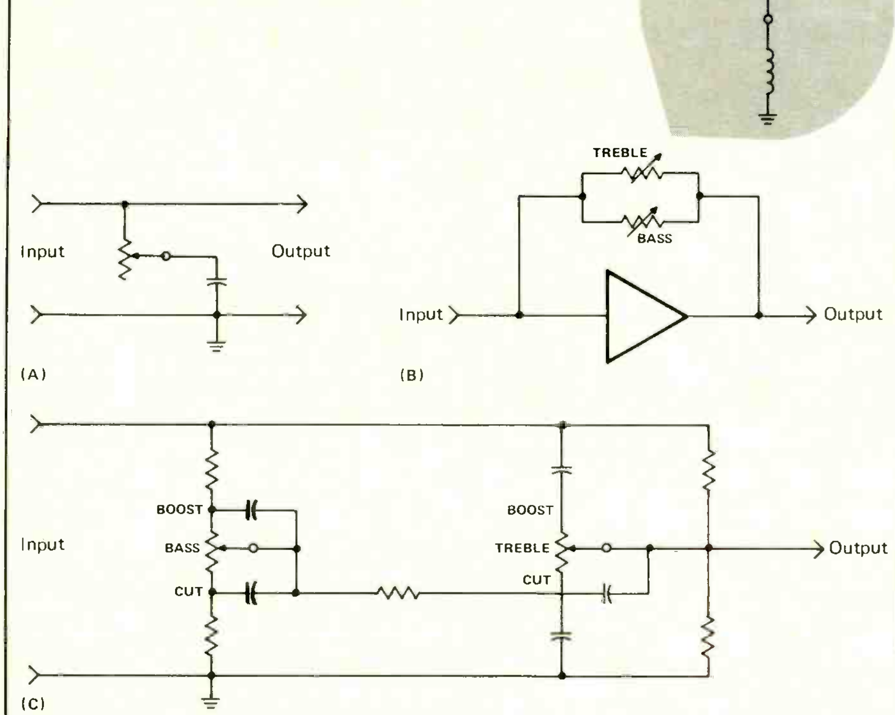


Fig. 7. Simple rolloff (A), negative-feedback frequency-sensitive (B) and Baxandall (C) tone-control circuits.

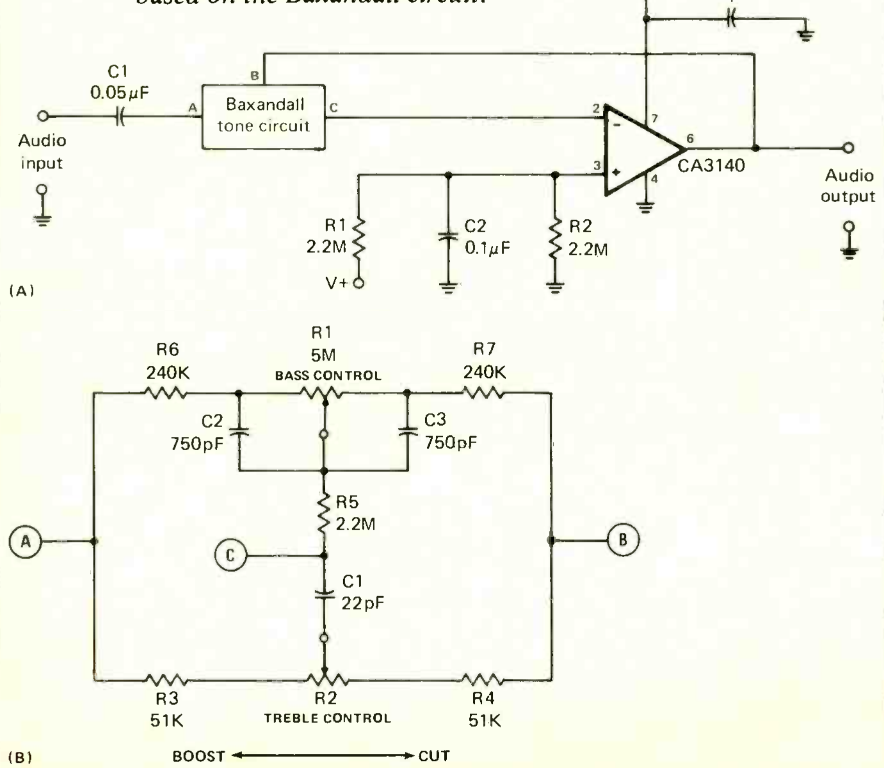


Fig. 8. Tone-control preamplifier circuit stage based on the Baxandall circuit.

shown in Figure 7B. In this version, a pair of frequency-sensitive RC or RLC networks is placed in the negative-feedback circuit of the amplifier. These circuits selectively amplify different bands of frequencies. An example of the RLC version is shown in the inset in Fig. 7B.

The Baxandall tone control circuit shown in Fig. 7 is used in almost all decent audio amplifiers. The Baxandall circuit consists of two cascaded frequency-selective RC networks, one each for bass and treble ranges. Each control boosts its design frequencies at one end of the control's range, and cuts it at the other end of the range.

Figure 8 shows the circuit for a tone control preamplifier stage based on the Baxandall circuit. The basic circuit is a CA-3140 op amp connected in a basic inverting follower configuration, with a single power supply. Resistors *R1* and *R2* bias the + input to V+/2. These resistors are higher in value than in certain other op amps because of the very-large input impedance of the BiMOS CA-3140 op amp. The three-terminal Baxandall tone circuit shown in Fig. 8B is essentially the same as in Fig. 7C, and is used as shown in the circuit of Fig. 8A. It provides a boost or cut of about 20 dB of either the bass or the treble.

In Closing

Now that you have some idea of what kinds of circuits are used and, more importantly, *how* they are used, you are ready to begin experimenting with them on your own. As you design your own circuits, you will find that preamplifiers and tone-control circuits may or may not be needed, depending on the requirements of your circuits. Whether or not you do need preamplifier or tone-control circuits, you will soon discover that experimenting with audio circuits is a lot of fun and that very little time is required to breadboard them. **ME**

New Developments In Video Technology

By Alexander W. Burawa

Developments now being made behind the scenes promise to lend a new meaning to our "video revolution." Two such developments are Sharp's Digital VCR and Sanyo's ultra-thin flat color video tube.

Sharp's digital memory circuitry (Fig. 1) provides special effects and functions that have heretofore been very difficult to attain. Large bins of digital memory and special control circuits, make it possible for Sharp's Digital VCR to remove disruptive noise bars and jitter from video images in still and slow-motion playback. Thanks to a wider tracking range, the Digital VCR can also play back video tapes at 1.5 to 2 times normal speed while allowing viewers to monitor the dialog without loss of intelligibility.

In addition to the above, the Digital VCR permits still image viewing of a TV program in progress, maintaining the audio portion of the program intact. Finally, a variable 0.1-to-1.0-second strobe effect is provided for both video playback and TV broadcasts without interrupting the audio. This last is a new effect made possible only with a Digital VCR.

Beam Index Technology, used by Sanyo in its new developmental ultra-thin color picture tube, takes video a step closer to the hang-on-the-wall TV receiver. The new 3″ tube is almost flat and requires less power than a conventional color CRT. Though it uses electron-beam-and-phosphor-screen technology, it departs from conventional CRT designs in several significant ways.

Unlike conventional color CRTs, the beam indexing tube has no shadow mask and a single electron beam (as opposed to the usual three). The screen has three primary color stripes plus an indexing stripe (see Fig. 2) to reduce distortion. The single beam directly scans the screen at a 30-degree angle, producing a color index signal that continuously indicates the position of the scanning spot relative to the color phosphor sripes. As the beam passes over all of the color stripes, an index signal collector plate and photodiode detect the index signals that identify its location. To produce the desired color, beam information is fed in the correct

Fig. 1. Block diagram of field memory system Sharp uses to create special effects capabilities in prototype of its Digital VCR.

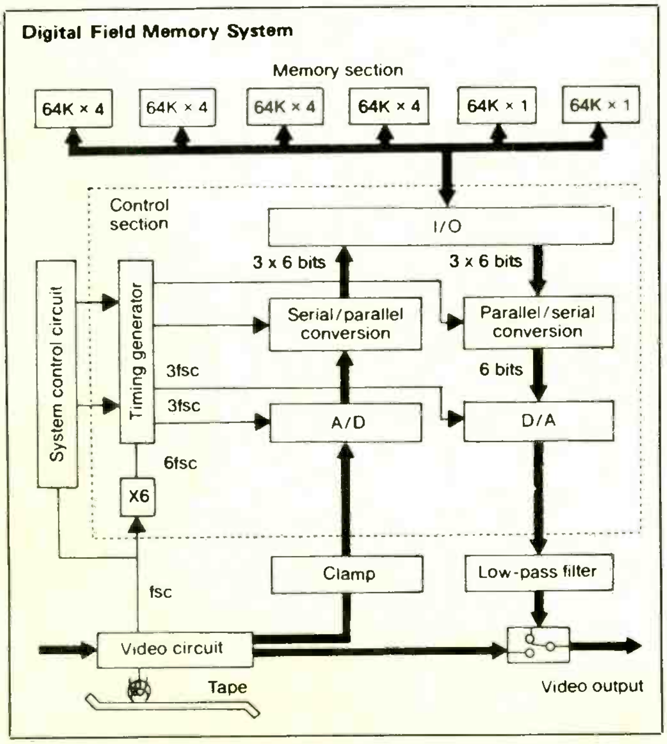
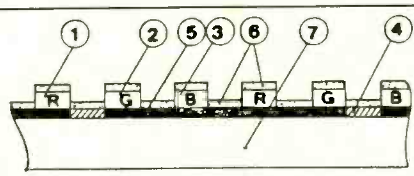


Fig. 2. Phosphor screen structure.



1—red phosphor stripe
2—green phosphor stripe
3—blue phosphor stripe
4—index phosphor stripe
5—nonemitting material
6—transparent protective film
7—coated glass panel screen

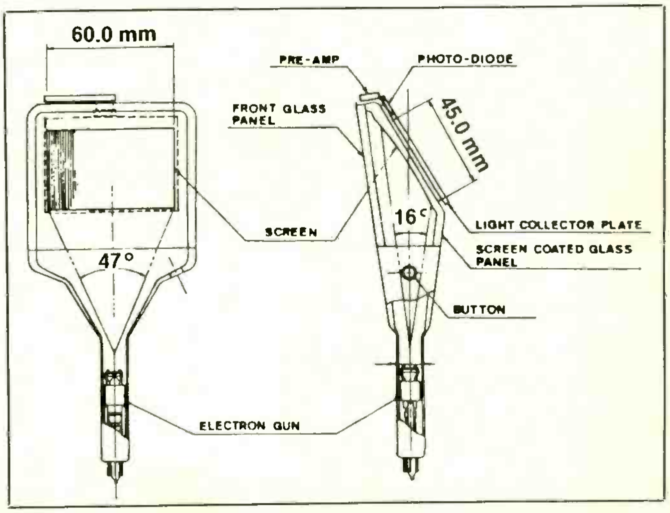


Fig. 3. Beam index tube geometry.

time sequence by picking up the index light signal.

Picture viewing is through a computer-designed glass screen on the back of which are the phosphor stripes. The deflection method used to image the picture on the screen corrects for trapezoidal distortion that otherwise might occur as a result of the 30-degree scan angle. The system's flyback transformer minimizes high-voltage fluctuations, and all index signal processing is handled by a CMOS integrated circuit.

Beam index tube geometry (Fig. 3) makes it possible to build a handheld TV receiver—or other video display device—with a thickness of as little as 50 mm (about 2″). Larger-screen products like desktop computer video display monitors, tabletop TV receivers, etc. would be commensurately thicker when and if beam index technology becomes available in 13″ and larger versions. But even the small 3″ screen of this first tube has a myriad of practical applications, ranging from pocket TV receivers to handheld computer displays.

The Versatile NAND Gate

By Forrest M. Mims III

A sign over my desk reads, "Give me a bucket full of NAND gates, and I'll build you a computer!" The sign could be altered to specify NOR gates. In either event, a completely functional digital controller or simple computer can indeed be designed using only NAND- or NOR-gate building blocks.

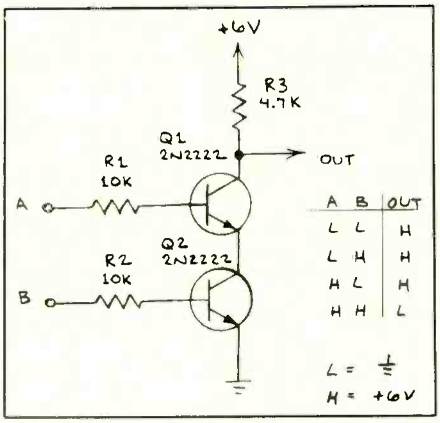
Of course, the rich diversity of reasonably priced integrated circuits available to electronic circuit designers and experimenters precludes the necessity of wiring together dozens or even hundreds of gates to accomplish a complex function. Nevertheless, it's easy to overlook the versatility of simple logic gates.

I was recently reminded about the importance of simple logic gates while writing *Engineer's Mini-Notebook: Digital Logic Circuits*, a new Radio Shack book that should be available shortly after this column appears. Though this book describes applications for only a handful of chips, it includes nearly 100 application and interface logic circuits, and dozens more could have been added had there been space.

