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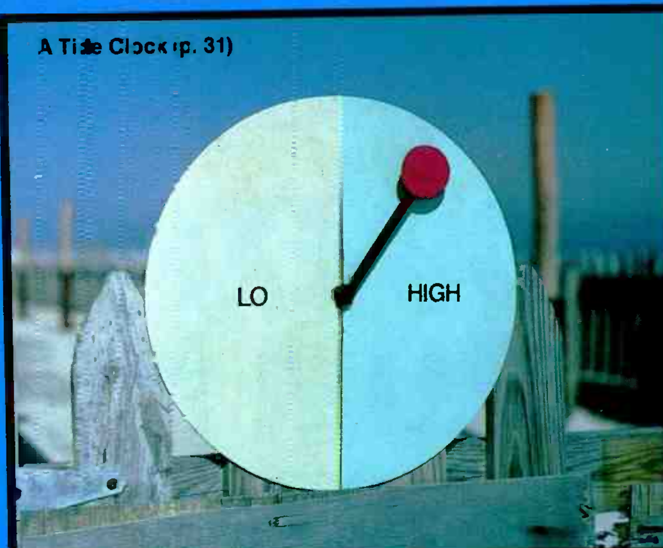
■ PHONE ANSWERING MACHINES:
- ■ How They Work
- ■ Buying Guide

■ OCEAN TIDE CHECKER

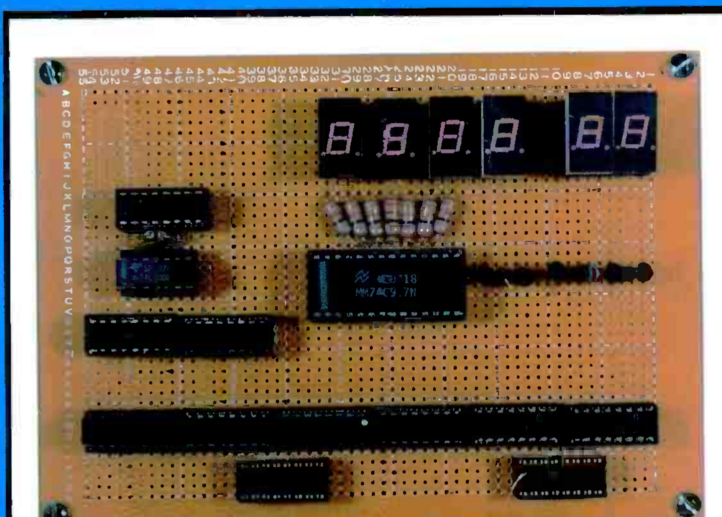


A Tide Clock (p. 31)

Also Featured:

- ■ A ±1.2-to-37-Volt Power Supply
- ■ BCD-to-Hex Converter/Display
- ■ A Pocket Snooze Alarm
- ■ Electronics Troubleshooting With Oscilloscopes

Dual-Polarity Power Supply (p.24)



BCD-to-Hex Converter/Display (p. 38)

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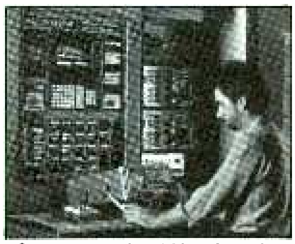

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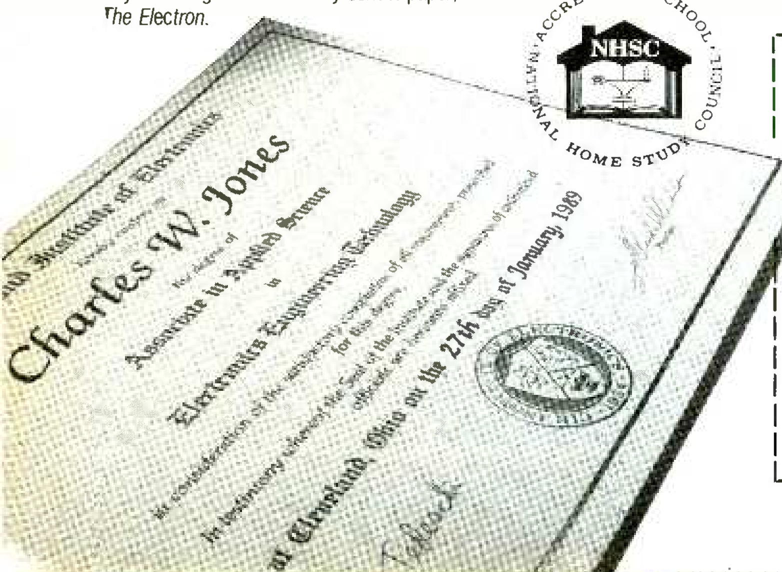

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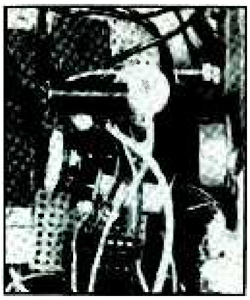

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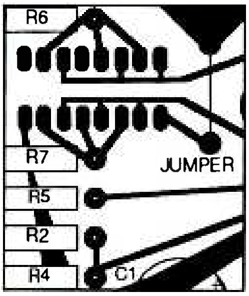

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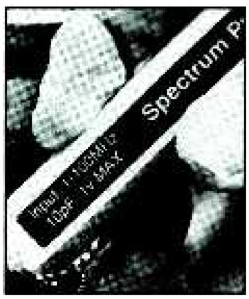

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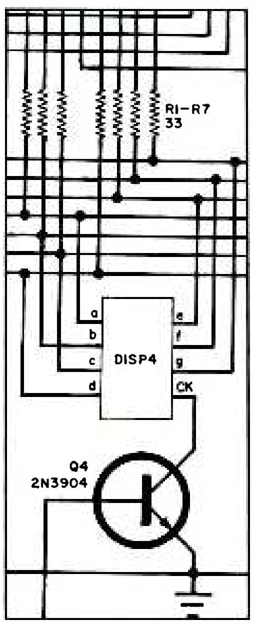

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EDITORIAL

Trying It Out

There's nothing like actually using a new product type to get a true feel for its utility. All the news press releases in the world won't prepare one for the experience. During the past year I tried out a bevy of new product types that underscored this fact of life.

Most recently I got my hands on Seiko Instruments' newly introduced "Home Contractor" product. It's a handheld device that simplifies taking room measurements and calculating the amount of material needed for construction or decorating purposes. If you've ever measured a room's dimensions with a tape measure in order to figure out how much paint, wall panels, floor tiles, ceiling tiles, wallpaper or carpeting would be needed, you'll certainly appreciate what this battery-powered "tool" can do for you. Just point and shoot, and the measurement automatically appears in a liquid-crystal display.

Although I couldn't get technical details, I believe that the instrument uses Polaroid's ultrasonic measuring system. In use, you hold the unit steady, generally by placing its back on a wall, and press a button that's located on both sides of the body. After a few clicking sounds, it'll beep and you can read the measurement in feet (or meters if you press a mode button). Pressing a dimension button (length, width or height) stores the information into memory. Follow this with an ultrasonic measurement of another dimension for area, store it, and then press an Area button. Total square feet will then be calculated and displayed. For volume, a third quick, long-distance measurement is made, and pressing Volume provides that information, too.

Turning the Home Contractor over to get at its other side reveals a conversion computer, also with an LCD display. This side has a series of "soft" switch buttons, including four-banger calculator buttons. Simply enter the area or volume that you had measured previously and press a materials button (paint, rug, etc.) on the same face. Doing this, a built-in software program automatically calculates how much material you'll need to do the job in appropriate form. That is, if you press Paint, the readout will indicate how many gallons you'll need; press Roll and the result will be in wallpaper rolls required; press 4 × 8 and you'll read how many wall panels you'll require. There are factors you can punch in to change the 4 × 8 to another dimension if wall panels you choose are not a standard size, and subtractions to account for doorways, windows, etc.

In addition to the foregoing, the conversion unit will also calculate how many BTU/Hour units an air conditioner would have to produce to cool the room properly, or BTU/Hour for heating.

In use, the Home Contractor performed just about how one would expect it to. However, it was disconcerting at first to discover that an LCD reading disappeared in short order. The operator guide notes indicated that it does this to conserve battery life (three replaceable lithium batteries with an estimated one-year-plus life). Pressing a Recall button restores the reading, though, but it is still a minor bother.

A second in-use revelation was that I dislike soft keys. You've got to press too hard to get it to work. A third and final criticism is that the ultrasonic activation switches at each side of the device are in a location where one's fingers seem to naturally press when handling it. This is compounded by the switches being especially sensitive; a light touch sets it off.

As you can see, trying out a product is especially important. In this case, I'm talking about a unique product, of course, which with its minor shortcomings is still an impressive device. A hands-on approach becomes more important when there are competitive models out there, of course. So whenever you can, do make an effort to operate a device before buying. Most storekeepers will cooperate.

A Winning Project

• My "Talking Telephone" (*Modern Electronics* October 1989) has been selected as one of the top nine circuits by the Design '89 International Design Awards committee. Sponsored by the Electronic Component News and OrCAD, the Design '89 Awards is an annual event that gives top engineers in the country recognition for their contributions to the advancement of the electronics industry for the previous year. It was held in the Civic Auditorium/Brooks Hall, Moscone Convention Center in San Francisco November 14 through 16, 1989.

Steve Sokolowski

Component Availability

• Readers who read my "Stepping Motors" article in the January 1990 issue of *Modern Electronics* may have difficulty in locating a source for the IC chips referenced in the text. Both the SMC20 (an upgraded version of the referenced SMC10) programmable indexer and AA8416 driver are available directly from Anaheim Automation, 910 E. Orangefair Lane, Anaheim, CA 92801 (tel. 714-992-6990).

While on the subject of the "Stepping Motor" article, there are two errors that should be corrected. In Table 1, under the heading Phase 4, the entries should be off, on, off and off from Step 1 through Step 4. The other is in the seventh line in the center column of the main text on page 21. The figure 0.15 inch should be changed to 0.00015 inch. This would make the final two figures in this paragraph 5.00015 and 4.99985.

Stephen J. Bigelow

Kudos and Corrections

• I really enjoyed the two-part article "Microprocessor Control With BASIC" in the April and May 1989 issues. In fact, it was because of this series that I decided to subscribe to *Modern Electronics*. Please keep this kind of article coming, and thanks for a good magazine.

While building the project presented in the April issue, I noted a few errors in the schematics. In Fig. 1: for IC3, pin 16 (not pin 14 as shown) connects to +5 volts and pin 8 (again, not pin 7 as shown) goes to ground. In Fig. 2: C4 should be labeled C14, and Q1 should be shown as an npn—not pnp—transistor.

Vic Richter
Kerville, TX

Setting the Record Straight

• The Table of Contents in the December 1989 issue of *Modern Electronics* lists the wrong author for "Making Printed-Circuit Boards Without Photography." This article was actually written by Jan Axelson, as shown on page 16.