To demonstrate the versatility of simple gates, this entire column is devoted to one of the most basic of gate packages, the 7400 quad NAND gate. With nothing more than some 7400s, a few resistors and LEDs, a few dozen jumper wires, and a solderless breadboard to plug everything into, dozens of different logic circuits can be assembled. Spending a few hours designing logic circuits composed of only NAND (or NOR) gates can provide a valuable review of the basics of digital logic for both beginners and experienced circuit designers. At the very least, the experience can provide a refreshing change of pace from the hyperactive world of advanced logic circuits like microprocessors, programmable logic arrays, and the like.

NAND Gate Basics

Figure 1 shows a NAND gate formed by ANDing (connecting in series) the collector-emitter conducting paths of two npn transistors. The circuit would form an AND gate if the output were taken from a load resistor connected from *Q2*'s emitter to ground. When the voltages applied to the input are at or near 6 volts (high) or at or near ground (low), the circuit will operate according to the truth table that accompanies Fig. 1.



A	B	OUT
L	L	H
L	H	H
H	L	H
H	H	L

Fig. 1. A 2-input NAND gate configured using two transistors.

Occasionally, it may be advantageous to assemble NAND and other gates from discrete components. Generally it's much more convenient to use standard integrated-circuit gate packages such as the 7400, whose pin outline is shown in Fig. 2. It is this gate package which is used for all the circuits that follow. Though the 7400 is a TTL chip, it's possible to use functional equivalents. The 74LS00, for example, is a direct substitute that uses only about a fifth the current of the standard TTL 7400. Even less current is consumed by the 74C00. However, since the 74C00 is a CMOS chip, special handling and operating requirements must be observed.

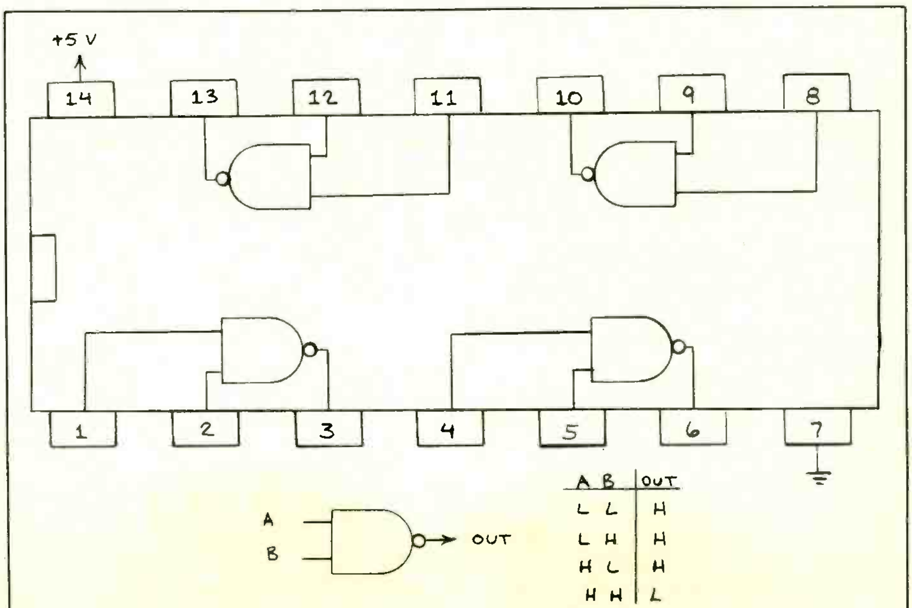
Figure 3 shows how four of the most basic logic functions can be achieved by interconnecting NAND gates. The key to assembly of these gates is the inverter, a function that can be achieved with a single transistor or by shorting together the inputs of a NAND gate.

TTL Logic Probes

Evaluating and troubleshooting logic circuits is greatly simplified with the help of a logic probe. Commercial logic probes are relatively inexpensive and usually include a pulse-trapping circuit for detecting and storing very brief pulses.

When a commercial logic probe isn't available or is in use elsewhere in a circuit, you can quickly assemble a pair of temporary probes from a single 7400 (or

Fig. 2. A 7400/74LS00 quad NAND gate.



A	B	OUT
L	L	H
L	H	H
H	L	H
H	H	L

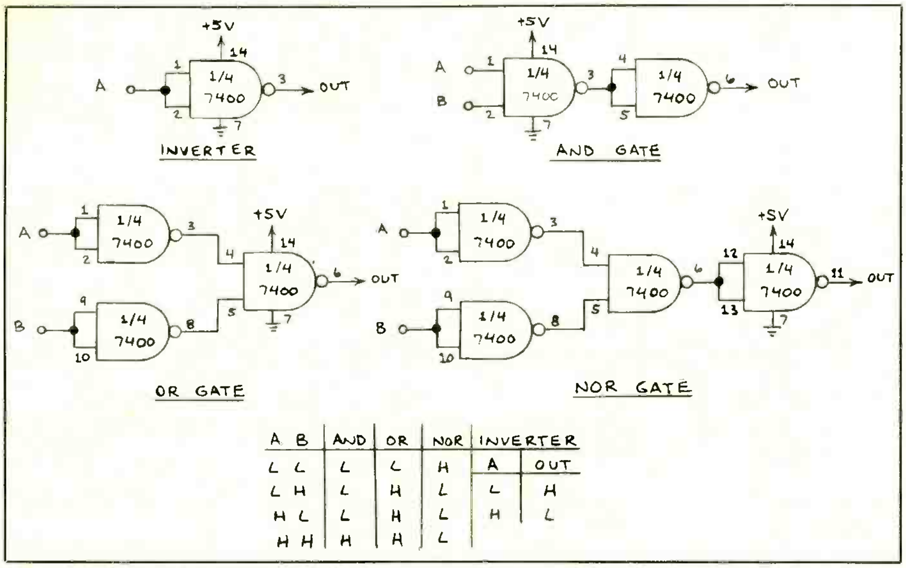


Fig. 3. Using NAND gates to assemble basic logic gates.

three probes from a 7404 hex inverter). Figure 4 shows two possible circuits, both of which use two inverters. The upper circuit displays the logic status at its input by means of a bicolor (red/green) LED. Once you learn to associate the two colors with their respective logic states, this single indicator circuit is very convenient to use. The lower circuit in Fig. 4 resembles conventional logic probes, since it uses a pair of separate LEDs to indicate the two logic states.

Incidentally, if you are building a fairly complex logic system, it's handy to have half dozen or more temporary logic probes like those in Fig. 4 ready to use at a moment's notice. I often dedicate a corner of a solderless breadboard or a spare breadboard for as many as a dozen temporary logic probes. They can be quickly connected to any part of the circuit for testing and be removed when they are no longer needed.

Combinational Logic with NAND Gates

Combinational logic circuits respond to incoming logic levels without regard to previous conditions. In other words, combinational logic includes no storage elements. The OR and NOR gates in Fig. 3 are examples of elementary combinational logic networks.

Figure 5 shows a rudimentary 4-bit decoder, a combinational network that can be easily modified to decode any combination of four bits. The output of the version in Fig. 5 remains high for all input combinations except one. When all four inputs are high, the output goes low. Therefore, this circuit decodes an HHHH input nibble. (A nibble is half an 8-bit byte.)

Figure 6 shows how the basic decoder in Fig. 5 can be expanded to decode other input nibbles. In Fig. 6, inverters have been inserted at the B and C inputs. Now the decoder ignores all but an HLLH input. For all other input combinations the output is high. For the HLLH nibble, the output is low.

No complicated procedures are required to custom-design any other 4-bit decoder. The object is for the output to go low in response to the appropriate nibble. We already know the output is low when all four inputs of the basic decoder in Fig. 5 are high. Therefore, all that's necessary to select a different input combination for decoding is to place an inverter at each low input. Therefore, as in Fig. 6, only the selected input nibble will supply an HHHH input to the basic decoder in Fig. 5. For example, to decode 0000, an inverter must be added to all four inputs to the basic decoder in Fig. 5.

Fig. 4. Simple TTL logic probes.

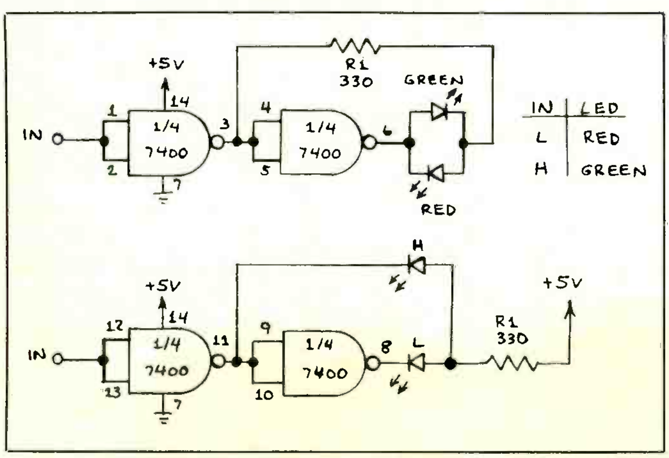
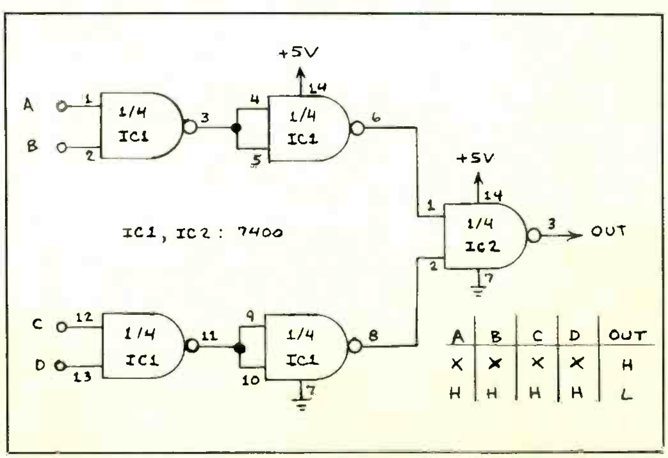
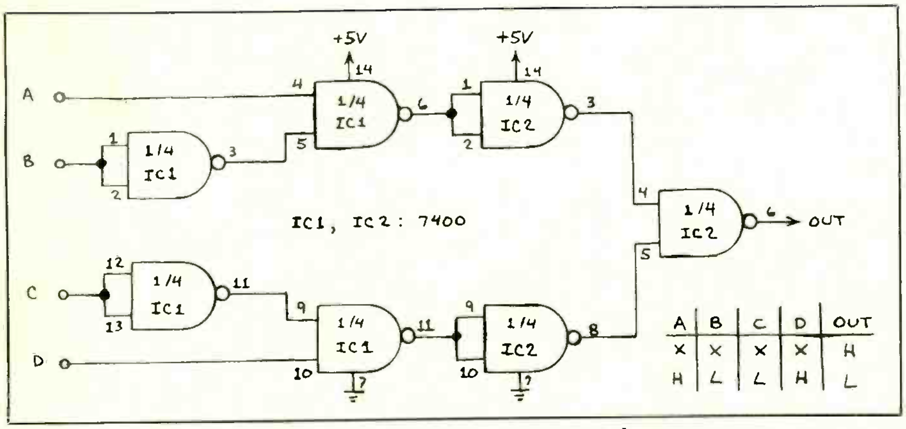


Fig. 5. A basic 4-bit decoder.





A	B	C	D	OUT
X	X	X	X	H
H	L	L	H	L

Fig. 6. A 4-bit decoder configured as a 1001 detector.

Now that you know how easy it is to design a simple 4-bit decoder, you will probably think of applications for these important logic tools. That's because decoders have an incredible variety of uses as stand-alone circuits. For example, the inputs to a decoder can be connected to various go/no-go sensors on an engine. If the predetermined combination of highs and lows from the sensors is not met, the decoder can actuate a warning light or shut off the engine. In combination with an input buffer, such as a shift register, a decoder can indicate the presence of a predetermined sequence of low and high pulses.

In a microprocessor, decoders can be used to respond to the bit patterns known as instructions. For instance, an 8-bit instruction word might be divided into two fields of 4 bits each. Each field is directed to a 4-line to 2-line decoder. Various patterns of bits in the two fields cause the decoders to enable and disable the control inputs of various registers and buffers tied to a common 3-state bus, thereby permitting the transfer of data in both directions through the bus.

Figure 7 shows how to assemble another important combinational circuit, a 2-input multiplexer or data selector, from nothing but NAND gates. Data selectors are the logical equivalent of mechanical rotary switches. The one in Fig. 7 is the equivalent of a 2-position switch. The address bit selects one of the two inputs and steers it to the single output.

Practical data selectors usually include four or more inputs and the required number of address lines. For example, a 16-line or 1-line data selector requires 4 address lines (four bits allows counting from 0000 to 1111 which is equivalent to 0 to 15, or 16 separate states).

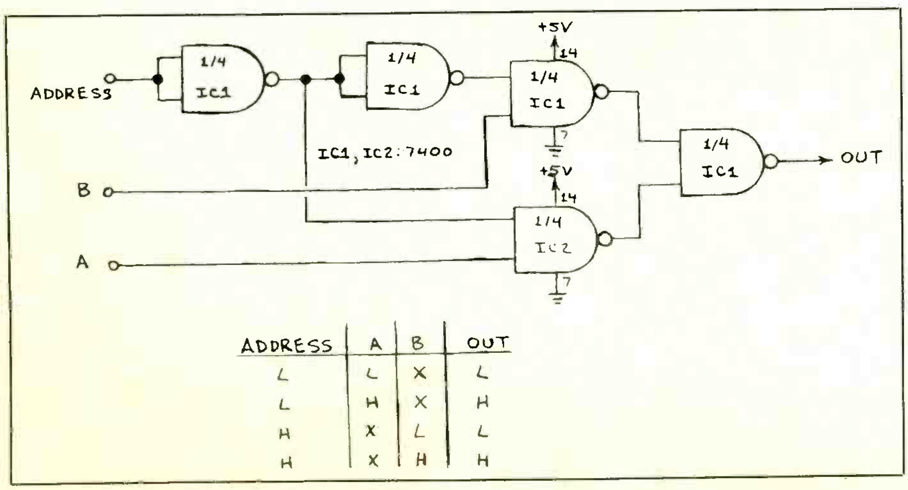
Data selectors can be used in standard combinational circuits or in sequential circuits in which the address bits are continually cycled by an external counter so that the input bits can be continuously sampled in sequence. A simple application for this operating mode is a bit-pattern generator. The pattern is designed by applying appropriate logic levels to the input lines. The speed of the counter determines the rate at which the bit pattern is cycled out the output. Another application is a parallel-to-serial converter. Here, a data word is applied to the inputs. The word is sent to the output bit by bit as the address inputs are incremented by a counter. The counter can also generate a control signal when all bits have been transmitted so that a new word can be entered at the inputs.

Figure 8 shows a 1-of-2 demultiplexer, the inverse of the data selector in Fig. 7. Here a single input bit is steered to the output port designated by the bit at the address input. An obvious use for the demultiplexer is to transform serial data back to its original parallel format.

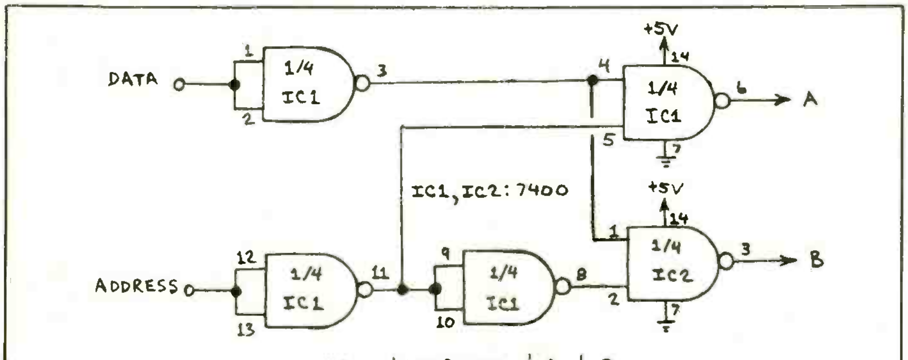
Consider, for example, a 2-bit communications link in which the output of the data selector/multiplexer in Fig. 7 is connected to the input of the demultiplexer in Fig. 8. A second line carries clock pulses to the address inputs of both circuits. The clock pulses simulate a 1-bit (0 . . . 1 . . . 0 . . . 1 . . .) counter. The bits at inputs A and B (Fig. 7) will be transmitted in serial fashion through a single line and reassembled into the original 2-bit pattern at the demultiplexer's output (Fig. 8). Rarely are only 2-bit patterns transmitted in this fashion. But the same principles can be applied to the transmission of much longer bit patterns.

Figure 9 shows an 8-input OR gate formed by a network of NAND gates. Only when all eight inputs are low is the output low. For all other input combinations the output is high. DeMorgan's theorem shows that a positive-logic (0 = L and 1 = H) OR gate is functionally

Fig. 7. A two-input data selector.

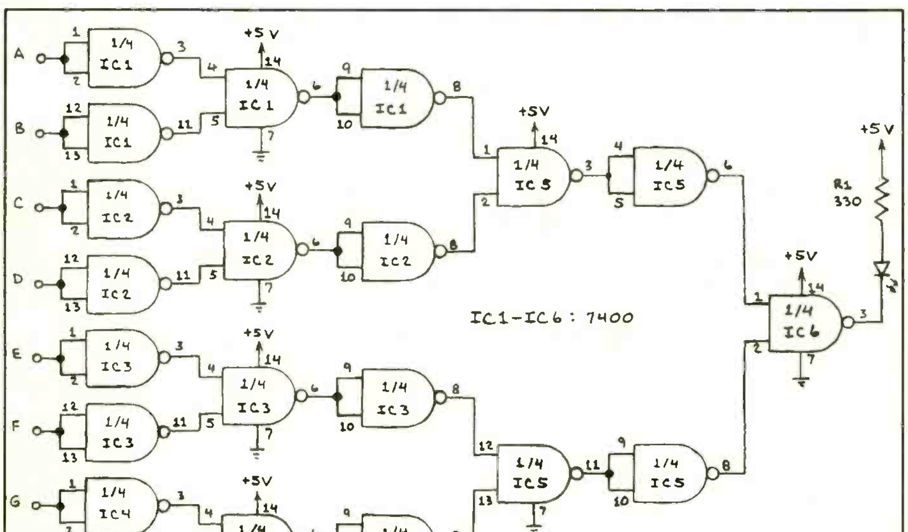


ADDRESS	A	B	OUT
L	L	X	L
L	H	X	H
H	X	L	L
H	X	H	H



DATA	ADDRESS	A	B
L	L	L	H
H	L	H	H
L	H	H	L
H	H	H	H

Fig. 8. A 1-of-2 demultiplexer.



A	B	C	D	E	F	G	H	OUT	LED
X	X	X	X	X	X	X	X	H	OFF
L	L	L	L	L	L	L	L	L	ON

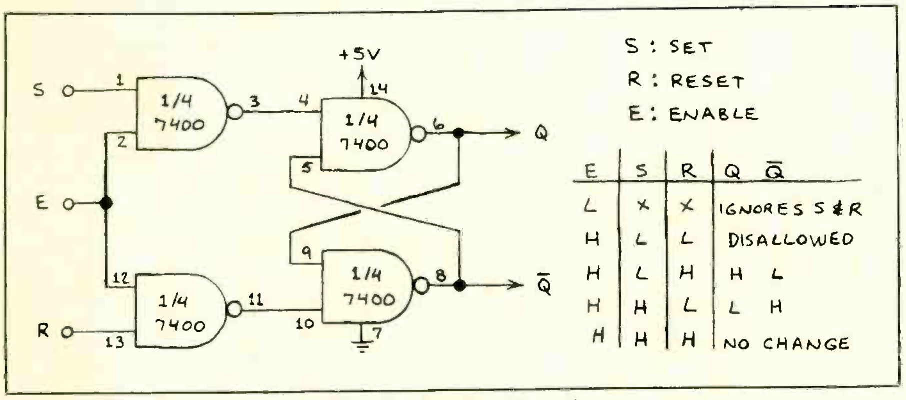
Fig. 9. An 8-input OR gate.

equivalent to a negative-logic (0 = H and 1 = L) AND gate. The circuit in Fig. 9 demonstrates this. Assume all eight inputs can be switched to +5 volts or ground by means of a row of toggle switches. If the switches are inverted (negative logic) so that their "on" positions indicate the eight gate inputs are connected to ground, then the circuit functions as an 8-input AND gate. Only when all eight input switches are "on" does the LED turn on. In this mode the circuit can be considered a unanimous vote detector.

Sequential Logic with NAND Gates

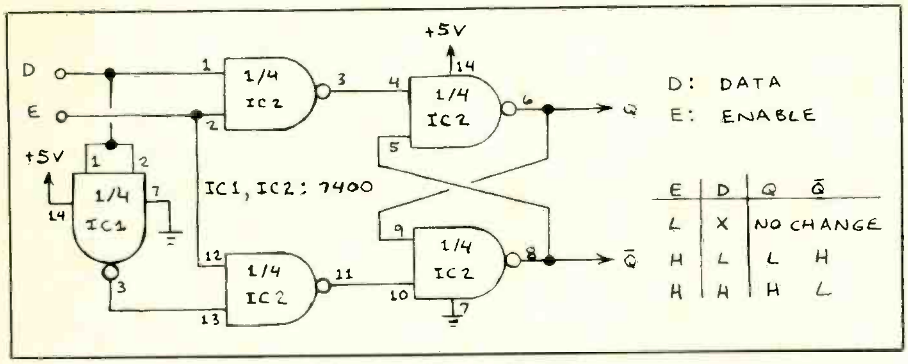
Sequential logic circuits are those in which the present state of an output is dependent on a previous operation. Generally, a clocking pulse is employed to trig-

ELECTRONICS NOTEBOOK . . .



E	S	R	Q $\bar{Q}$
L	X	X	IGNORES S & R
H	L	L	DISALLOWED
H	L	H	H L
H	H	L	L H
H	H	H	NO CHANGE

Fig. 10. A gated RS latch.



E	D	Q	$\bar{Q}$
L	X	NO CHANGE	
H	L	L	H
H	H	H	L

Fig. 11. A D-type flip-flop.

ger logic state changes in sequential circuits in a synchronized fashion.

Figure 10 shows a simple sequential circuit called an RS flip-flop or simply a latch. Note that this entire circuit can be made from a single 7400. The circuit ignores data at its S (set) and R (reset) inputs when the ENABLE input is low. When the ENABLE input is high, the latch responds as shown in the truth table. Latches can be used to store status bits. By extension, arrays of latches are used as memory registers.

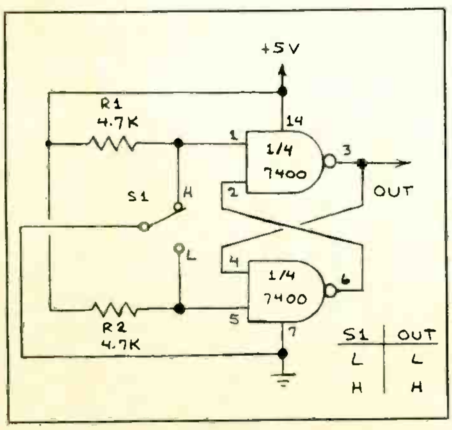
As shown in Fig. 11, a D-type flip-flop can be formed from only five NAND gates. As with the latch, the D-type flip-flop ignores the data at its D input when the ENABLE input is low. Otherwise, the Q output of the circuit follows (stays equivalent to) the bit at the D input.

Figure 12 shows a circuit that is indispensible when designing and testing sequential logic circuits. It's a switch debouncer formed by cross-coupling the outputs with one of the inputs of a pair of NAND gates. The logic state of the single output follows the position of *S1*. The significance of the circuit is that it ignores the mechanical "bouncing" and consequent multiple output pulses that occur during closing and opening a switch. Instead, the circuit switches states on the arrival of only the first pulses in a series of bounced pulses, thereby ignoring subsequent bounces.

Bounceless switch circuits are handy for single-stepping a sequential logic circuit through its paces and observing what happens. Often, the only practical alternative is to slow the clock down to a few cycles a second and follow the action with logic probe(s), but sometimes that's not practical or possible.

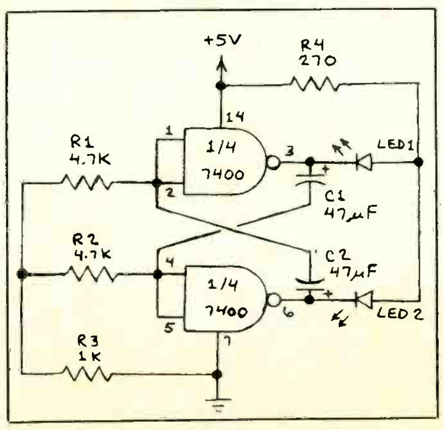
Finally, Fig. 13 shows how to form a self-switching circuit by cross-coupling the inputs and outputs of a pair of inverters. With the values shown for *C1* and *C2*, the LEDs will flash on and off about twice each second. The value of capacitors *C1* and *C2* can be increased to slow down the flash rate. The circuit can also be used as a logic clock.

Fig. 12. A two-gate switch debouncer.



S1	OUT
L	L
H	H

Fig. 13. Two-gate LED alternate flasher.



Going Further

The circuits presented here illustrate the role of the NAND gate as a fundamental digital logic building block. The NOR gate can also be used to accomplish these same functions. If you want to brush up on digital logic fundamentals, review the opening chapters in Don Lancaster's *TTL Cookbook* and *CMOS Cookbook*. Don's discussion of data-selector logic in these two classics is particularly good.

If you want to experiment with CMOS versions of the circuits presented here and others as well, see Radio Shack's *Engineer's Mini-Notebook: Digital Logic Circuits*. This book also includes numerous input, output and interfacing circuits for both the TTL and CMOS logic families of devices. **ME**

BOOKS

The Linear IC Handbook by M.S. Morley. (Tab Books Inc. 616 pages. $48.50.)

This encyclopedic volume, offered by Tab's Professional and Reference Books division, is both a tutorial textbook and technical data manual on linear IC technology. A one-stop reference, it can help engineers, technicians and hobbyists to select, specify and use all kinds of linear ICs for any possible application. Each type of linear component is assigned its own chapter in which theory of operation and device specifications are exhaustively covered. These discussions are supported by healthy servings of schematics, block and timing diagrams and formulas. Furthermore, each device chapter closes with one or more tables of available devices, along with their major technical specifications.