K. Furstman
Astoria, NY

PARTS DISTRIBUTOR NEWS. Digi-Key Corp., the nationwide distributor of electronic components since 1972, added Industrial Devices products to its store of parts. This rounds out the distributor's offering in neon and incandescent lamps, says Stan Springsteen, Digi-Key's Vice President of Marketing.

JDR Microdevices, which has an extensive catalog of microcomputer devices, has started a 24-hour electronic bulletin board system (BBS) with on-line product information, tech help, free software, conferences,and more, including on-line orders from JDR. The BBS will also host several SIG (special interest Group) sub-boards for Apple, Amiga, Atari and Commodore users, plus Tech Talk and High Tech, among others, as well as 20 categories of software for downloading (utilities, games, tech files, ham radio, etc.). The BBS supports TTY and ANSI color terminals connecting at 300, 1200 or 2400 bps, plus 9600 bps HST and V.32 connections. The BBS access numbers are 408-559-0253; for 9600 bps, it's 408-559-0297 or 0298.

NEW ELECTRONICS TRADE ASSOCIATION. Installers of home entertainment systems and other home electronics devices formed a new national trade association to promote the profession and develop service standards. It's estimated that custom installation of home electronics (electronic equipment for media rooms, whole-home entertainment systems, home automation systems, etc.) is a $250-million business...and growing rapidly. Companies seeking CEDIA (Custom Electronic Design & Installation Association) membership must show compliance with federal, state and local laws, all applicable licensing, and insurance requirements including liability, worker compensation and bonding in their marketing area. Additionally, the company must have been in business using the current company name for at least two concurrent years preceding membership application, and has to submit names of three industry references (such as manufacturers, sales organizations or other installers). Contact CEDIA, 10400 Roberts Rd., Palos Hills, IL 60465 (Phone: 708-598-7070).

NEW LA FM SIGNAL. A powerful Los Angeles radio station, KROQ-FM, now broadcasts an additional signal: paging messages to business travelers on the unused portion of the station's FM radio transmission band (a popular rock-and-roll music program). KROQ is the 200th station to carry CUE Paging Corp.'s nationwide network of FM subcarriers to its subscribers. The subcarrier is the part of the FM band that transmits signals like Muzak background music, weather reports and time signals. The CUE pager also provides voice message service to its customers.

FREE SAMPLES. Motorola (MOS Memory Products Div.) announced an offer of free engineering samples of its 12-nanosecond 16K x 4 fast static random access memory (FSRAM), one of its newest products. Each sample pack contains 8 one-micron MCM6290J12 devices in the SOJ package. This is a full 64K bytes of memory for use with the newest 33 MHz, 32-bit systems. To order the free sample pack, send your business card and a brief description of your application to Motorola Semiconductor Products, Literature Distribution Center, P.O. Box 20924, Phoenix, AZ 85036-0924 or call your local Motorola sales person.

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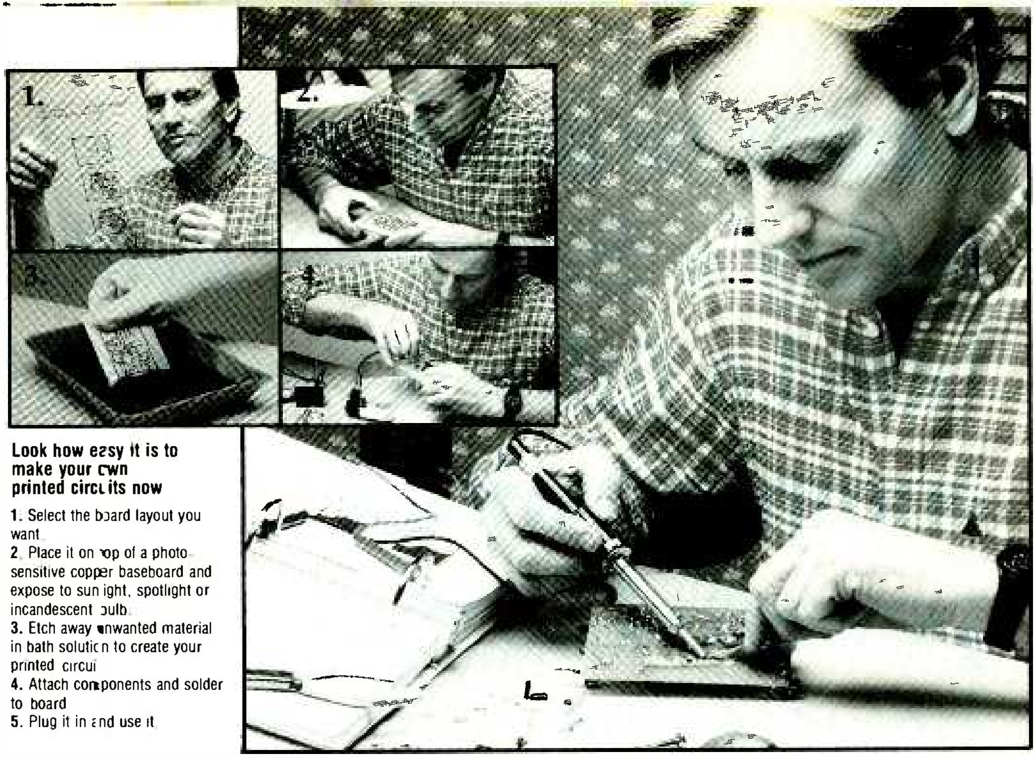

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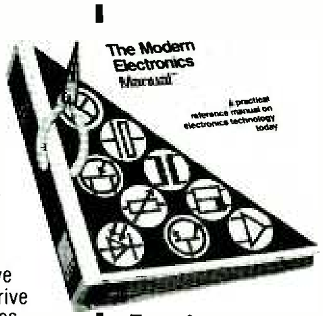

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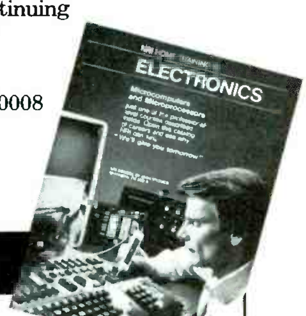

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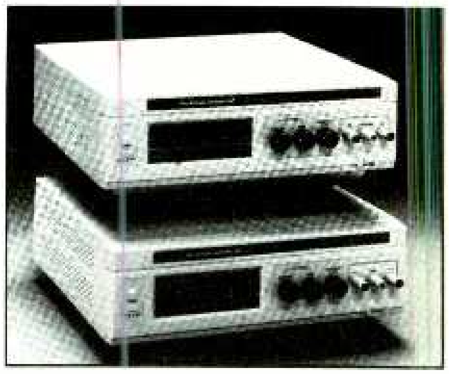

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CD-ROM-Based PC

New from Headstart Technologies (Great Neck, NY) is a CD-ROM-based PC that offers the user quick access to large volumes of data, interaction with other drives, ability to play audio CDs with stereo sound and unlimited possibilities of interactive information, combining sound, graphics and text in single applications. The 8/12-MHz 80286 HeadStart III-CD has a socket for 80287 match coprocessor. It features 1MB of RAM (expandable to 3 MB); clock/calendar with lithium battery back-up; six 8/16-bit expansion slots; 256K of video RAM; 101-key PS/2-style keyboard; 5.25-inch 680M CD-ROM drive with stereo sound; 40-MB, 28-ms hard disk with 1:1 interleave; 1.44M/720K 3.5-inch floppy drive; VGA card; stereo headphones; mouse; 9- and 25-pin serial, a parallel port, bus mouse connector and game ports; stereo phono jacks for CD audio; and stereo mini headphone jack for playback of CD video.

One CD-ROM supplied with the III-CD has on it: New Grolier Electronic Encyclopedia; Microsoft Bookshelf with dictionary, almanac, manual of style, thesaurus, etc.; HeadStart CD-ROM Library Disk; PC Globe computerized world atlas; and CD Audio Music Disk Sampler. A second CD-ROM comes with: Small Business Consultant and Stat Pack, both from Microsoft.

Software accessed by the III-CD's hard disk includes: MS-DOS version that permits partitions greater than 32 MB on the hard disk; GW-BASIC; HOT Pop-Ups utilities with notepad, datebook, calendar and calculator; HeadStart Office Manager with word processor, spreadsheet, database and spelling checker; Publish-It! desktop publishing system; Splash VGA graphics program for 256 colors; Twist & Shout for printing wide spreadsheets and large banners; and Chessmaster 2000 chess program. Other software includes: ATI Skill Builder tutorial for mastering the computer; Computer*Ease animated tutorial for color graphics; Mavis Bacon Teaches Typing typing tutor; XTree disk file-management program; Backup Pro for hard disk back-up to floppies; DS Recover and DS Optimizer for recovering erased files from the hard disk and speeding up and de-fragmenting hard disk files; Bookmark Plus automatic file saver; Above Disc EMS Emulator; Ashton-Tate's Framework II and Perspective 3-D Graphics. $2,995.

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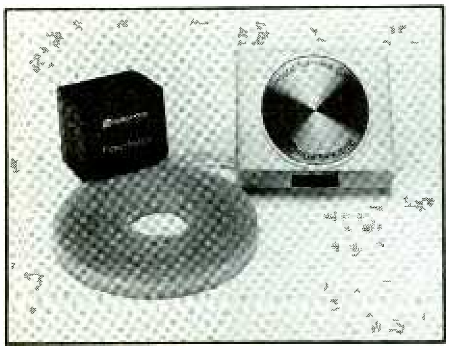
ulates output voltage at the load to compensate for test-lead losses. Both models feature digital numeric metering systems for simultaneous viewing of output voltage and current and current limiting, reverse-polarity protection and isolated outputs. Range adjustment is provided by separate COARSE and FINE controls on the front panel. Also on the front panel is a control for setting output current. $395, Model MPS60; $425, Model MPS100.

CIRCLE 53 ON FREE INFORMATION CARD

Remote-Controlled Thermostat Set-Back

New from X-10 (USA) Inc. is the Model TH2807 X-10 Powerhouse Thermostat Set-Back for remote control of set-back at preset times for central heating and air condition-



ing. It automatically tells the thermostat with which it is used to initiate set-back when the user retires for the night and then prompts the thermostat to restore the home to a comfortable level in the morning. The unit works with any kind of thermostat—low-voltage, 117-volt, pneumatic or otherwise. No wiring to the existing thermostat is required during installation. Instead, the unit attaches to the wall just below the existing thermostat, where it supplies a small amount of local heat to "fool" the thermostat. The unit plugs into the ac line through an appliance module and is operated from an X-10 remote-control unit, timer, telephone responder, etc. $19.99.