Much more exhaustive tables of specifications, arranged by manufacturer, are given in the appendices that are title keyed to the device chapters. These appendices by themselves can serve the more knowledgeable user as a selection guide to the various linear ICs currently on the market.

Though this is a rather expensive book, its cost is far outweighed by its value as both a tutorial textbook and reference work.

Solid-State Relay Handbook with Applications by Anthony Bishop. (Howard W. Sams & Co. Soft cover. 224 pages. $19.95.)

Though solid-state relays (SSRs) have become increasingly more important during the past 20 years, little has been written about these devices. This book corrects this. To set the stage, the book begins with a tutorial on what SSRs are and why they are used in various industrial applications.

Written by an expert in the field, the text provides the engineer, technician and hobbyist with much of the information he needs to implement SSRs in his circuit designs. Through extensive use of schematic diagrams, graphs and tables, the author guides the reader through the basics of device design and application in real circuits. In addition to describing the various coupling and drive methods commonly employed, the author stresses the importance of working within device parameters. Much emphasis is placed on applications of SSRs in microprocessor-based equipment for industrial machine control, which is the major application for these devices.

This book is both lucidly written and comprehensive in its coverage. With regard to the latter, it even includes a director of SSR manufacturers and suppliers.

Telecommunications and Data Communication System Design with Troubleshooting by Harold B. Killen (Prentice-Hall. Hard cover. 300 pages. $37.95.)

A fairly rigorous mathematical introduction to the design and testing of communication systems is presented in this college-level book. It uses a textbook approach and end-of-chapter review questions to competently guide the reader through basic analog and digital telecommunications, data communication systems and techniques, and protocols and networks. Beginning with modulation coding and working up to data communication satellite links and local area networks, the book is well written and fully supported with informative illustrations. The mathematics used gets into elementary calculus. In keeping with the current trend, heavy emphasis is placed on communication media using computers. For example, three computer interface standards are detailed: IBM, Apple, and IEEE-488, as well as various modern formats from RS-232C to RS-423.

Almost as important as the theory covered, the author includes a chapter on analog and digital communication system testing. Test techniques for examining transmission modes, I/O terminals, levels I and II protocols and troubleshooting in general are discussed here. As is common with more formal textbooks, however, the presentation is rather weak in this area.

Anyone interested in the technology of modern telecommunications should give this book serious consideration.

NEW LITERATURE

Electrical Troubleshooting Brochure. A 16-page color brochure from Fluke describes a wide variety of troubleshooting and repair procedures for electrical systems using digital multimeters. It explains procedures for general electrical measurements and specific techniques for troubleshooting motors and circuit components. An application chart shows what DMM features are most useful for performing different types of measurements. For a free copy of the "Electrical Troubleshooting With Fluke Multimeters," write to: John Fluke Mfg. Co., Inc., P.O. Box C9090, Dept. ME, Everett, WA 98206.

Kits & Products Catalog. The latest edition of the popular Heathkit catalog covers a wide range of kit and assembled consumer and hobby items, ranging from audio and video, communications, home security, automotive and marine products to test instruments, computers and educational materials. New products are included in almost every area, such as a wireless microphone, digital carpenter's level, VHS-C Video Movie camcorder, Loran receiver, removable-disk Winchester drive, etc. For a free copy, write to: Heath Co., Dept. ME, St. Joseph, MI 49085.

BASIC Tutorial. A booklet that teaches programming in BASIC, titled "Learning BASIC with Voice Master," is available from Covox. Designed for use with the company's Voice Master vocal device and a Commodore 64 (or 128 in the C-64 mode), the tutorial program allows the user to record and play back digitized speech and make templates. lesson examples include a talking keyboard, adding machine and cash register; listening and talking adding machine and language translator; receiving advisories relating to outside events by voice; and more. For a free copy, write to: Covox, Inc., 675-D Conger St., Eugene, OR 97402.

RFI Technical Note. Palomar Engineers' "Using Ferrite Beads to Keep RF Out of TV Sets, VCR's, Burglar Alarms and Other Electronic Equipment" technical note explains what kinds of ferrite beads and toroids to use and where to put them to suppress most common r-f interference. The 2-page note is available free by writing to: Palomar Engineers, Box 455, Escondido, CA 92025.

Electronic Clinometers; Low-Frequency Communications; Fundamentals of A/D Converters . . .

By Don Lancaster

There sure has been a lot of interest in our "neuron" A/D converter from the July 86 *Modern Electronics*. Several comments on all this. First, be sure you are using "buffered" CMOS inverters that consist of three cascaded stages. The unbuffered types just do not have enough gain for sharp switching.

Secondly, many of you seem to want to build a video A/D converter using our simple low-frequency "neuron" circuit. Simply put, the circuit will probably glitch too badly, and will respond too slowly for high-speed video use. I'll try to have more on high-speed A/D converters in a future column.

Thirdly, the resistor values are not nearly as sneaky as they seem. The resistors at the input to any gate form a simple voltage divider. They are adjusted so that a "yes" output occurs for any voltage even slightly under 2.5 volts, while a "no" output occurs for any voltage even slightly over 2.5 volts.

Note that the feedback resistors are always connected either to +5 volts or ground, while the input summing resistor goes from 1 volt (a logical "15") to 4 volts (a logical "0"). Note also that the CMOS inverter itself draws no input current.

We sure are getting lots of response on this. Most of the responses are really well thought out.

Onward and upward . . . .

What makes A/D conversion so messy?

Analog to Digital (A/D) converters are used to change varying voltages or currents into digital logic levels. Important uses of A/D converters include computer game paddles, digital voltmeters, industrial process controls, robotics, video processing, military radar, and digital audio, to name a few.

Some A/D converters are very simple, while others are insanely complex. What causes the big difference?

There are two important things used to spec an A/D converter. One is the resolution, or the number of output bits that will result. A 6-bit A/D converter can resolve only one level in 64, but might be well suited for video uses. An 8-bit version easily interfaces a personal computer, but allows only 256 input levels.

Industrial 10- and 12-bit converters allow 1,024 and 4,096, respectively, levels at added cost. Digital audio needs 14-to-16-bit converters that can handle from 16,384 to 65,536 levels.

Finally, an A/D converter used in a 5½ decade digital voltmeter has to resolve better than one part in 200,000, the binary equivalent of 18 bits.

The second important spec is conversion time. A few conversions per second is all that is needed for a digital voltmeter or tachometer, because anything faster will only blur the display. A millisecond or so is available for personal computer game inputs. An industrial process control or digital audio needs conversion rates in the tens to hundreds of microseconds. Video requires conversion rates of 10 megahertz and higher, while military radar might need 0.5-gigahertz conversion speeds. The higher the resolution or the higher the speed, the greater the cost of the A/D conversion scheme that must be used.

To further complicate things, most real-world A/D converters require four very important accessories. These are an input sample-and-hold, an antialiasing filter, very careful guarding, and an output latch.

If the input is allowed to change during the conversion process, you will get a wrong answer. This means that any higher-resolution A/D converter can accept only ridiculously low input frequencies if it does not have an input sample-and-hold. For instance, a 16 bit A/D converter with a 16 microsecond conversion time can only accurately accept a few hundred Hertz as its maximum input frequency without a sample-and-hold.

Sample-and-hold works by "catching" the input signal and keeping that sample at a constant value during the conversion process. This will dramatically up the maximum permissible conversion rate. You can build a most useful sample-and-hold out of a CMOS 4066 analog switch, an output capacitor, and a decent op amp.

But when you add a sample-and-hold, a new problem results. If you input any frequencies that are anything above one-half the sample rate, you will create all sorts of erroneous artifacts that will totally mask the signal being converted.

These artifacts are called "aliases." To get rid of aliases, you use an antialiasing filter. This is a sharp cutoff low-pass filter that is set to one-half the sampling rate or lower.

Guarding is the process of making sure that no digital output noise gets back on the input lines. This is usually handled by careful circuit layout with separate grounds for the analog inputs and the digital outputs.

As an example, a 16-bit A/D converter with a 0-to-5-volt analog input can resolve one part in 65,536, giving you a resolution of 5/65,536 volts or 76 *microvolts* of input sensitivity.

It is not at all unusual for a digital logic system to generate 300,000 microvolts (0.3 volt) of ground noise. Let so much as a tiny whiff of this show up at the input, and you lose all of the resolution you set out to achieve.

Other tricks can be used for noise reduction. In a digital voltmeter, conversion time is often made an exact multiple of the power line period. This will cancel out any hum that is present, since any ac waveform will always average itself to zero over its period.

Turning to the output side, wildly wrong answers may appear during the conversion process. This is particularly sticky with video, since a glitch or two will totally smear the works, besides ruining your entire day.

An output latch can often be nothing but some flip-flops, but even here you can get into trouble. You must be absolutely sure your computer or whatever accepts the input only during valid data times. At high speeds, even the difference between the "turn-on" and "turn-off" times of the latch can become very important.

There are a wide variety of A/D conversion schemes in use that differ greatly in their resolution and speed tradeoffs.

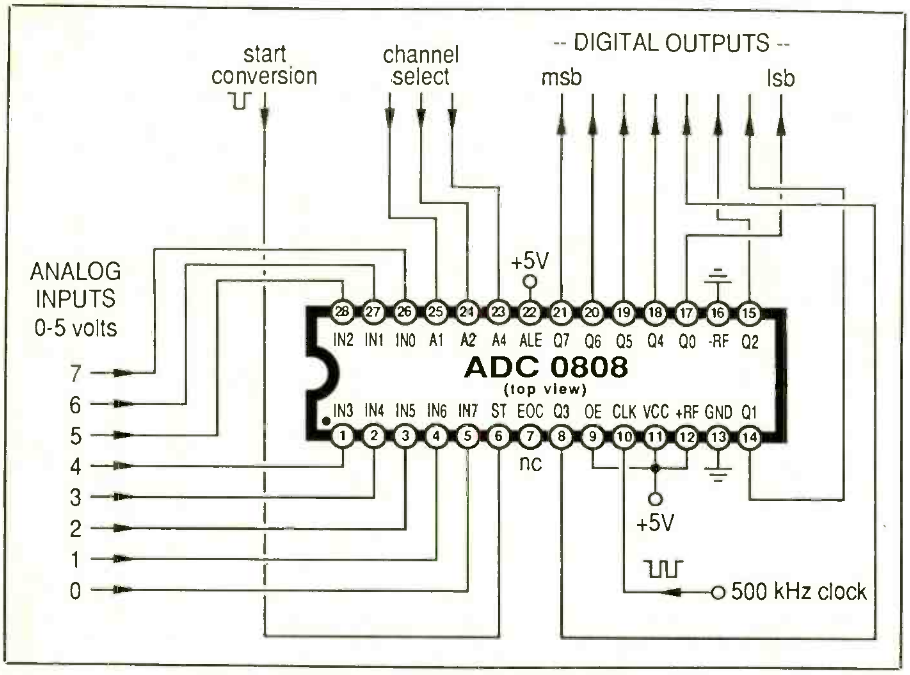


Fig. 1. A medium-speed, 8-channel A/D converter.

These include simple voltage-to-frequency converters used for game paddles, dual-slope integrators intended for digital voltmeters, brute-force circuits used for video and radar, our own "neuron like" experimental converter, older industrial successive approximation converters and their new feedforward converter replacements that are a little slower than brute force circuits but are also quite a bit simpler.

We'll try to have examples of all these different converter types from time to time. More details on many of them appear in my *Micro Cookbook*, Volume II.

Show me a typical A/D converter circuit

Figure 1 shows a great little successive-approximation converter that interfaces beautifully with most microcomputers. This jewel has eight selectable input channels of 0 to 5 volts each and provides an 8-bit output resolution of 1 part in 256. Cost is around $9. This is a *National* part. You can find variations and improvements on this device from both National and *Analog Devices*.

To use it, you first output three bits worth of binary "channel selection" from your computer. Then you output a "start conversion" command, wait for a millisecond or more, and then read your input port. It's that fast and that simple.

How can I get involved in low-frequency communications?

Low frequency, or lf, communications involve radio waves that are lower in frequency than those used on the AM broadcast band, ranging from 30 to 500 kHz. Very low frequency, or vlf, communications are lower still, being under 30 kHz. Important uses of these bands include time standards such as WWVB, navigation aides, submarine communications, cave mapping and communications, beacons, signaling devices, and other unique services.

As we saw last month, there is a great quarterly underground technical publication out named *Speleonics* that covers a lot of this sort of stuff. At $4 per year, Speleonics is a real bargain.

But the "mother lode" of general lf and vlf information seems to be a group called the Longwave Club of America. You may want to check out these people. Their publication is called *The Lowdown*, and costs $10 per year. They also have lots of reference materials available.

One unique vlf device that recently caught my attention was a cave-mapping transmitter. It consists of a loop antenna, a transmitter, and a level, all built into an all-plastic BMX bicycle wheel.

The transmitted frequency is 3,580 Hz. This frequency is a magic number that (1) is low enough to go through lots of rock, (2) is a stock TV crystal frequency divided by 1,000 and (3) is far enough away from both 50- and 60-Hz harmonics that it can be used here or in Canada without any worries about power-line interference. The 3580-Hz is pulse modulated at a 3.58 Hz-rate, which is obtained with another division by 1,000.

Such a device could be used either for mapping or rescue. Either way, the transmitter is hauled somewhere inside a cave, turned on and very carefully leveled. A somewhat similar receiver is then used on the surface to pinpoint the location of the underground transmitter. The exact location and depth can easily be found. The null point at which the signal drops to zero for a level receiver will be directly over the transmitting loop.

A loop antenna has a very precise and mathematically defined field. By moving the receiver around in circles and measuring the null tilt angle, the depth of the transmitter can be found. To do this accurately, the transmitter must be perfectly level.

Some hairy math is involved in the depth calculation. This is easily handled by a BASIC program, run on most any personal computer.

For some strange reason, the calculated depth always ends up a few percent lower than the actual depth. A suitable fudge factor is then used to predict the read depth.

Which way is up?

Electronic level sensors have lots of interesting uses. These have traditionally included aircraft instruments, construction levels, robotics, and percent-of-grade indicators for road machinery.

Thanks to some recent developments,

low-cost electronic levels are now becoming available and will open up all sorts of new uses. For instance, table saws can now automatically indicate the depth of cut versus table angle, a calculation that is otherwise far from trivial. Better yet, the latest electronic level scheme is easily done as a simple yet challenging hacker project. With some ingenuity, you should be able to build an electronic level for well under $4.00.

Let's review.

The correct name for an electronic level is a "clinometer." As Fig. 2 shows, you can build a simple clinometer out of a plumb bob, a string, and a protractor. The plumb bob points straight down, and the angle you read tells you the slope of the top of the protractor.

You could use a bubble level instead of a plumb bob. This is how the clinometer on a Brunton compass works. You slide the level arm until the bubble is centered and then read the inclination off a dial.

Electronic levels must instead provide some sort of analog or digital output. You can "electrify" either of these simple clinometers, but you are likely to get into resolution and "stiction" problems.

Some precision aircraft clinometers use a device called a "linear differential transformer" to sense the small angular changes needed for high accuracy. The cost of these is horrendous.

Figure 3 shows another older approach to electronic level sensing. It is called an "electrolytic gravity sensor" and looks suspiciously like a bubble level with three terminals on it. A mildly conductive liquid (often bromine) partially fills the sensor. When level, the same amount of bromine will be in contact with both outside electrodes. The outside-to-center resistance, therefore, will be the same at both ends.

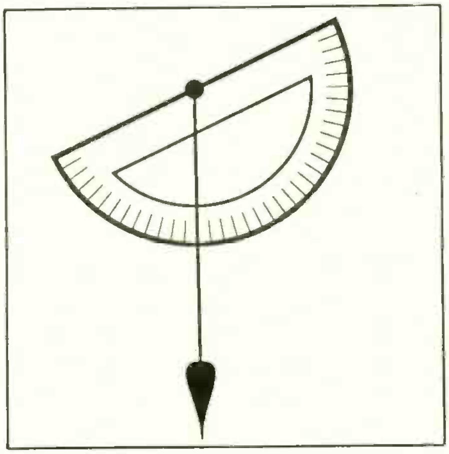


Fig. 2. A mechanical clinometer.

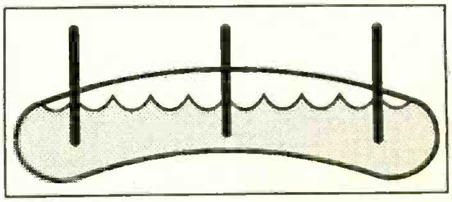


Fig. 3. An electrolytic level.

As the sensor tilts, the bromine moves down to the low end, increasing the high-end resistance and decreasing the low-end resistance. A simple bridge circuit can then give an analog output.

Hamlin is one source of these. Last time I checked, these beasties ran around $30 each. Besides the high cost, they are fragile, slosh sensitive, and have a strong "wrong axis" cross-sensitivity.

The latest, and potentially the cheapest, type of clinometer is the capacitance level sensor of Fig. 4. What you have here is a very thin metal tank that houses a liquid and two capacitor plates. The liquid should be an insulator with a high dielectric constant. Propylene glycol (antifreeze) with its dielectric constant of 30

NAMES AND NUMBERS

Analog Devices
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(617) 329-4700

Hamlin Incorporated
612 E. Lake Street
Lake Mills, WI 53551
(414) 648-5244

National Semiconductor
2900 Semiconductor Drive
Santa Clara, CA 95051
(408) 721-5000

Longwave Club
45 Wildflower Road
Levittown, PA 19057

Speleonics
Box 5283
Bloomington, IN 47402
(812) 335-7305

Sperry Sensing Systems
Box 21111
Phoenix, AZ 85036
(800) 545-3243

comes to mind as one possibility, although mineral oil with a constant of 3 is probably much better behaved.

At any rate, the portion of the sensor plate that is covered by the liquid will have a much higher capacitance than the part that is not. As the sensor rotates, capacitance to the case of one plate increases, while the other one decreases. The particular shape shown gives a linear sensor output over a $\pm 60°$ range.

The plates are routed to a pair of 555 timers. The difference in time delay created by the liquid coverage is then easily converted into an analog or a digital output.

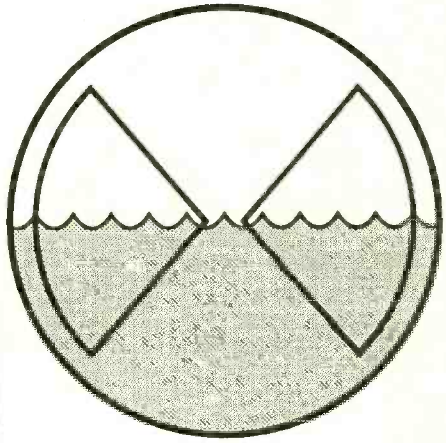

Fig. 4. A capacitive clinometer.

Cross-axis sensitivity is nearly eliminated by putting two sensors back to back in the same case. As you tilt the sensor in the "wrong" direction (towards or away from you), the liquid on one side creeps up on its sensor, while the liquid on the other creeps down. The two will thus nicely cancel out.

The Accustar Electronic Clinometer by *Sperry* is one example of this new technology. Being aerospace people, their $100 single-quantity pricing is totally out of line for something like $4 worth of low-tech parts that anyone could throw together on a kitchen table.

Nonetheless, their data sheet and application notes make very good reading on this new clinometer. More technical info on the capacitance level sensors appeared in the June 16, 1986 issue of *Design News*.

It seems that this product could be dramatically "value engineered," putting the plate sensors on the same circuit board as the rest of the electronics, and using metalized plastic cups for the tanks. There's no reason an outfit in a Hong Kong alley couldn't knock these out for under $2.00 each.

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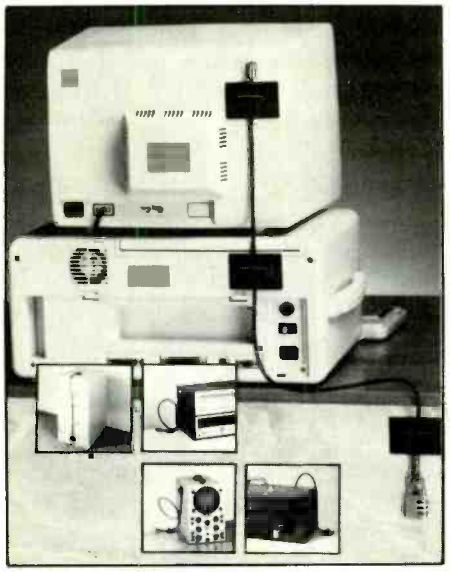
secures plates to equipment to be protected and the shelf, desk, etc. on which it is to remain. A tough, flexible vinyl-coated steel cable is then threaded through the plates and terminated with the lock that comes with the system.



Installation can be in an out-of-sight location at the rear of the item being protected. More than one item can be protected by a single cable and lock, such as a stacked system unit and video monitor in a computer system. The adhesive used to bond the plates to the equipment is claimed to be very strong, requiring up to 400 lbs. of force to break the bond. $24.95; expansion kits available.

CIRCLE 52 ON FREE INFORMATION CARD

Parental Control TV Lockout Device

Cable TV subscribers can now exercise control over their childrens' TV viewing options with a new Parental Control device from Pico Products,

Inc. When installed between the cable output jack and the input of the cable TV converter, the small black-box device's internal trap eliminates both the audio and the video signals on desired channels with the turn of a key. Two keys are supplied for locking out single, dual or tiers of channels to give adults the ability to exercise "parental guidance."

Snap-on security shields that fit over cable connections prevent unauthorized bypassing of the Parental Control Lock. The device works on cable channels 2 through 6, A through C, D through F, G through I, 7 through 13 and J through W. It features easy user installation and a high-impact, tamper-proof case.

CIRCLE 53 ON FREE INFORMATION CARD

The Antenna Noise Bridge: A Forgotten Tool

By Joseph J. Carr

Modern radio receiver design is especially exciting to an old radio hacker like myself. Having cut my teeth on a Knightkit regenerative SW radio and an elderly Hallicrafters S-20R, and then graduating to the might SX-28A (with a WW II surplus BC-342 along with way), I find modern designs extremely exciting. We can now buy performance that matches the top-dollar Collins 51J4 and R-390 models of yesteryear for about the same price as medium-grade receivers cost a generation ago. While the newcomer who is trying to raise $500 for a receiver might not believe it, that translates to a tremendous price deflation.

In the "good old days" we used non-resonant long-wire antennas. Given receiver performance of the day, there was little incentive to upgrade to single-band resonant antennas. When we wanted to improve performance we added preselectors and other electronic gimmicks but left the antennas alone.Today, receiver performance is usually so good that we now look to the antenna to effect further improvement.

The Forgotten Instrument

Because shortwave listeners can not legally use a transmitter to test antennas, using the VSWR meter as a check of antenna performance is out. However, the SWL can use an antenna noise bridge for a variety of measurements on r-f circuits. The noise bridge is perhaps the most overlooked test instrument that a hobbyist—and especially the SWL—can own.

Over the years several companies have produced noise bridges, mostly for the amateur radio market—among them—Omega-T, Palomar Engineers and others. More recently, the Heath Company has introduced the Model HD-1422 (Fig. 1). Over the years I have used noise bridges for a variety of radio tests and measurements, especially in the hf region. Contrary to popular belief, those applications are not limited to the testing of antennas, which is the main job of the noise bridge.

A noise bridge can be used to measure impedance in r-f circuits at frequencies

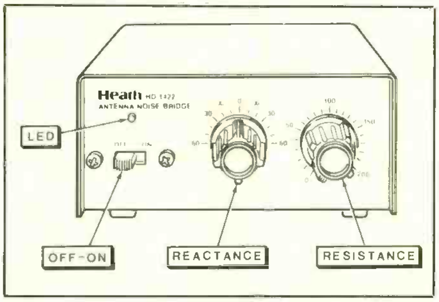


Fig. 1. Heath's HD-1422 noise bridge.

up to 30 MHz and will give relative indications up to 100 MHz. Impedance consists of resistive and reactive components; the reactance can be either capacitive or inductive, but is zero for a perfectly resonant circuit or antenna. A good noise bridge will measure reactive components as well as resistive.

Figure 2 shows the internal details of the HD-1422. Note that the bridge circuit consists of four arms. The inductive arms form a "trifilar" wound transformer over a ferrite core with the input winding of *T101*. A signal applied to the input is injected into the bridge circuit. The "Measurement" arm consists of series circuit *R1/C1*, a 200-ohm potentiometer and a 120-pF variable capacitor. The potentiometer is used to set the range of the resistive component (0 to 200 ohms) of impedance, the capacitor the reactance component.

Capacitor *C2* in the UNKNOWN arm of the bridge is used to balance *C1*. With *C2* in the circuit, the bridge is balanced when *C1* is approximately in the center of its range. This arrangement accommodates both inductive and capacitive reactances, which appear on either side of the "zero" point, which is the mid-range capacitance of *C1*. When the bridge is in balance, the R and C settings reveal the impedance across the UNKNOWN terminals (e.g. your antenna).

Zener diodes normally operate in the reverse-bias mode, which produces a large amount of noise because of the avalanche process inherent in the zenering operation. While that noise is a problem in most applications, in a noise bridge it is highly desirable, and the richer the noise spectrum, the better. The spectrum is enhanced somewhat in the HD-1422 because of the 1-kHz square-wave modulator that chops the noise signal. An amplifier boosts the noise signal to the level needed in the bridge circuit.

The detector used in the noise bridge is your hf receiver. An AM receiver is preferable, but an SSB receiver with a wide i-f bandwidth is also useful. Although it is quite easy to use your ears to detect the noise null that indicates bridge balance, it is best to use a receiver with an S meter. Thus, the best receiver to use is an AM hf model that is equipped with an S meter. If your antenna lacks an S meter, you can use an old-fashioned (analog) ac voltmeter across the receiver's speaker output. Since antennas are not always convenient to ac power, you might consider adding "battery-powered" to the list of attributes required of the receiver.