CIRCLE 54 ON FREE INFORMATION CARD

A/V Disc Player

Said to be the industry's first 5-in-1 audio/video disc player with multi-disc carousel, Sharp's Model MV-D100 can handle 3- and 5-inch CDs, 5-inch CD-Videos and 8- and 12-inch videodiscs. Its rotating carousel can

accommodate any combination of 3- and 5-inch CDs, including CD-V for sequential play.

The player features a three-beam laser pickup, 8 × oversampling, dual D/A converters, an optical output connection, and an S-Video output enables easy connection to a video monitor for picture quality with up to 420 lines of resolution. Video special effects include pause and still frame. Full wireless remote-control facilities are provided via a 53-key controller.

Among the player's other features is a time counter and mode indicator, variable audio outputs for analog or digital sound tracks, and a vhf output with channel selector. The player is fully programmable for special tape editing functions. $1,499.95.

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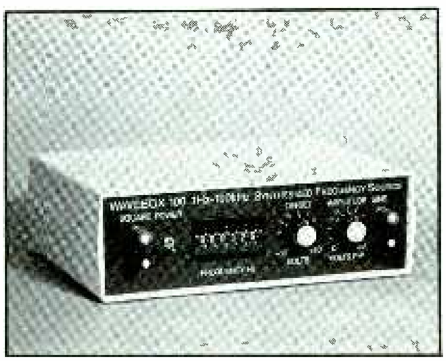
Frequency Source

The key feature of Teledata Systems' (New Milford, CT) Wavebox 100 Synthesized Frequency Source is its 100-ppm (0.001%) accuracy and sta-



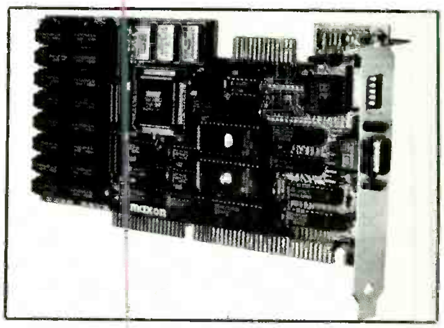
bility over its 1-Hz to 100-kHz range. Output frequency of this low-cost instrument is dialed up directly with thumbwheel switches on the front panel. Resolution is rated at 1 Hz over the entire range of the instrument. The sine-wave output is variable up to 20 volts peak-to-peak, with a ±10-volt offset. Harmonic and non-harmonic distortion are both rated at better than 40 dB. An auxiliary TTL/CMOS-level square wave output is also provided. $325.

CIRCLE 62 ON FREE INFORMATION CARD

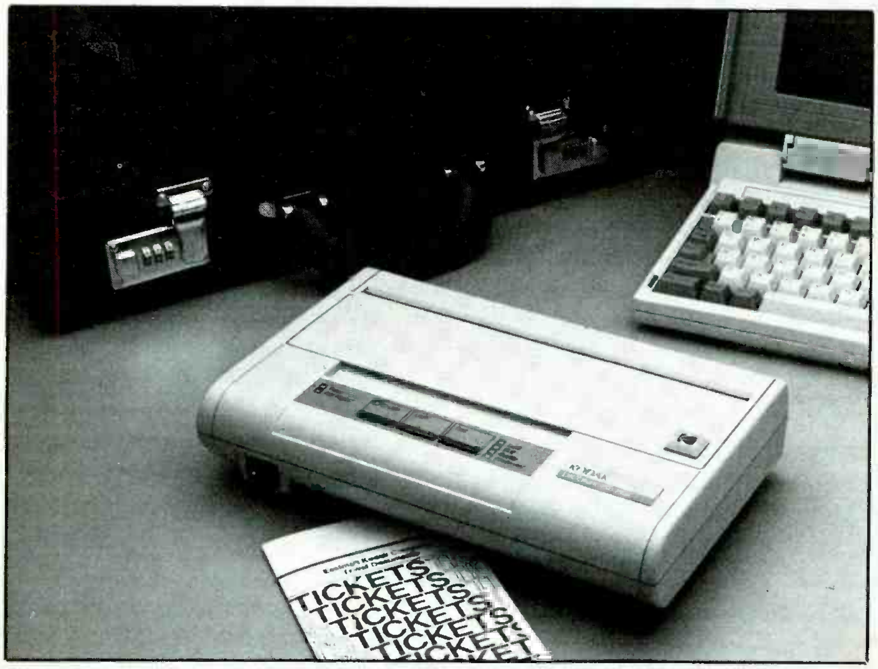
Video Adapter Card

Maxon Systems' MVGA-16 video adapter card is said to be 100% IBM VGA compatible at both the BIOS and register levels. It comes with drivers that allow any popular programs to work in the VGA mode that do not otherwise support this standard. Special extended-resolution drivers are also included for popular software.

This card supports, in addition to VGA, monochrome (MDA), color



graphics (CGA), enhanced graphics (EGA), gray shades (MCGA), and Hercules graphics standards. Switching among the various operating



Portable Printer for Macintosh Computers

Kodak's Diconix Model M150-plus battery-powered ink-jet printer for use with Apple Macintosh computers is an enhanced version of the Model 150-plus printer. It was designed to be a traveling companion for the new Macintosh portable and other "totable" Mac computers. Its small-footprint occupies minimal desktop space. The printer comes with the new Adobe type manager (ATM) software that builds type at any size from PostScript outline fonts. All 13 PostScript outline fonts provided in the original Apple LaserWriter printer are included in the ATM package.

Also supplied is MacPrint, a QuickDraw printer driver that installs in the Macintosh system folder and appears as a printer choice in the Chooser menu. When printing text, MacPrint driver and ATM automatically generate printer font bit maps from font outlines, optimized for the M150-plus printer's full 192 × 192-dpi resolution. The bidirectional printer uses QuickDraw routines to image graphics. This software combination allows users to interchange Adobe Type 1 fonts across output devices. The resulting device independence permits the same outline fonts to be used across a broad range of printers that use PostScript and AMT-drive.

The printer is compatible with all models of Macintosh computers equipped with 1 MB of RAM and Apple system software version 6.0.2 or later. It prints on plain paper and uses a printhead with self-contained disposable ink supply that is rated to deliver up to 500 pages of text. Both portrait and landscape printing modes are possible. Resolution is rated at 192 × 192 dpi in quality mode, 96 × 96 dpi in draft mode. Connection between computer and printer is via a serial interface operating at 9,600 baud. Rated operating noise level is 45 dB.

Five C-size rechargeable cells (not included) power the printer and can print more than 100 pages of text before the battery requires recharging, either overnight or while the printer is being used. The printer comes with a 117-volt ac wall-mount transformer for use when such power is available. When the printer is in use, built-in software senses when data is being received from the computer and temporarily interrupts charging; charging is automatically resumed after about 2 minutes of inactivity. The printer measures 10.8"W × 6.5"D × 1.97"H and weighs 3.1 lbs. (3.75 lbs. with battery). $699.

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standards is done with simple software commands and does not require setting of switches or jumpers.

The MVGA-16 works with multi-frequency IBM PS/2 and compatible monitors. Depending on the monitor used, extended resolutions of 800 by 600 pixels with 16 colors, 640 by 480 pixels with 256 colors and 1,024 by 768 pixels with 16 colors can be displayed. Additionally, several 132-column modes can be displayed on all compatible monitors. High-speed design is said to improve graphics drawing of the card by more than 50% over that achieved by the IBM VGA. $499 with 256K of RAM; $699 with 512K of RAM.

CIRCLE 59 ON FREE INFORMATION CARD

Levered Cutting Tweezers

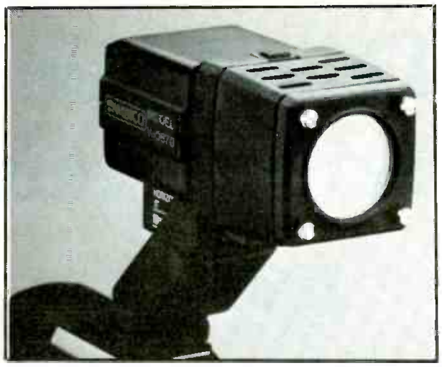
Cutting tweezers with a lever-action device are available from Aven Tools, Inc. (Ann Arbor, MI). The lever is said to dramatically reduce the force required to make cuts, re-

ducing muscle tension and thereby providing better muscle control for miniaturized work. The "E-Z" cutting device is available on 12 different cutting tweezers that have various blade configurations and sizes. The lever can be positioned to accommodate both right- and left-hand use.

CIRCLE 60 ON FREE INFORMATION CARD

Cordless Video Light

The Model V-0870 Compact One Gun™ Powerlight from Ambico (Norwood, NJ) provides 20 watts of quartz-halogen illumination at a color temperature of 3,200 degrees Kelvin. It features a built-in diffuser



that spreads the light out evenly and eliminates glare. A lightweight Ni-Cd battery pack, which clips onto the light, provides power for up to 20 minutes. The battery pack can be recharged hundreds of times with the charger supplied with the light. The Powerlight mounts onto the light shoe of virtually any camcorder. $129.95.

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Telephone Answering Machines

(Part I)

What they are, how they work and tips on buying the right model for your application

By Stephen J. Bigelow

According to a recent report, sales of telephone answering machines rose from 3-million to nearly 8-million units in just five years, with purchases for home-office use accounting for almost 2.5-million units alone. Sales are still going strong, making telephone answering machines among the hottest personal convenience communications devices in the marketplace.

Modern answering machines make widespread use of VLSI (very-large-scale integration) and custom integrated circuits that have been one of the primary reasons for shrinking of both sizes and prices. These IC designs have also contributed to providing sophisticated capabilities that were not available in the most expensive of machines only a decade ago. As a result, these machines are commonplace in homes for personal use and in business for professional use.

In this installment, we will cover the basic operating principles of telephone answering machines and describe the various features and functions you can expect to find in conventional models. Next month, in the Conclusion, we will detail important machine installation and maintenance procedures.

Record a Call's Model 2140 answering machine with digital numeric message counter and built in telephone instrument.

The Components

In spite of their small size, answering machines perform a remarkable variety of functions to accomplish their task. A complete block diagram of a simple answering machine is shown in Fig. 1, which details each major function area and identifies it with a key number. Let us look at each of these areas in turn.

(1) **Telephone Switching & Coupling Circuit**. This part of the system is run by the control circuit. It draws the current required to pick up a ringing telephone circuit and switches the audio path as needed into and out of the machine. It also switches the mi-

crophone and speaker as needed.

(2) **Main Microprocessor & Control Circuit**. This is the "heart" of the system in terms of controlling operations. It controls the switching actions of the coupling circuit, interprets the panel controls, and directs enable signals to the motor mechanisms and record/play heads. It also handles the machine's security code when used with a remote-control unit.

(3) **Ring Detector/Counter**. This portion of the system senses the presence of a valid ring signal from the telephone line and converts it into a series of logic pulses. Each pulse is counted until the appropriate number of rings is reached, at which time an enable signal is generated to the pickup circuit. A ring selector switch determines the number of rings counted before the machine picks up.