Adjusting Antennas

Perhaps the most common use for the antenna noise bridge is finding the impedance and resonant points of an hf antenna. To make this measurement, connect the RECEIVER terminal of the HD-1422 to

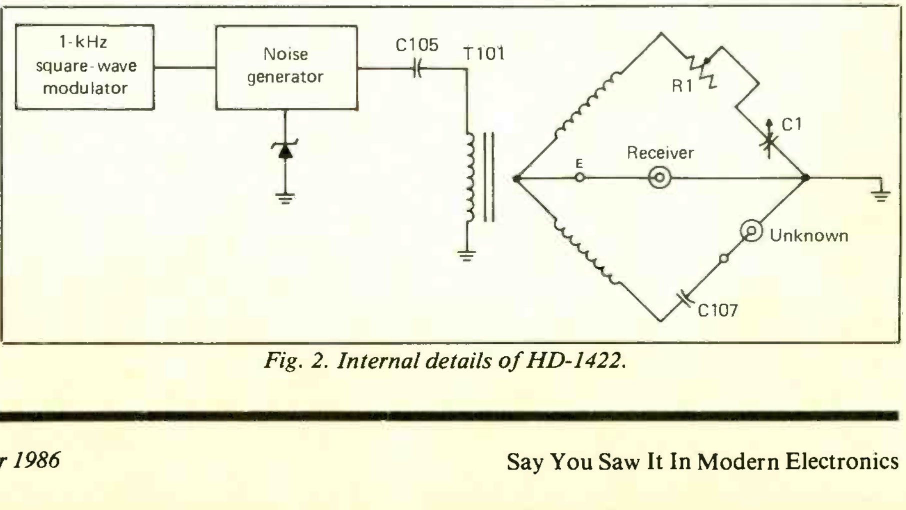


Fig. 2. Internal details of HD-1422.

the ANTENNA input of the hf receiver through a short length of coaxial cable as shown in Fig. 3.

The Coax length should be as short as possible, and the characteristic impedance should match that of the antenna feedline. Next, connect the antenna's coaxial feedline to the ANTENNA terminals on the HD-1422. You are now ready to test the antenna.

Finding Impedance. Set the noise bridge's RESISTANCE control to the antenna feedline impedance (usually 50 or 75 ohms for most amateur antennas) and the REACTANCE control to mid-range (zero). Now tune the receiver to the *expected* resonant frequency (F_{exp}) of the antenna. Turn on the noise bridge and look for a noise signal of about S9 on the S meter. This will vary on different receivers.

Adjust the RESISTANCE control (R) on the bridge for a null (minimum noise as indicated by the S meter). Next, adjust the REACTANCE control (C) for a null. Repeat these adjustments until you obtain the deepest possible null, as indicated by the lowest noise output on the S meter. Because there is some interaction between the two controls, it is important that you trim both repeatedly until no lower reading can be obtained.

A perfectly resonant antenna will have a reactance reading of zero ohm and a resistance of 50 to 75 ohms. Real antennas may have some reactance (the less the better), and a resistance different from the ideal 50 or 75 ohms. Impedance-matching methods can be used to transform the actual resistive component to the 50- or 75-ohm characteristic impedance of the transmission line. If the resistance is close to zero, there is most likely a short circuit on the transmission line. Conversely, if the resistance is close to 200 ohms, the line most likely has an open circuit.

A reactance reading on the X_L side of zero indicates that the antenna is too long, while a reading on the X_C side of zero indicates an antenna that is too short. An antenna that is too long or too short should be adjusted to the correct length to obtain optimum performance.

To determine the correct length, you must find the Actual Resonant Frequency, or A.R.F. To do this, reset the REACTANCE control to zero, and then *slowly* tune the receiver in the proper direction—downband for too-long and upband for too-short—until the null is found. On a high-Q antenna the null is easy to miss if you tune too fast. Don't be surprised if the null is out-of-band by quite a bit. The percentage of change is given by dividing the expected resonant frequency (F_{exp}) by the A.R.F. and multiply by 100: Change = (F_{exp} × 100%)/A.R.F.

Resonant Frequency. Connect the antenna, noise bridge and the receiver in the same manner as above. Set the receiver to

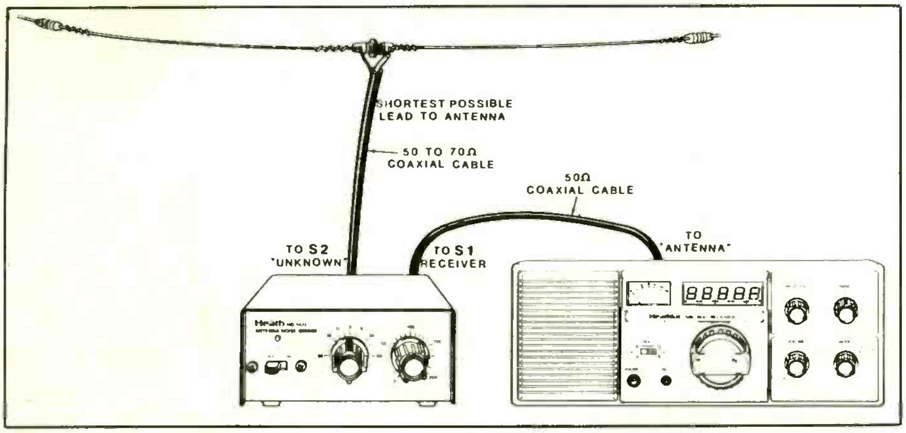


Fig. 3. Finding the impedance and resonance points of an hf antenna with a noise bridge is accomplished with setup shown.

the expected resonant frequency—468/F for half-wavelength types and 234/F for quarter-wavelength types. Set the RESISTANCE control to 50 or 75 ohms, as appropriate for normal antenna and transmission-line impedance. Set the REACTANCE control to zero. Turn on the bridge and listen for the noise signal.

Slowly rock the REACTANCE control back and forth to determine on which side of zero the null appears. Once the direction of null is determined, set the REACTANCE control to zero, and then tune the receiver towards the null direction, which is down-band if null is on the X_L-side and up-band if it is on the X_C side.

A less-than-ideal antenna will not have an exact 50- or 75-ohm impedance. So some adjustment of the R and C controls must be made to find the deepest null. You may be surprised at how far off some dipoles and othe types of antennas can be if they are not in "free space" (close to the Earth's surface).

Nonresonant Antenna Adjustment

Antennas can operate on frequencies other than their resonant frequency if you know its impedance (R and X components) and provide a matching network to provide impedance transformation. After setting up the receiver and noise bridge as in the first case above, tune the receiver to the desired operating frequency. Find the nulls for R and X, and note the scale readings. The X readings are not the reactance in ohms, but rather the capacitance (0 to 60 pF). You can now calculate the normalized reactance at 1 MHz as follows: $X_C = X = [159{,}155/(68 - C)] - 2340$ and $X_C = X = 2340 - [159{,}155/(68 + C)]$. Then plug the X value into $X_F = X/F$, where F is the desired frequency in MHz.

Other Jobs

The Heath HD-1422 noise bridge can be used for a variety of jobs, such as finding the values of capacitors and inductors, characteristics of series and parallel tuned resonant circuits, and adjusting transmission lines.

Transmission Line Length. Some antennas require antenna feedlines that are either quarter- or half-wavelength at some specific frequency. Use the HD-1422 to find these lengths as follows:

(1.) Connect a short-circuit across the UNKNOWN terminals of the HD-1422 and adjust R and X for the best null at the frequency of interest (both will be near zero);

(2.) Remove the short-circuit;

(3.) Connect the length of transmission line to the UNKNOWN terminal—it should be longer than the expected length;

(4.) For quarter-wavelength lines, shorten the line until the null is very close to the desired frequency. For half-wavelength lines do the same thing, except shorten the line at the far end for each trial length.

Transmisssion Line Velocity Factor. The velocity factor (usually expressed by the letter "V") is a decimal fraction that tells how fast the radio wave propagates along the line relative to the velocity of light in free space. For example, coaxial cable with a foam dielectric has a velocity factor of 0.80, which means that radio signals travel along the line at 0.8 times the velocity of light.

Since all radio wavelength formulas are based on the velocity of light, you need the V value to calcute the physical length needed to equal any given electrical length. For example, a half-wavelength piece of coax has a physical length of $(492 \times V)/F_{MHz}$ feet. Unfortunately, the real V value is often quite different from the published value. You can use the HD-1422 to find the actual value of V for any given sample of coaxial cable as follows:

(1.) Select a convenient length of the coax more than 12 feet in length and install a PL-259 coaxial connector on one end and short-circuit the other end.

(2.) Accurately measure the length of the cable in feet (either cut off the shorted end to the nearest foot, or convert the spare inches to tenths of a foot—don't forget to reconnect the short circuit.

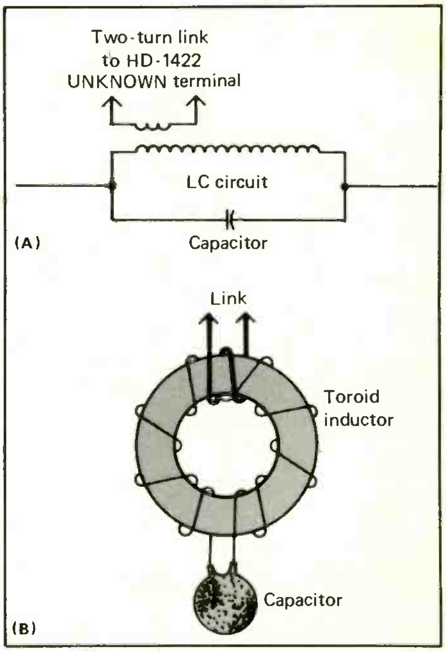


Fig. 4. Making measurements in a parallel-resonant circuit requires loop coupler. Different approaches are required for axial and toroidal coils.

(3.) Set the HD-1422's RESISTANCE and REACTANCE controls to zero.

(4). Adjust the receiver for deepest null. Use the null frequency to find velocity factor V = FL/492, where *V* is velocity factor (a fraction); *F* is frequency in MHz; and *L* is length in feet.

Tuned-Circuit Measurements

An inductor/capacitor (LC) tuned "tank" circuit is the circuit equivalent of a resonant antenna, so there is some similarity between the two measurements. You can measure resonant frequency with the noise bridge to within ±20 percent or better if care is taken. This accuracy may seem poor, but it is better than one can usually get with low-cost signal generators, dip meters, absorption wavemeters and the like.

Series Tuned Circuits. A series tuned circuit exhibits a low impedance at resonance and a high impedance at all other frequencies. Start by connecting the series tuned circuit under test across the UNKNOWN terminals of the HD-1422. Set the RESISTANCE control to a low resistance value, close to zero ohms. Set the REACTANCE control at mid-scale (zero mark). Next, tune the receiver to the expected frequency, and then for the null. Make sure the null is deepest by rocking the R and X controls for best null. At this point, the receiver frequency is the resonant frequency of the tank circuit.

Parallel Resonant Circuits. A parallel resonant circuit exhibits a high impedance at resonance and a low impedance at all other frequencies. The measurement is made in exactly the same manner as for the series resonant circuits, except that the connection is different. Figure 4 shows that a two-turn "link" is needed to inject a noise signal into the tank circuit. If the inductor is a toroidal type, the link must go through the hole in the doughnut-shaped core and then connects to the UNKNOWN terminals of the noise bridge. After this, do exactly the same as you did for the series tuned circuit.

Capacitance and Inductance

The HD-1422 noise bridge comes with a 100-pF mica test capacitor (CTEST) and a 4.7-μH test inductor (LTEST), which are used to measure inductance and capacitance, respectively. The idea is to use the test components to form a series-tuned resonant circuit with an unknown component. If you find the resonant frequency, you can calculate the unknown value. In both cases, the series tuned circuit is connected across the UNKNOWN terminals of the HD-1422, and the series-tuned procedure above is followed.

Inductance. To measure inductance, connect the 100-pF CTEST in series with the unknown coil across the UNKNOWN terminals of the HD-1422. When the null frequency is found, find the inductance: $L = 253./F^2$, *L* is the inductance in microhenrys (μH) and *F* is the frequency in megahertz (MHz).

Capacitance. Connect LTEST across the UNKNOWN terminals in series with the unknown capacitance. Set the RESISTANCE control to zero, tune the receiver to 2 MHz, and readjust the REACTANCE control for null. Without readjusting either noise bridge control, connect LTEST in series with the unknown capacitor and retune the receiver for a null. Capacitance is now $C = 5389/F^2$, where *C* is capacitance in picofarads (pF) and *F* is frequency in megahertz (MHz).

Conclusion

The Heath HD-1422 noise bridge is an easily constructed kit of simple but good design. It is also an immensely useful tool. I recommend that all radio hobbyists who listen or experiment in the medium-wave and high-frequency shortwave bands purchase and use one of these instruments. ME

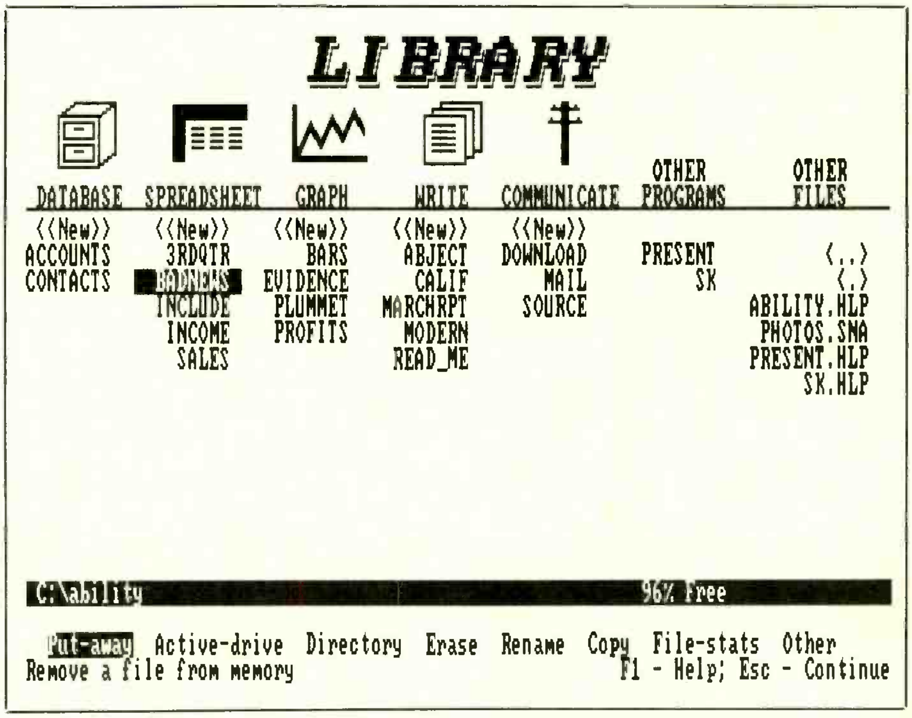
First Impressions: Leading Edge Model D; Ability and Able One Software

By Eric Grevstad

Hi there, everybody! I'll soon get to my review of one of the hottest-selling compatibles today—the Leading Edge Model D—but first, this word from me about Crazy Dave of Crazy Dave's Software Clearinghouse, right on Route 10 across from Workmen's Lumber! "I've got the deal of the year on advanced MS-DOS software!" he says.

Now, I know you're thinking, "Come on, Dave, what's the catch? Is this some junk program? Slight damage to disks during warehouse fire?" No! It's a top integrated package from a famous maker —well, not as famous as they hoped to be, but they got good reviews and sold to satisfied buyers just a few months ago for $495. Now he's making this six-function bundle available to you for just $99!

More about this $99 special in a minute, but first, this public service warning and consumer alert . . . .



Ability's Library screen, showing applications and file-handling commands, which are accessed with the F2 key.

Dog of the Year

No one except Crazy Dave likes low software prices more than I do, so naturally I was intrigued by ads for an $84.95 integrated package. You may have seen the same ads, and thought Able International's slogan, "Everything Symphony was supposed to be," seemed too good to be true. In fact, the Able One program is almost too bad to believe.

A fair amount of thought went into Able One's integration. Telecommunications and printing are available as background tasks. You can link cells in different spreadsheets, and paste a spreadsheet —not selected rows, but the whole file— into a word-processing document.

But while Able One does windows, it barely does word-processing, spreadsheet, or database work. The word processor is so slow as to be useless for all but the poorest typists; press the End key to move to the end of the file, even if the cursor's only a few words away on the last line, and you'll see a "Working, Please Wait" message.

Reformatting is done a paragraph at a time, WordStar fashion, though Able One's command-menu syntax requires pressing F9, six down arrows, and Enter (or, to be fair, the shortcut: F9, type REF, Enter). All application functions are on F9 menus; the spreadsheet menu lets you scroll through over 50 commands. No wonder Able One has a keystroke macro facility.

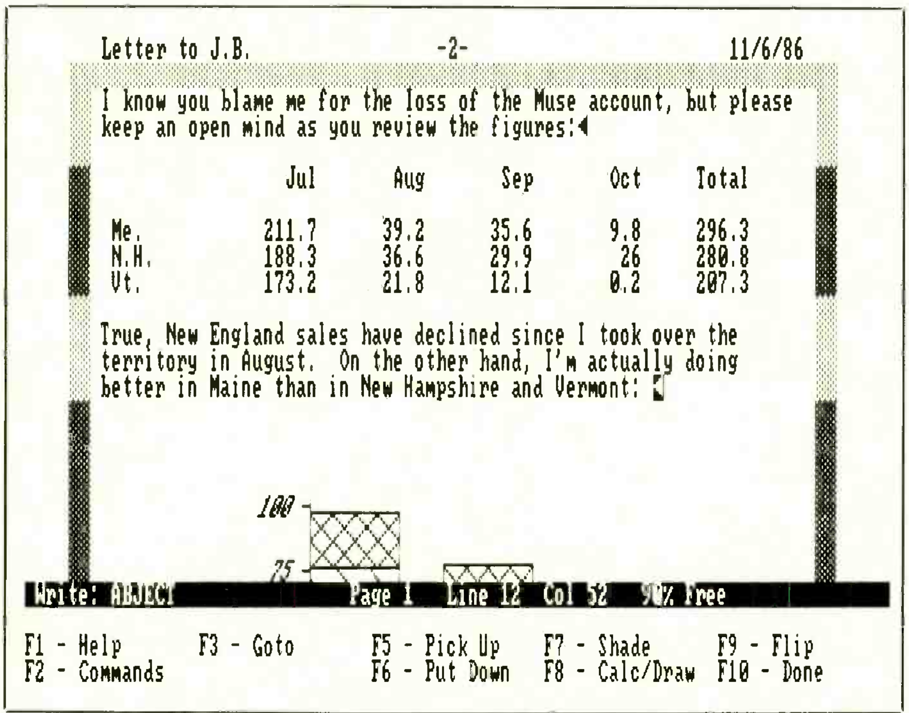
The spreadsheet is slow and has few financial functions; in this age of gigantic worksheets, it opens to a whopping nine columns by 23 rows. (According to the manual, you can enlarge it to over 10,000 active cells. Two hundred copies of Able One, and you'd match the theoretical limit of 1-2-3 Release 2.)

What about the database? Fine, if you don't mind planning field lengths and data types ahead of time, or won't need the commands the manual lists but the program lacks for data template modification. I was briefly impressed by the U (for unique) data attribute, supposed to let you specify a data item that can occur only once per database as a guard against duplicate records, until I tried it and got scrambled gibberish.

Able One may be buggy, but it isn't worth debugging—or going past its amusing opening menu. There's artificial intelligence, with a "How may I help you, Your Name?" line that lets novices type "I want to print now" or "Please open a spreadsheet," but not anything useful like "Get the customer file." The functions menu lists "Quit," which exits to DOS, and "Utilities"—another exit to DOS, so you can run utilities like FORMAT. Able One is howlingly bad.

Their Loss, Your Gain

Turning from cheap software to good software sold cheap, several firms have had to sacrifice their products at low prices. Analytica's Reflex, a critically praised flop at $495, now belongs to Borland and costs $149.95. Infocom leapt from text adventure games to corporate applications with Cornerstone, a powerful (if not programmable) relational database bursting with prompts and menus for those with dBase III anxiety; Infocom is now part of the entertainment



This is Ability's word processor, and those aren't pasted numbers but a working, recalculating spreadsheet. Changes also affect the graph below.

and home software firm Activision, and the Cornerstone package is well worth a look at only $99.95.

The latest adopted orphan is Ability, a multifunction package launched by Canada's Xanaro Technologies with a $495 price, fancy plastic box, and colossal ad campaign (16 color pages and demo disks in *PC World*, Nov. 1985). The cash outlay led to Chapter 11. Now the plastic box is gone, the price is $99, and a sticker on the Xanaro manual credits Ability to Migent Software of Incline Village, Nevada—which has its hands on a flawed but remarkable bargain.

Ability needs an upgrade from Xanaro's version 1.0A; if nothing else, Migent should get rid of the two cartoonish opening screens and add Xmodem to the communications module. But even so, Ability is the most fascinating integrated program I've seen. It reminds me of a famous vaporware victim, Ovation, which wowed me and other writers in 1983 and 1984 (it made the cover of *Popular Computing*) but died before being offered for sale. Ovation's appeal was that it had everything connected to everything in real time—change the spreadsheet rows within your word-processing letter, and the graph also located in your letter redrew itself right on the spot. Ability can do that, too.

It also lets you go amazingly far without opening the manual. From both the file-selecting Library screen and the applications, the F2 key calls menus and submenus of cursor-key or first-letter commands. Other function-key jobs are consistent across applications, such as F7 to shade a block of text or range of cells, F5 to pick it up (copy it to an undelete buffer), and F6 to put it down. Between the last two, you can use F9, the Flip key. In lieu of windows, Ability supports two full-screen sessions, whether a spreadsheet and document, database and communications, graph and Library, two documents, or whatever. It's a little slow even with a hard disk (squeezing into 384K), but it makes cutting and pasting operations a cinch.

Ability can turn spreadsheet rows into word-processing text as well as any package, but I'm willing to wade through its foot-scuffling for something greater. Instead of dead numbers in a document, you can have all or part of a live spreadsheet, recalculating right there amidst your sentences, headers, and footers. Changes there appear in the source (Flip) spreadsheet file, and vice-versa. (Do the same for worksheet cells and database records, if you prefer.)

To top that, pick up a spreadsheet range and put it down as a graph value, so recalculation equals redrawing (unless you disable the automatic update feature). Go back to your word-processing document, which already contains the spreadsheet, and insert the graph—a three-ring circus, integrated software to the nth. I rarely play computer games, but I was up till 1:00 AM playing with the Ability software package.

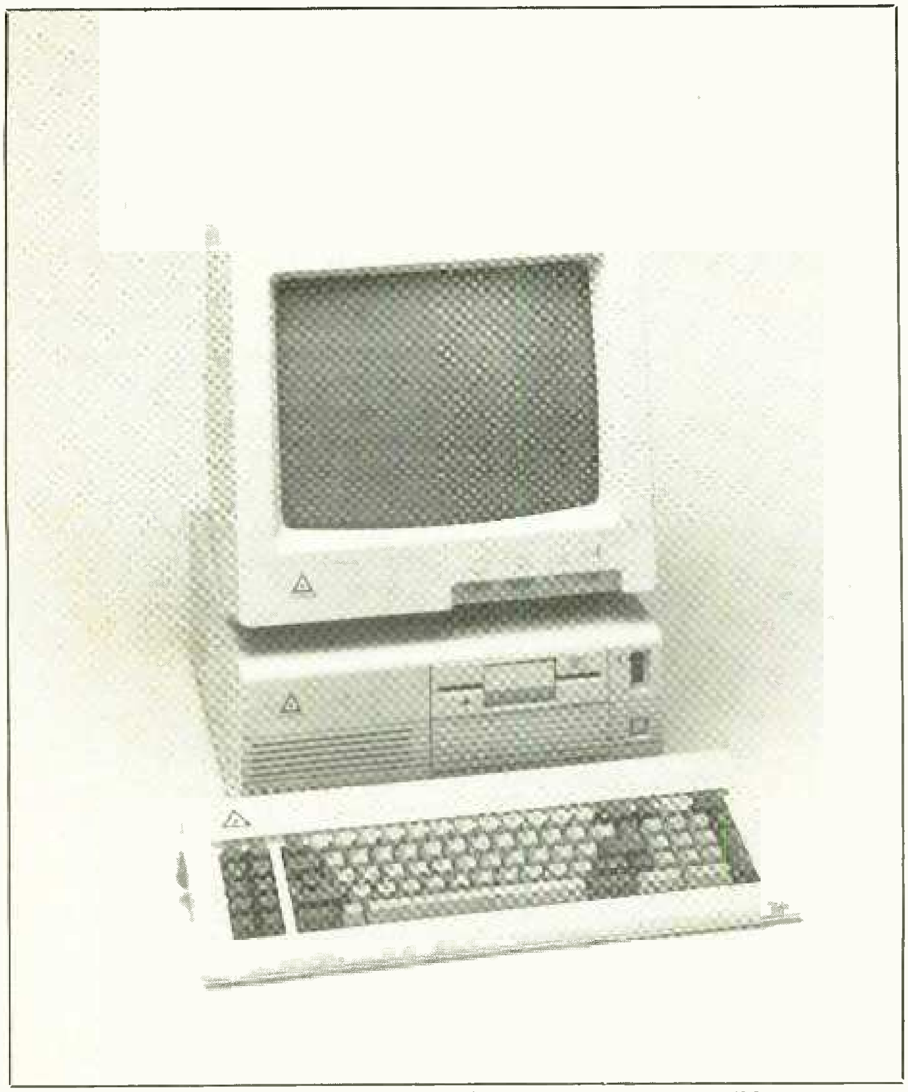
Complaints? As I said, the interaction is more inertial than instantaneous, and I found a few quirks besides—worksheet/graph links didn't wake up until I hit the F8 (Calc/Draw) key, then responded automatically thereafter. I locked up my system once, using F6 to copy an empty buffer location.

Except for the spreadsheet, which has plenty of functions and a theoretical maximum of a staggering 702 columns by 9,999 rows, the modules have various limitations. The word processor is sluggish with word wrap, and its automatic reformatting requires an awkward Ins, type text, and Ins (to close the gap) rather than true insert mode. The database is a simple forms-based or card-file affair at heart. Graph colors don't appear onscreen as well.

On the other hand, there's Ability's amazing integration—and a playful sixth function, Presentation, that lets you arrange "slide shows," snapshots of Ability screens shown with fancy fade-effect transitions, titles, clip-art symbols, and short, beeping snatches of over 20 familiar tunes. Slow and imperfect, Ability is still a great deal of software for $99.

The Clone of Choice?

There are lots of cliches about yuppies, the young upwardly mobile, status-



The Leading Edge Model D: A fashion-conscious compatible.