(4) **Pickup Circuit**. Activated by the ring counter, this circuit tells the control circuit that an incoming call is waiting and to pick up the line and execute the outgoing message (OGM) sequence.

(5) **Message-Duration Timer**. This is activated when the incoming message (ICM) sequence begins. It tells the machine to disconnect when its preset timer runs out. Timer duration is determined by the setting of the message-duration timer switch.

(6) **Security Code Switches**. These restrict access to the answering machine to only the remote controller that has the matching security code number, or a dialpad code that a beeperless remote machine recognizes. These switches can be fixed into the machine, or changeable inside.

(7) **Panel Controls.** These consist of the PLAY, REWIND, FAST FORWARD and MEMO buttons on the front panel. Other controls can also be present, depending on the particular features of the machine. This area also contains the controls for recording and reviewing the OGM and any indicators and displays.

(8) **Motor Speed & Direction Controls.** These determine whether the ICM or OGM tape moves (if it is a two-tape system) along with that tape's speed and direction. Though only one motor is used in most machines, gears and solenoids switch the motor's force and direction to the mechanism that has been selected by the control circuit.

(9) **Head Assemblies.** These comprise the most delicate and sensitive part of the system, since they are the actual elements used to record onto and play back from the ICM and OGM tape(s). The play heads sense the magnetic information stored on

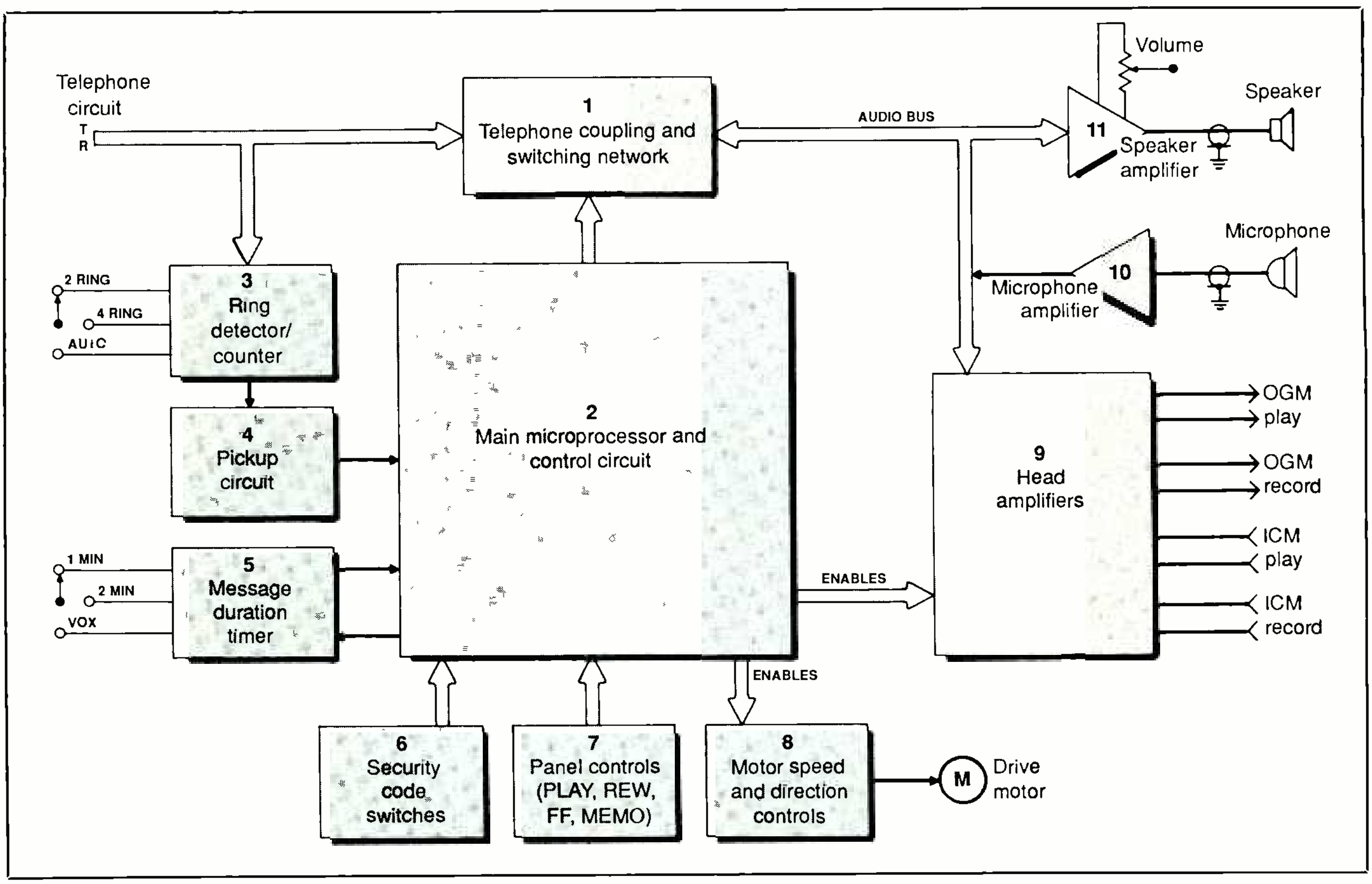


Fig. 1. Block diagram of a simple telephone answering machine.

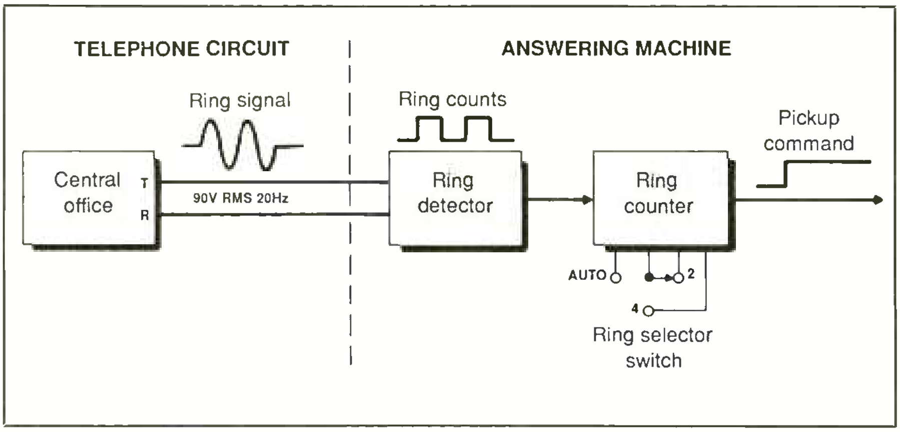


Fig. 2. Ring signal from Central Office alerts answering machine to pick up line after preset number of rings.

the tape and amplify those signals for distribution by the switching network. Information to be stored on-tape is conditioned by the record amplifiers and output through the recording heads to the tape(s).

(10) **Microphone Amplifier.** This portion of the system simply conditions the speech signal from the microphone and sends it to the switching network.

(11) **Speaker Amplifier.** This is an audio power amplifier that drives the answering machine's speaker from the switching network.

Machine Operation

The modern telephone answering machine operates in a very orderly and logical manner. The procedure is as follows:

• *Picking Up the Line.* A 90-volt ac 20-Hz ring signal is sent from the telephone company's central office to the called telephone instrument whenever a connection is made to the line to signal an incoming call (Fig. 2). The Ring Counter circuit in the answering machine detects the ring signal and generates a counting pulse for each series of rings. Virtually all machines are equipped with a RING SELECTOR switch that can be set to allow a certain number of ring cycles to pass before it enables the Pickup Circuit (Fig 1). Typical settings for this switch are for two rings, four rings, and "Toll Saver."

Toll Saver is a clever feature that lets the line ring four times before making a connection when there are no messages and only twice when there is at least one recorded message. This is handy when making a toll call to check on messages by remote because you can hang up the handset after the second ring if the machine is not activated without generating a toll charge, saving on the cost of expensive long-distance connect charges.

When the appropriate number of rings have passed, the Pickup Circuit activates the main control, which then switches in the Telephone Coupling Circuit to make the connection to the line. The caller hears only a click as the machine picks up.

• *Outgoing Message (OGM).* The Control Circuit activates the tape motor and the OGM play mechanism, which then plays the outgoing message tape. The caller hears the outgoing message that is read by the OGM play head, amplified and coupled into the active telephone line by the telephone coupling circuit. Depending upon the design of the particular machine, the OGM can be made to play through the speaker as well as being transmitted over the telephone line to the caller.

The OGM is generally recorded on an "endless" cassette tape with a conductive strip that joins both ends. As this strip passes an internal sensor at the end of the recorded outgoing

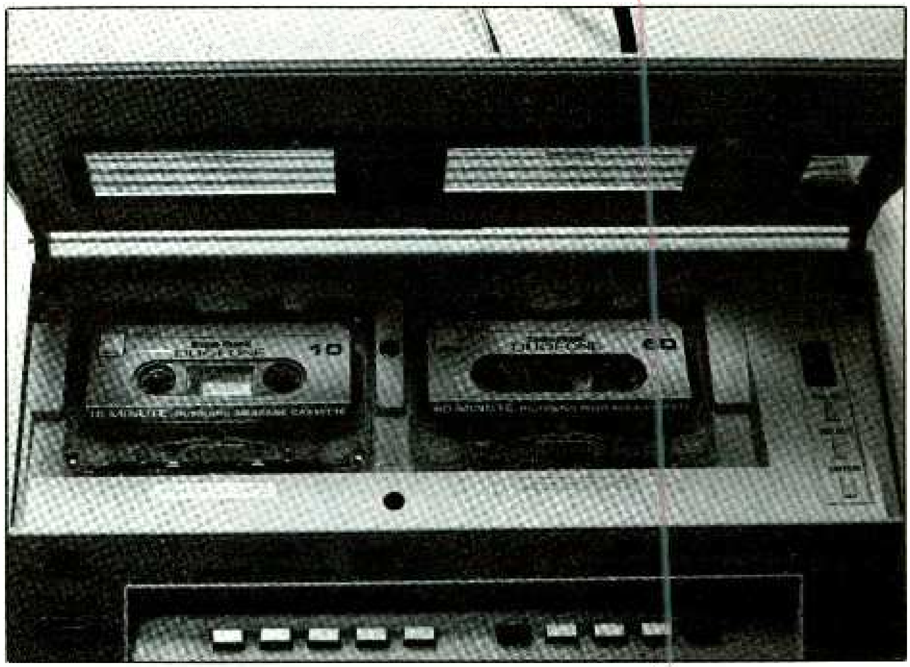


Photo shows OGM and ICM tapes inserted into a Radio Shack Realistic-brand answering machine.

message, the Control Circuit is signaled to stop the OGM cycle and begin the ICM cycle. Since the OGM tape plays until the conductive strip is sensed, an outgoing message can be of any duration up to the time length of the tape on which it is recorded. Common OGM tape lengths are 30, 60 and 90 seconds.

Another method of controlling the OGM cycle is the recording of a series of control tones at certain points on the tape. The answering machine recognizes these tones as OGM plays and controls the cycle accordingly. Typically, a control tone marks the beginning and end of an OGM. Since control tones can be located anywhere on a tape, the OGM can be just about any length. This is also the technique commonly employed in units in which a single cassette is used to hold both the OGM and any ICMs. Presence of the OGM control tones allows an answering machine to know where the OGM ends and to begin the ICM sequence. The tone before the beginning of the OGM allows the machine to position itself at the beginning of the OGM once again as it resets for the next call.

• *Incoming Message.* When the outgoing message is finished, the Control Circuit turns off the OGM play mechanism and switches in the ICM record mechanism (Fig. 3). The telephone Coupling Circuit switches the telephone line to the ICM play head as well as the speaker. The Control Circuit starts the tape motor and generates a short tone—the start-recording tone or beep—that the caller hears. Everything the caller says is then heard over the machine's speaker and passed to the ICM recording head to be placed on the ICM tape (Fig 4). This is what makes Call Screening possible.

The type of cassette tape used depends on the design of the individual answering machine. Some machines use one or two standard-size audio cassettes similar to those used in home and car stereos; others make use of one or two microcassettes to store the OGM and ICMs. Regardless of which size cassette is used, the operation of the answering machines is the same.

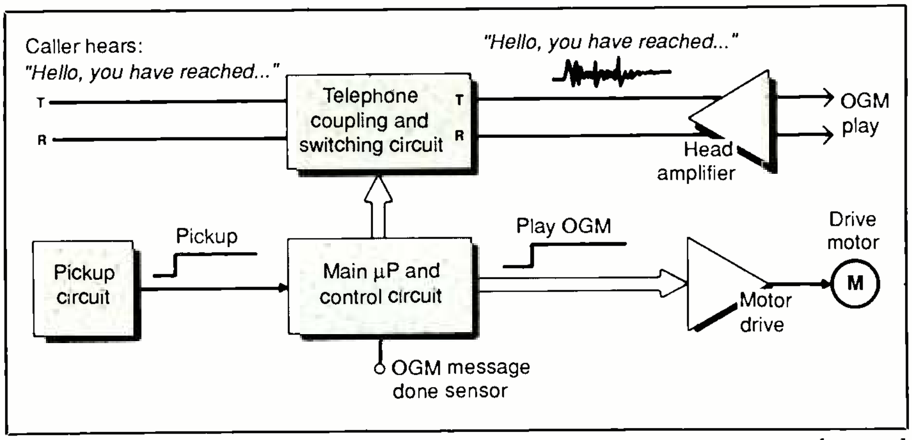


Fig. 3. When outgoing message is finished, Control circuit stops play and switches in incoming-message record head.

The ICM cycle continues until the selected message duration times out. A variety of time selections are used in telephone answering machines. There are usually a short fixed time of 1 minute or less, a long fixed time of 2 minutes or more, and a VOX voice-activated selections. The VOX causes the machine to record an ICM for as long as the caller speaks, with no time limit. If the caller stops speaking for a few seconds, the VOX times-out and causes the machine to disconnect. Many current machines build a VOX function into their fixed times. With this arrangement, a 30-second duration selection will cause the machine to record an ICM for 30 seconds or until the caller stops talking for a few seconds, whichever comes first.

The number of messages that can be recorded on one side of a tape depends on the length of the tape and the selected recording duration. If a 60-minute (30 minutes per side) cassette is used and a 2-minute time limit is chosen, the minimum number of messages that can be recorded on one side of the incoming-message tape is 30/2, or 15 messages.

• *Disconnecting.* Modern telephone company central-office facilities usually have a Calling Party Control (CPC) circuit. When the caller hangs up the telephone, a brief interruption in the *called* party's telephone circuit is generated by the central office. This break can be short (about 10 milliseconds) or long (about 350 milliseconds). A machine with CPC control will disconnect on that signal.

The CPC switch on an answering machine usually has LONG and SHORT duration positions (Fig. 5) that allow for differences in central-office equipment. If the length of the central-office CPC signal is unknown, it is usually a good idea to initially set the machine's CPC switch to the LONG position. If the line is equipped with Call Waiting, it may be necessary to leave the CPC switch set to LONG because Call Waiting often uses short pulses for other functions, which can easily confuse an answering machine and cut off a caller in mid-sentence if the switch is set to the SHORT position.

If in the LONG mode the machine records a lot of unwanted sounds (dial tone or a hang-up alarm from the central office, for example) after the caller hangs up, the machine is not interpreting the long CPC pulses. The solution to this is to set the CPC switch to the SHORT position. If the machine still does not disconnect promptly and continues to record un-

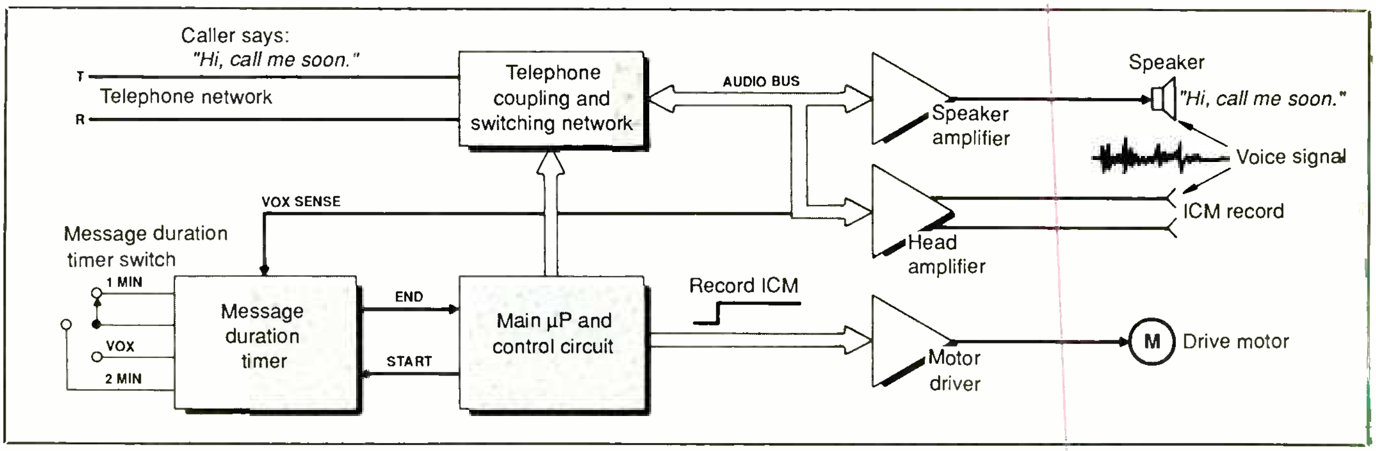


Fig. 4. Control Circuit switches in internal speaker to permit everything caller says to be reproduced through speaker.

wanted noises, the central office in your area may not be equipped with CPC signals. In this event, set the CPC switch to OFF.

Disconnection occurs automatically when the preset recording time expires or the VOX sensor signals that the caller has stopped talking for more than a few seconds. After the Control Circuit disconnects the Telephone Coupling Circuit from the line, it resets the OGM and message-duration timer for the next cycle. Machines that have message displays increment or blink at this time to signal that an incoming message has been recorded.

• *Playback.* Typically, PLAY, REWIND and FAST FORWARD buttons are provided on the front panel of an answering machine to permit the ICM tape to be manipulated as in any other cassette recorder (Fig 6). The PLAY button causes the control circuit to start the tape motor, engage the ICM play mechanism and switch the amplified audio signal from the ICM play head to the machine's speaker output. Sound level from the speaker is adjusted as desired with a VOLUME control in the Speaker Amplifier circuit. In playback mode, the Telephone Coupling Circuit makes no connection to the telephone line. If remote control is used for playback, however, a connection *is* made to the phone line.

Features

A wide variety of features appear in today's answering machines. These vary according to the make and model of a given answering machine. Among those that can be found are listed here, though not all machines have all of them.

• *Memo.* This feature permits the answering machine to be used as a traditional audio cassette recorder (Fig 7). Pressing the MEMO button causes the ICM tape to start and record just like a regular incoming message. However, instead of recording the caller's voice from the telephone line, the voice of the person speaking is recorded through the machine's pickup.

Use of the memo function makes no connection to the phone line. Pressing the MEMO button again exits

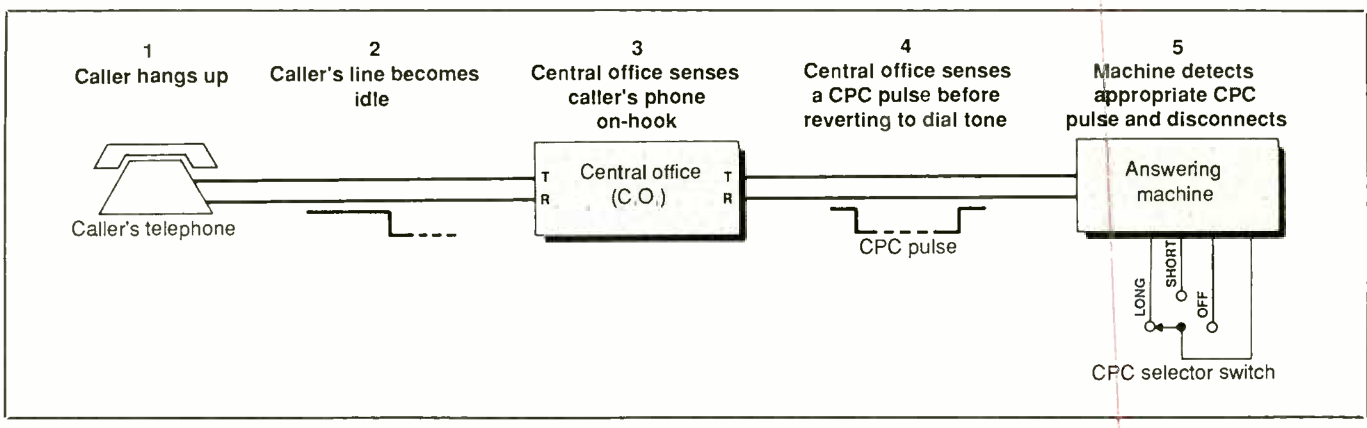


Fig. 5. The CPC switch usually offers a choice of pulse- duration and "off" positions to accommodate differences in Central Office equipment.

memo mode, increments the ICM count and displays the presence of the memo on the tape just as it would a normal incoming message. The memo function can be very useful when it is necessary to leave a message to other people who share a machine and check messages.

• *Message Display.* This indicates the number of messages that have been recorded on the ICM tape. Discrete LEDs are often used for this purpose. In normal operation, a typical indicator may be on constantly when there are no messages. After an ICM has been recorded, the LED begins to blink. In some machines, the LED blinks at a fixed rate, regardless of the number of recorded messages. In most such systems, the LED blinks to signal the number of waiting messages. For example, a LED could blink five times to indicate five waiting messages, briefly extinguish to signal the end of the count and then continue to blink to signal the count. The cycle repeats until the messages are played back, at which point, the circuit resets and causes the LED to remain lit continuously once again until new messages are recorded.