Names and Addresses

Able International Inc.
301 North Main Street
Pueblo, CO 81003
303-544-9600

Migent Software Inc.
P.O. Box 6062
Incline Village, NV 89450
702-832-3700

Leading Edge Hardware Products Inc.
225 Turnpike Street
Canton, MA 02021
800-343-6833

minded professionals of the baby boom. They have MBAs, they drive BMWs, their favorite computer is Apple's Macintosh. The BMWs and degrees are true, but the idea of corporate climbers buying Macs is foolish. The true yuppie computer is the Leading Edge Model D.

Yuppies are success-oriented; they know you can't get within 50 yards of a corner office today if you don't speak fluent 1-2-3. The Model D (for Daewoo, one of the Korean manufacturers now stealing the Japanese mantle of U.S. commodity item production) carries the trustworthy Intel 8088 and the latest Phoenix ROM BIOS, giving it topnotch PC compatibility. It has 256K of memory; two of its four rows of 64K-bit chips are socketed, so with 256K-bit chips it's an easy job to put a full 640K on the motherboard. There's an ample 195-watt power supply, an 8087 math coprocessor socket and four full-length expansion slots (three with a hard disk controller).

A Phoenix BIOS is a good idea borrowed from the Tandy 1000; so is a standard parallel port, but Leading Edge has an RS-232C serial port as well. The Tandy has its video circuitry right on the motherboard; the Leading Edge tops that with sharp TTL instead of composite monochrome, with Hercules-compatible 720 by 348 graphics, as well as conventional Color/Graphics Adapter RGB.

Yuppies want a computer that looks good; the Leading Edge's footprint is a trim 14.25 by 16 inches, and it's the most sleekly sculptured machine since 1984's museum-piece Mindset. More important, it's got a first-class keyboard.

After two weekends with a borrowed Model D, the only things I can find to complain about are the flimsy, two-piece floppy drive latches (close a door, then slide a button) and the lack of a clock driver on the MS-DOS 3.1 master despite the presence of an onboard clock/calendar (all you have to do is tap Enter twice, but I'd rather skip the DATE and TIME prompts altogether). I even like the paperback manuals—not only nicely thorough but with one or two little jokes, such as explaining hard-disk subdirectories with a family tree taken from Wagner's Ring (Wotan, Siegmund, Sieglinde, *et al*).

Finally, yuppies are very money-conscious, and outside of Radio Shack or mail-order it's hard to beat Leading Edge's prices. A 256K, two-disk Model D costs $1,495 with monochrome monitor; Leading Edge dealers, like Honda dealers, generally resist discounting or haggling, but local ads indicate some flexibility. Some dealers add Leading Edge's word processor free or the 640K upgrade for $100; some seem to be shipping 30- instead of 20-megabyte hard disks in their $1,895 models. ME

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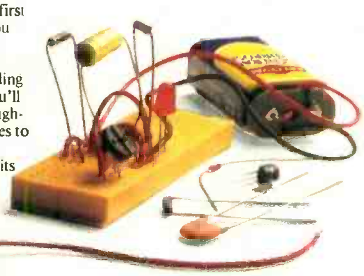

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including a hole for POWER switch *S5*. If you are using a metal enclosure, deburr all holes. Now, dry-transfer label the various switches according to function and position, the LEDs and 10-turn vernier-dial potentiometer *R1*. Then spray three or four *light* coats of clear acrylic over the lettering, waiting for each coat to dry before spraying on the next.

Mount the LEDs on the front panel via either clips or small rubber grommets. Then mount *R1* via its vernier dial and the various switches, orienting them as shown in the details given in Fig. 7. Note that *R11*, *R12* and *R13* wire directly across the lugs of *S1* and that *R21*, *R22* and *R23* wire to the position lugs of *S3*. In the latter case, tie together the free ends of the resistors and terminate the common connection with a length of heavy-duty stranded hookup wire.

Capacity and Charge Rate for Popular Nickel-Cadmium Cells

Size	Capacity mAHr	Standard Charge mA	Standard Charge Hrs.	Quick Charge mA	Quick Charge Hrs.
N	150	15	15	38	6
AAA	180	18	15	45	6
1/3 AA	110	11	15	—	—
2/3 AA	250	25	15	75	4.5
AA	500	50	15	150	4.5
1/2 C	600	60	15	150	6
SC	1,200	120	15	300	6
C	1,800	180	15	—	—
D	4,000	400	15	—	—
F	7,000	700	15	—	—

Mount the circuit board in place, using ½" spacers and ¾" machine hardware. Place a No. 6 ground lug under one of the board's screws nearest the front panel. Then connect the free ends of the wire coming from the board to the indicated lugs of *R1* and switches, trimming their lengths as necessary to keep the project neat. Tie the free end of the wire connected to the common junction of *R21*, *R22* and *R23* to the solder lug and solder the connection.

Before connecting and soldering the wires to the leads of the LEDs, slip over them lengths of insulating tubing. Then push the tubing up to cover the exposed metal of the leads to prevent them from shorting to each other or the chassis.

Securely bolt *C2* and *T1* to the floor of the enclosure. If you are using discrete rectifier diodes for *D5* through *D8*, secure the 4-lug terminal strip in place with one of the screws used to mount *T1* in place and, referring back to Fig. 4, wire the diodes to the lugs. (Make sure that you select a terminal strip whose lugs are isolated from its mounting tabs.) Otherwise, mount the bridge rectifier assembly and fuse holder on the rear wall of the enclosure. Pass the free end of the ac line cord through a rubber-grommet-lined hole and tie a knot in it about 6" from the inside end. Finish wiring the power supply circuit according to Fig. 5.

If the battery holders and connectors are to be external to the main project, terminate their interconnect cable with a plug to match the project-mounted jack. You can start from scratch making an enclosure for the connectors and holders, or you can cannibalize a commercial battery charger.

Your choice of battery holders depends on your needs. If you want a universal charger, design the system to handle all possible types of batteries and cells.

Calibration and Use

To calibrate 10-turn V MAX control *R1*, connect an accurate voltmeter between the control's wiper and ground terminals. Prepare a two-column calibration chart with headings of "Number of Cells," "Volts" and "Setting." Under the first heading, write the numbers 1 through 10 in a vertical column and under "Volts" the figures 1.4, 2.8, 4.2, 5.6, 7.0, 8.4, 9.8, 11.2, 12.6 and 14.0. Now adjust *R1* for meter readings of each of the voltages entered in the second column, filling in the vernier dial settings at which each occurs in the appropriate location under the "Setting" heading in the table. Tape the calibration table to the project's enclosure for ready reference.

To calibrate the deep discharge limit, first set *R1* for a meter reading of 8.4 volts. Then connect the voltmeter between the wiper terminal of V MIN control *R3* and ground and adjust this trimmer for a reading of 6.0 volts. No further adjustment of *R3* is required since it tracks *R1*.

Discharge load resistor *R21*'s 20-ohm value gives discharge rates and times that vary according to the voltage and capacity of the battery or cell(s) connected to the Recycler. With a 10-cell 12.5-volt, 500-mAHr pack, this load discharges at a 625-mA rate in about 1 hour. A 1.25-volt, 500-mAHr single AA cell will discharge at a 62.5-mA rate in approximately 8 hours, while a single 4,000-mAHr D cell will discharge at the same rate in 64 hours—which is excessively time-consuming for practical recycling!

If you intend to recycle low numbers of high-capacity cells, you may want to switch in some lower-resistance loads via *S3* to speed up the process. The values of discharge resistors *R22* and *R23* are calculated using the formula R = E/I, where *R* is in ohms and *E* is total voltage and *I* maximum allowable discharge current for each cell and battery combination. Maximum discharge current should not exceed cell capacity. (See the Table for capacity and charge rate information for various popular Ni-Cd cells.) Use the P = IE formula to determine wattage. Just make sure to use resistors with high enough wattage ratings to safely handle the current flow.

Use of the Recycler feature is not limited to HT packs. Batteries from electric razors, emergency lights, soldering irons, etc., all tend to be maintained on trickle charge until needed and are, thus, susceptible to memory problems. By periodically exercising them with this project, they can be restored to full capacity.

When first recycling a battery suffering from the memory effect, best results are obtained by using a low charge rate, such as 50 mA for a 500-mAHr AA cell.

When using the Zap mode, remember that the CONDITION LED will light to indicate that the short has cleared, but you must make sure that the cell remains in this condition. To do this, continue to zap the cell for 10 to 30 minutes (the time being in proportion to how long it took to initially burn away the internal short) after *LED2* lights continuously. This assures that the cell is fully restored before it is put back into service. Also, after zapping, immediately put the cell on a low charge cycle until you measure 1.4 volts across it during charging. (It will initially measure about 1.25 volts at the end of zapping.) This ensures that whiskers will not grow back in just a few days.

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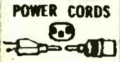

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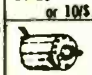

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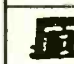

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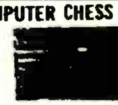

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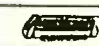

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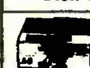

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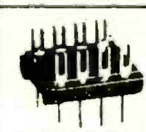

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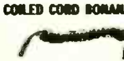

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TO-3
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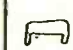

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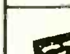

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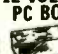

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Dual Trace Oscilloscopes

Fig. 10, lowers the input capacitance and prevents loading of the r-f circuit under test.

Demodulator probes are most often used when servicing sensitive r-f circuits, such as those used in i-f amplifiers and r-f tuners. Demodulator probes can also be used as a detector to extract modulated information from an r-f carrier.

Another popular special-purpose probe has an internal FET amplifier. The output impedance of the amplifier in this "active probe" is typically 50 ohms, which matches the impedance of the coax used with it.

Using an active probe, the amplifier isolates the signal from line disturbances. Thus, the length of the coax has little effect on the waveform at the scope input.

One of the advantages of the active probe is that it gives full bandwidth response with no signal attenuation. This makes the probe ideal for measuring low-level pulse signals in high-frequency circuits.

A third popular probe, the current probe, is used for measuring current and displaying it on the screen. Because the oscilloscope is basically a voltage measuring device, the current probe is needed to convert the current in a circuit under test into a voltage that can be displayed. Most current probes are of the split-core type in which the core slides back to allow the current-carrying lead in the circuit under test to be inserted into its center without breaking the lead.

In Conclusion

Knowing how to use an oscilloscope is as important as the quality of the scope itself. We have presented here the important fundamentals and talked about using the scope to make measurements in various types of circuits. We also touched upon the types of probes commonly used for different applications. We hope this information will lead you to studying in more detail oscilloscope operation and use. **ME**

ADVERTISERS' INDEX

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Scale Factor Readout	Yes	Yes
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Time Cursors	Yes	No
Voltmeter	Yes	No
Vertical Sensitivity	2 mV/div	2 mV/div
Max. Sweep Speed	2 ns/div	2 ns/div
Vert/Hor Accuracy	2%	2%
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Trigger Level Readout	Yes	No
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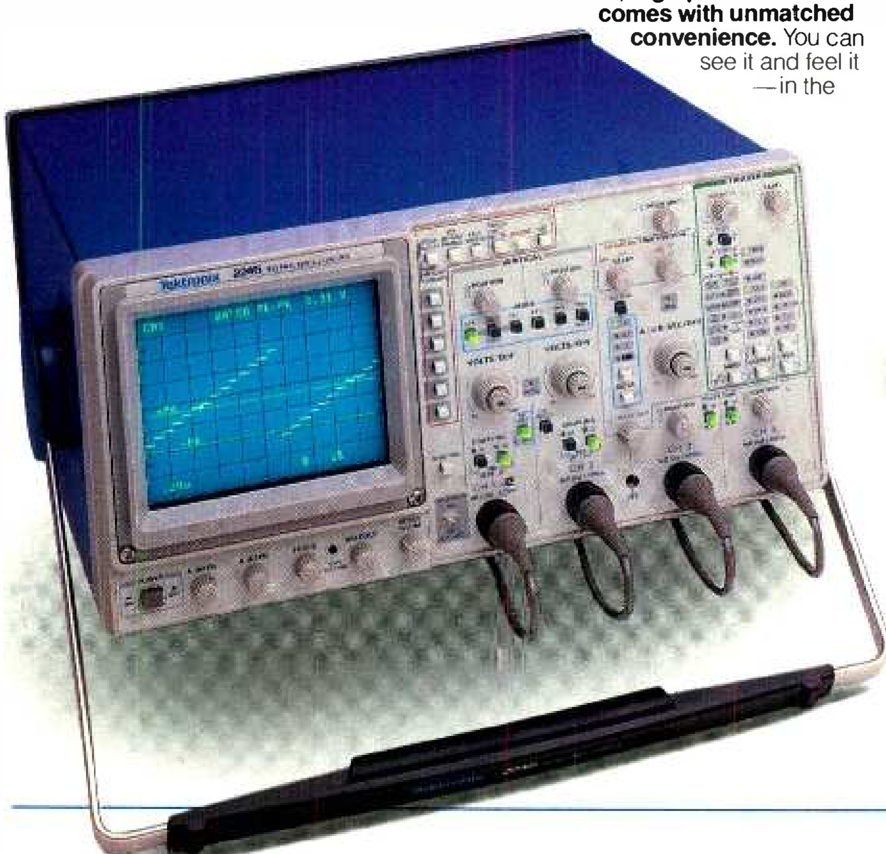

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