Some answering machines employ seven-segment numeric displays to show the number of recorded ICMs. The counters in most such machines count from 00 to 99. Seven-segment LEDs and LCDs are used for this task. Upon message playback, the counter resets and the display reads "00" again until new incoming messages are recorded.

Newer, more expensive machines may use a built-in speech synthesizer to actually announce the date and time, as well as the number of recorded messages. Voice synthesis may also be used to provide vocal prompts from the machine to guide the user through each operating step.

• *Paging.* Automatic paging is rarely found in answering machines and then only in more expensive ones. When the machine answers an incoming call and finishes recording a message, it automatically picks up the line again and dials out to any number (or numbers) preprogrammed into it. After dialing, the machine allows the line to ring for a set amount of time. If that line is answered, the machine sends an identification tone that indicates at least one message has been recorded. If there is no answer from the ringing line, the machine will re-dial the number periodically until the line is answered.

Paging is a very handy feature to use with pocket beepers when such service is available. Upon acknowledgment of a page, someone can call into the machine to access waiting messages.

• *Remote Control.* This is used to unlock the messages contained in the machine and play them back over the phone line to the calling instrument. To use this feature, a caller dials the number of the instrument to which the machine is connected. After the selected number of rings, the machine picks up the line and begins to play the OGM. At this point, the remote controller is placed against the mouthpiece of the telephone handset and a PLAYBACK button is pressed to generate a tone/pulse train that should be unique to that particular remote. The Control Circuit in the machine compares the code to the code in its memory. When a code match is obtained, the answering machine stops and resets the OGM, then rewinds and plays back the ICM tape, and transmits any recorded messages back to the calling instrument over the telephone line (Fig. 7).

The caller hangs up after the last message is played back and the machine immediately disconnects from the line and resets itself to be ready to record the next incoming-call message.

If the remote controller and answering machine codes do not match, the machine will complete the outgoing message and record the incoming message in the normal manner, simply ignoring the remote controller. In some machines, the codes for the remote and machine are fixed. In many other models, however, code selector switches permit the user to enter the

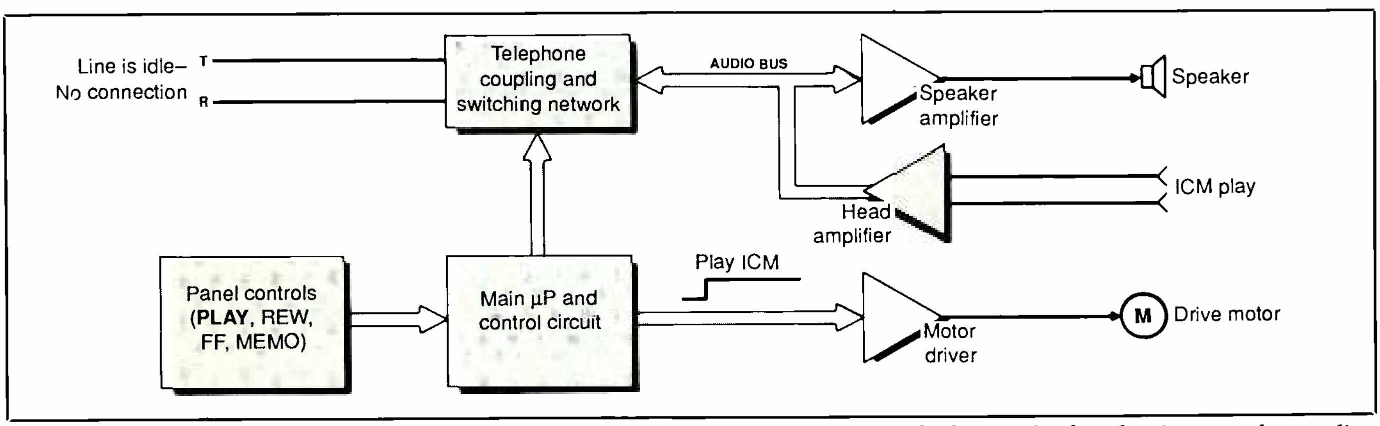


Fig. 6. Buttons on an answering machine permit the incom ing-message tape to be be manipulated as in any other audio cassette recorder in the play mode.

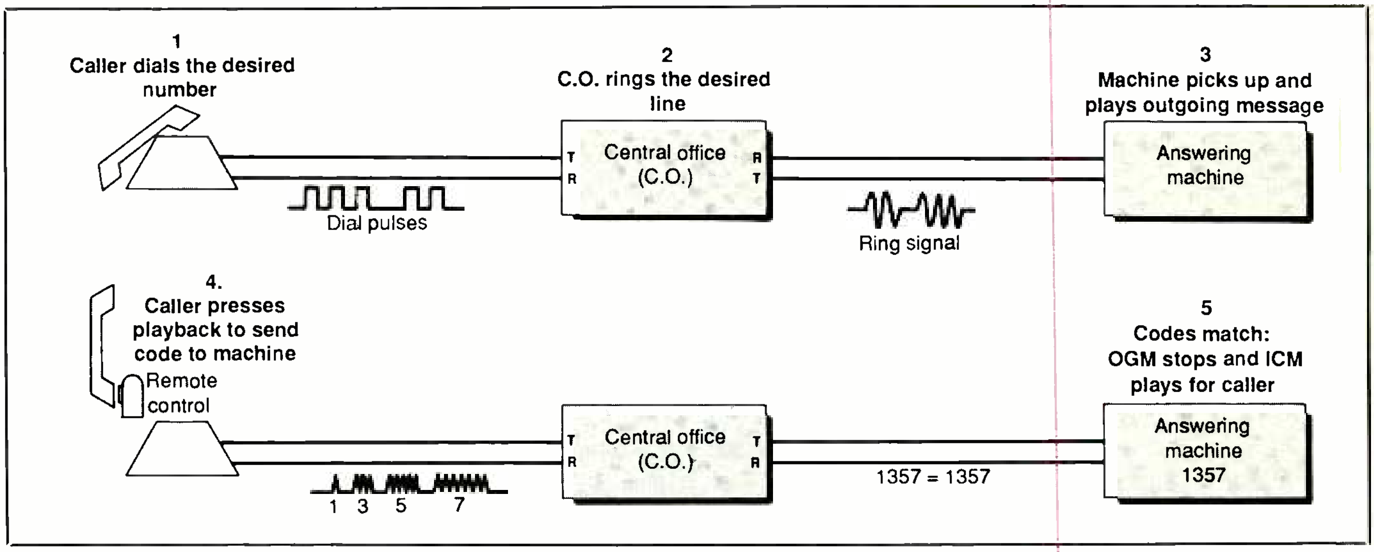


Fig. 7. When using remote control, the answering machine resets the outgoing message tape, rewinds and plays the incoming-message tape, and transmits any recorded messages back to the calling party.

number he desires and to change that code at will. Whatever the case, the remote controller and answering machine codes *must* be the same for the system to operate properly.

Older telephone instruments employ carbon-microphone transmitting elements in their handsets. With the passage of time, the carbon granules inside such a microphone can pack and shift, resulting in poor audio quality. When this occurs, the distortion introduced by the microphone may prevent the answering machine from recognizing the proper code from its remote controller. Should this occur, you simply tap the handset several times gently on a firm surface to loosen the carbon granules and try the remote again.

• *Beeperless Remote Control.* A hand-held beeper is an inconvenience if it breaks, is lost, loses battery power or is not at hand. Many current answering machines employ a beeperless system that permits the user to access messages and other machine functions from another telephone via a Touch Tone™ (DTMF) or compatible telephone keypad instead of using a separate beeper device. Consequently, beeperless operation is preferred by most answering-machine manufacturers.

Beeperless access can vary slightly from machine to machine. Simple beeperless machines are able to only play back recorded messages, while more complex machines will accept subsequent codes to control such other functions as: change OGM, turn on/off the machine, save re-

(Continued on page 72)

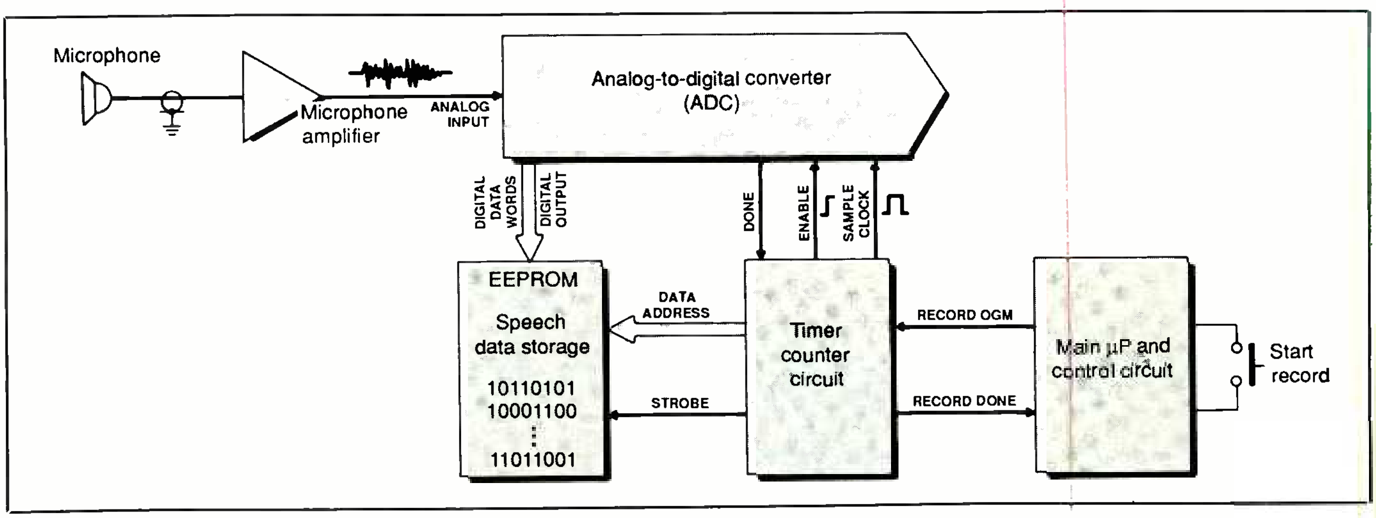


Fig. 8. One possible approach for assembling a voice digitizer/recorder.

Dual-Polarity Power Supply

This project offers a dual-polarity power source that is adjustable from ±1.2 to ±37 volts and a built-in digital-numeric metering system

By Tim Swogger

Modern electronic circuits often require a variety of voltages and two polarities. The Dual-Polarity Power Supply described here fulfills the needs of virtually all solid-state circuits you are likely to encounter or build. It offers a wide range of adjustable output voltage at moderate current. The design of the circuitry gives you a choice of adjustment ranges, from a low of 1.2 volts to a high of 24 or 37 volts, depending on the power transformer selected.

As a bonus, the Power Supply features a built-in three-decade LED numeric metering system that can be used to monitor output voltage or current. The project uses readily available components and is relatively low in cost to build compared to equivalent commercial supplies.

About the Circuit

Shown in Fig. 1 is the complete schematic diagram of the circuitry used in the Dual-Polarity Power Supply. The positive and negative voltage outputs that appear at binding poses *BP1* and *BP3*, both referenced to common or ground binding post *BP2*, are adjustable. The circuit is designed to give an adjustment range on both supply outputs of from ±1.2 volts to a high that depends on the choice of power transformer *T1*. If you use a 48-volt transformer, the maximum output voltage will be about ±24 volts; alternatively, use of a 70-volt transformer, maximum output will be about ±35 volts.

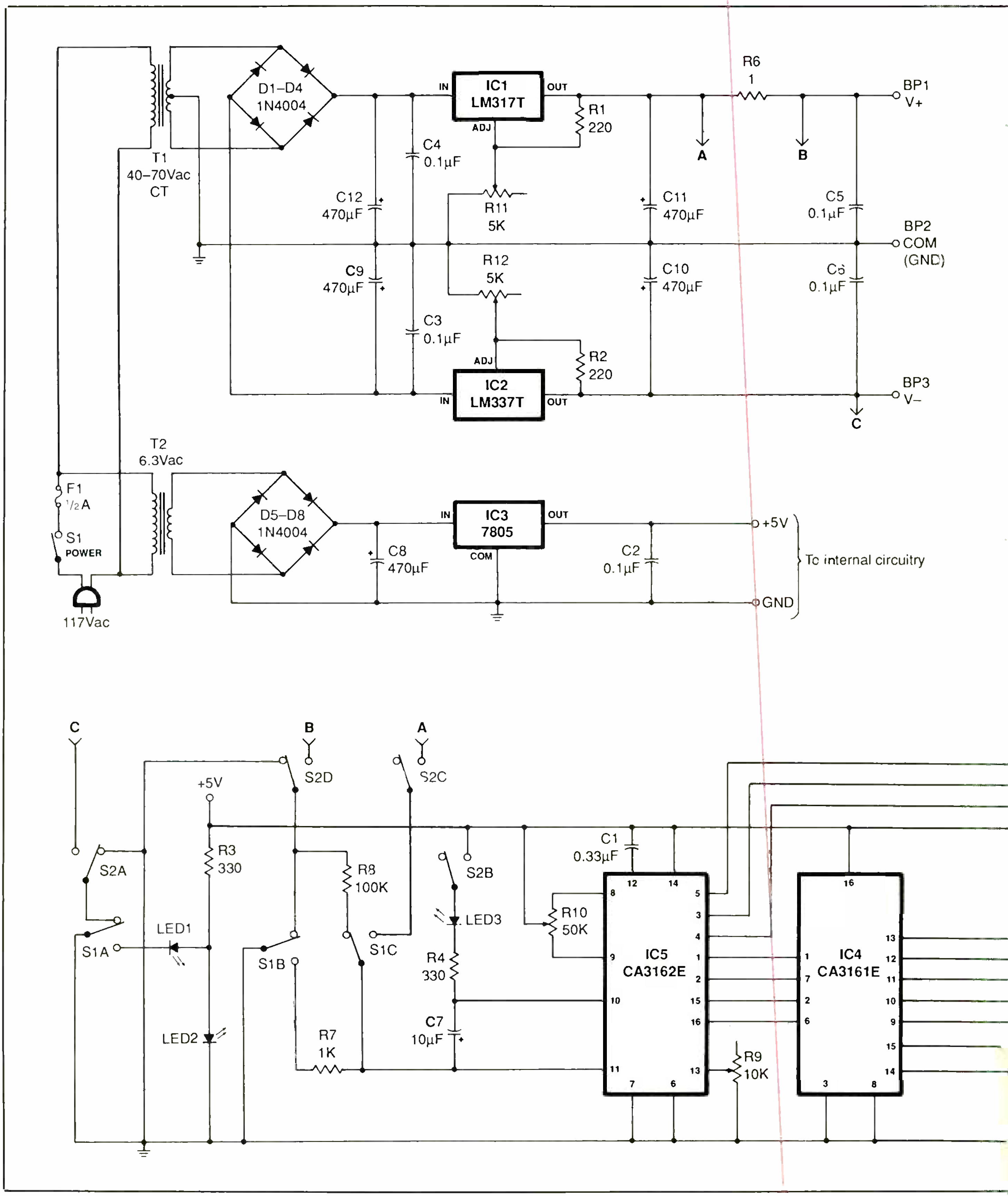
By setting switch *S2* to its alternate positions, you can monitor either the positive or negative output voltage. Switch *S1* allows you to monitor positive or negative current, depending on the setting of switch *S1*.

Operation of the circuit begins with closing POWER switch *S1*. This delivers 117-volt ac line power to the primary of power transformer *T1*. The output voltage that appears across the secondary of *T1* is applied to the bridge rectifier composed of diodes *D1* through *D4* (these individual diodes can be replaced by an integrated bridge-rectifier module).

The pulsating dc emerging from the rectifier assembly is fed to filter capacitors *C9* in the negative supply and *C12* in the positive supply sections. The reference point for the two supply sections is established by connecting the center tap of the transformer to circuit ground.

Once the pulsating voltages are filtered to pure dc, they are fed to adjustable voltage regulators *IC1* in the positive supply and *IC2* in the negative supply. From the outputs of both regulators, the final voltages are fed to *BP1* and *BP3*, where they are made available for external use. This makes up the basic Dual-Polarity Power Supply. The remaining circuitry is for metering purposes.

Adjustment range for the positive and negative supplies is provided by POSITIVE and NEGATIVE adjust controls *R11* and *R12*, respectively. Capacitors *C11* and *C10* provide post-regulation filtering for *IC1* and *IC2*,


D1–D4
1N4004
IC1
LM317T
IN
OUT
ADJ
R1
220
R6
1
BP1
V+
A
B
T1
40–70Vac
CT
C4
0.1µF
C12
470µF
R11
5K
C11
470µF
C5
0.1µF
BP2
COM
(GND)
C9
470µF
R12
5K
C10
470µF
C6
0.1µF
C3
0.1µF
R2
220
IC2
LM337T
BP3
V–
C
T2
6.3Vac
F1
1/2 A
S1
POWER
D5–D8
1N4004
IC3
7805
COM
C8
470µF
C2
0.1µF
+5V
GND
To internal circuitry
117Vac
S2D
S2C
+5V
R3
330
R8
100K
S2B
C1
0.33µF
S2A
LED1
LED3
R10
50K
IC5
CA3162E
IC4
CA3161E
S1A
S1B
S1C
R4
330
LED2
R7
1K
C7
10µF
R9
10K

PARTS LIST

Semiconductors

D1 through D8—1N4004 or similar silicon rectifier diode (or substitute 100-PIV, 5-ampere bridge-rectifier modules—see text)

DISP1,DISP3,DISP3—Common-anode 7-segment LED numeric display (MAN72A or equivalent)

IC1—LM317T adjustable positive voltage regulator

IC2—LM337T adjustable negative voltage regulator

IC3—7805 fixed +5-volt regulator

IC4—CA3161E BCD-to-7-segment decoder/driver

IC5—CA31262E three-digit dual-slope A/D converter

LED1,LED2,LED3—Jumbo red light-emitting diode

Q1,Q2,Q3—2N3906 or similar general-purpose npn silicon transistor

Capacitors

C1—0.33-μF, 16-volt Mylar or other type

C2 thru C6—0.1-μF, 50-volt ceramic disc

C7—10-μF, 35-volt electrolytic

C8 thru C12—470-μF, 50-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1,R2—220 ohms

R3,R4,R5—330 ohms

R6—1 ohm (4-watt or greater)

R7—1,000 ohms

R8—100,000 ohms

R9—10,000-ohm pc-mount trimmer potentiometer

R10—50,000-ohm pc-mount trimmer potentiometer

R11,R12—5,000-ohm linear-taper, panel-mount potentiometer

Miscellaneous

BP1,BP2,BP3—Five-way binding post (color coded for easy visual identification of polarity)

F1—0.5-ampere slow-blow fuse

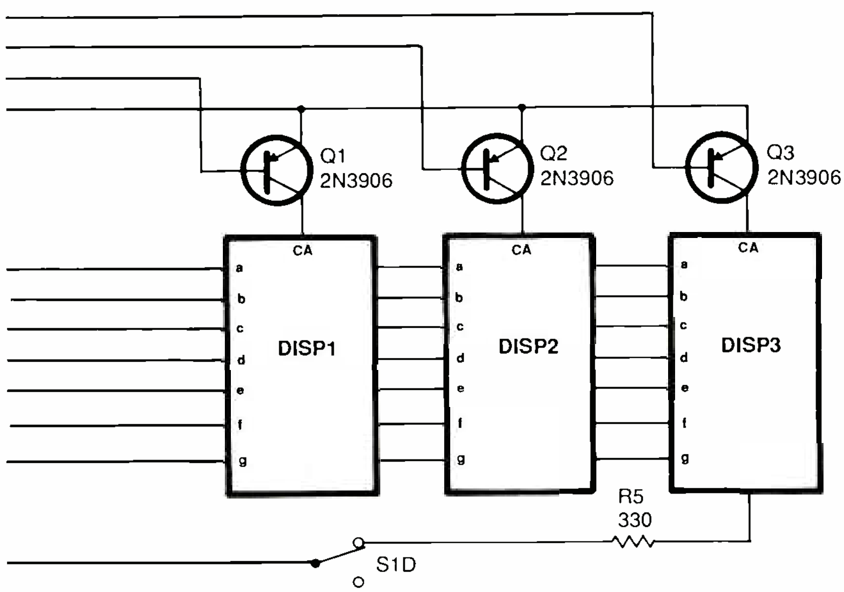
S1,S2—4pdt switch

S3—Spst toggle or slide switch

T1—40-to-70-volt rms, center-tapped power transformer (see text)

T2— 6.3-volt power transformer

Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (a 5.9″ × 5.3″ × 3.0″ metal instrument case is suitable for basic power-supply circuitry; if you add optional 5-volt power supply, select a larger enclosure—see text); DIP IC sockets; control knobs for R11 and R12; holder for F1; ac line cord with plug; small rubber grommets for mounting LEDs; rubber grommet for line cord entry hole; small-diameter heat-shrinkable or other insulated tubing; dry-transfer lettering kit; clear spray acrylic; machine hardware; hookup wire; solder; etc.



while bypass capacitors *C5* and *C6* provide noise immunity on the two output voltage lines.

A separate power supply is provided for powering the metering/display circuitry. This supply is composed of power transformer *T2*, the bridge-rectifier assembly made up of diodes *D5* through *D8* (again, the discrete rectifier diodes can be replaced with an integrated bridge-rectifier assembly), filter capacitor *C8* and fixed +5-volt voltage regulator *IC3*. The regulated output of this supply is distributed throughout the remainder of the circuitry.

Voltages fed to the pin 11 input of three-digit, dual-slope A/D converter *IC5*. This IC converts the analog voltage into a digital BCD equivalent at output pins 1, 2, 15 and 16. These outputs are directly coupled to input pins 1, 7, 2 and 6, respectively, of BCD seven-segment decoder/driver *IC4*. In turn, *IC8* provides the driving voltage for the selected segments in LED numeric displays *DISP1*, *DISP2* and *DISP3*.

The numeric displays are enabled by output lines from 4, 3 and 5 of *IC5* through driver transistors *Q1*, *Q2* and *Q3*. The collectors of these transistors are connected to the common-anode (CA) pins of *DISP1*, *DISP2* and *DISP3*, respectively. When any given transistor is conducting, it turns on (enables) the LED numeric display to which it is connected.

Trimmer control *R10* across pins 8 and 9 of *IC5* is used to zero the display. Trimmer control *R9* between pin 13 of *IC5* and ground calibrates the voltage reading displayed.

The display must always be zeroed before connecting the output of the Power Supply to the display. (Remember that minimum supply potential is approximately 1.2 volts.)

Fig. 1. Complete schematic diagram of the Dual-Polarity Power Supply circuitry.

Once the display is zeroed by adjusting the setting of *R10*, calibration against a meter of known accuracy can be accomplished using *R9*.

Three light-emitting diodes are included in the circuit. Power-on indication is provided by POWER *LED2*. Separate + and − voltage/current indications are provided by *LED3* and *LED1*, respectively. Power resistor *R6* provides current limiting for the metering circuit when the current-monitoring function is selected.

If you wish to incorporate into your bench power supply a fixed + 5-volt output, you can use any of a number of regulated supply designs. You can find schematic diagrams for these in a wide variety of electronics magazines and books.

Use of a separate 5-volt supply requires a third power transformer that connects directly across the incoming ac line. Install a separate 5V POWER switch to enable and disable this supply as needed, as well as a separate LED indicator to inform you when this auxiliary supply is on and off. If you go this route, be sure to include a separate fuse of appropriate rating in series with the 5V POWER switch and primary lead of the new power transformer.

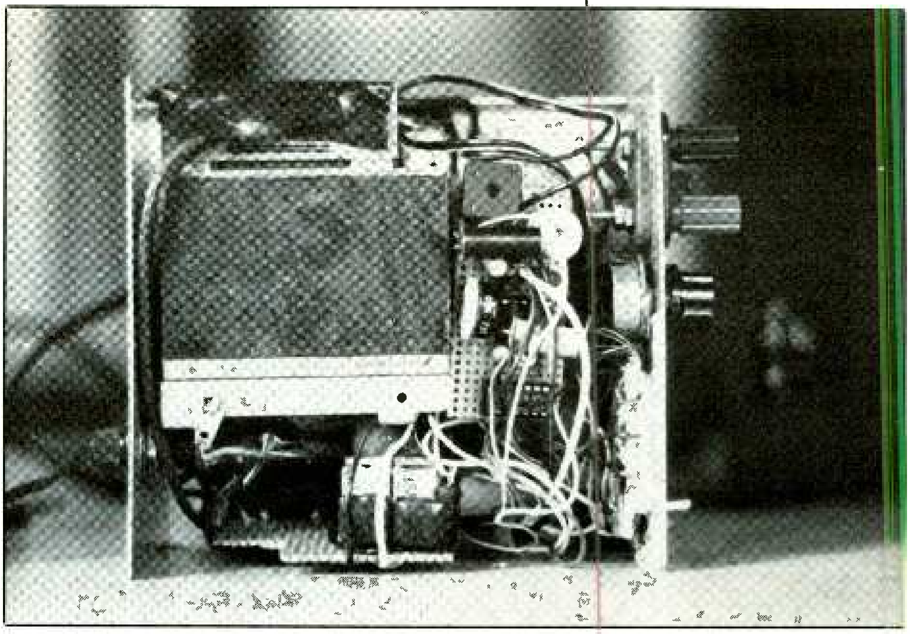


Fig. 2. Prototype of project was built on perforated board using point-to-point wiring. The circuitry is housed inside a standard instrument enclosure.

Construction

There is nothing critical about component placement or conductor runs. Therefore, you can use any wiring technique that suits you to build the project. For example, if you wish, you can design and fabricate a pair of printed-circuit boards on which to mount the basic power supply circuitry and the metering circuitry. Otherwise, use perforated board that has holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware.

Whichever way you go, be sure to use sockets for the two DIP ICs and LED numeric displays. Wire first the basic power-supply circuit and then the metering circuit and its power supply on boards that are as small as possible. Make certain in both cases that you properly orient all diodes and electrolytic capacitors and properly base any integrated bridge rectifier assemblies used and the three voltage regulators. Mount a heat sink on the tabs of voltage regulators *IC1* and *IC2*.

Do *not* plug *IC4* and *IC5* in their sockets. These ICs are to be installed only after you have conducted initial voltage checks and are certain that the circuitry is correctly wired.

POSITIVE and NEGATIVE controls R5 and *R12* in the basic power supply section mount off the board, as does power transformer *T1*. Trimmer controls *R9* and *R10* mount on the metering circuit board, while *T2* can mount on or off the board, depending on its size and weight.

Once the two circuit-board assemblies have been wired, temporarily set them aside. Now machine the enclosure. The type and size of enclosure you use will depend on how you configure your Power Supply.

The circuit-board assemblies should require very little room inside the enclosure. The power transformer(s) will have a significant effect on enclosure size, as will the amount of front-panel space required for the LED numeric display, switches, controls, LEDs and binding posts. If you incorporate a fixed 5-volt supply in your project, you must also take into account the space required for it.

Machine the enclosure as needed. That is, drill mounting holes through the front panel for the POSITIVE and NEGATIVE adjust controls, output binding posts, POWER switch(es) and LEDs. Also, cut slots in the panel for the two pushbutton switches and window for the LED numeric display. Locate these slots accurately!

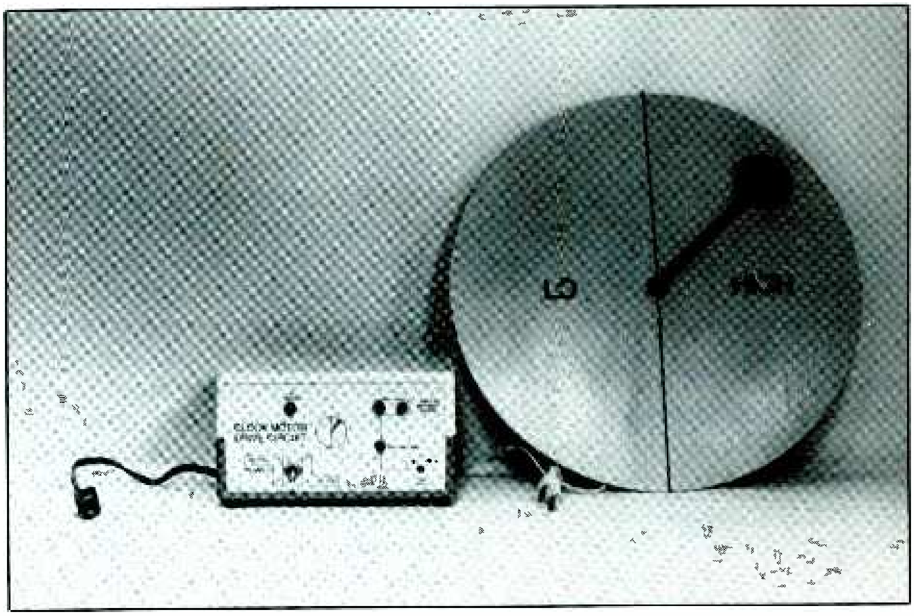
Then drill the mounting holes for the circuit-board assemblies, fuse holder(s) and transformers through the floor and/or rear panel of the enclosure. Also drill an entry hole for the ac line cord. When you are finished machining the enclosure, deburr all drilled holes and cut slots to remove sharp edges, cement a red transparent plastic filter over the display window cutout and line the en-

(Continued on page 77)

A Tide Clock

Keeps track of the rise and fall of water affected by ocean tides

By Joseph P. O'Connell



The ebb and flow of tidewater, being most influenced by the moon, ordinarily do not occur at the same rate as the standard 24-hour solar clock. Therefore, a different kind of clock is needed to keep track of high and low tides—a Tide Clock like the project presented here. It can be a highly valued indicator for people living near a shoreline. whether for swimming, boating or fishing.

At the heart of our Tide Clock is a 117-volt ac power supply that drives synchronous motors from either a 12-volt dc or 117-volt ac power source. The project produces up to 300 milliamperes, which is enough current to drive several small motors simultaneously. Frequency adjustment is accomplished with a potentiometer and either an external frequency counter or a clever beat-frequency display that especially simplifies calibration of the power supply at frequencies close to 60 Hz.

Although in this article we will concentrate on using the power supply, which comprises the major portion of the project, in a Tide Clock application, there are many other uses for it. These include operating small appliances and powering a telescope drive motor for stargazing. Astronomers should appreciate the variable frequency control the project affords, allowing them to temporarily convert from solar drive to sidereal tracking.

Making of a Tide Clock

Our Tide Clock works on the assumption that there are two equal tide cycles per day, each comprising a high and a low tide. For all but a few locations on Earth, where coastal features cause irregular tide intervals, this is a valid assumption.

Most areas on Earth can be represented as discrete points on a rotating globe that pass through two high and two low tides with every revolution. Locations of the high and low tides are fixed by the moon. If the moon stood still, each revolution of the lighthouse depicted in Fig. 1 would take 24 hours exactly and anyone in the lighthouse would see the tide change every 6 hours. If this were the case, an ordinary clock could be used to tell when the high and low tides would occur. However, because the moon revolves around the Earth in the same direction as the latter is rotating, each revolution of the lighthouse with respect to the tides takes 25 hours and 50 minutes.

One way to represent this cyclical event is with a specially designed synchronous motor that makes one revolution every 12 hours and 25 minutes. Using this approach, two revolutions of the motor would be needed to complete every cycle of four tides. This approach makes it easy to use a "clock-face" arrangement with a single hand to point to the condition of the tides depicted on the face of the clock at any given moment for a given location.

Another approach to obtaining the same effect is to drive a standard clock motor at a slightly lower frequency than the 60 Hz of the standard ac line. With proper selection of drive frequency, the hours hand will complete one revolution around the dial face in 12 hours and 25 minutes instead of the usual 12 hours.

Rather than being fixed to either an ac or a dc power source, our Tide

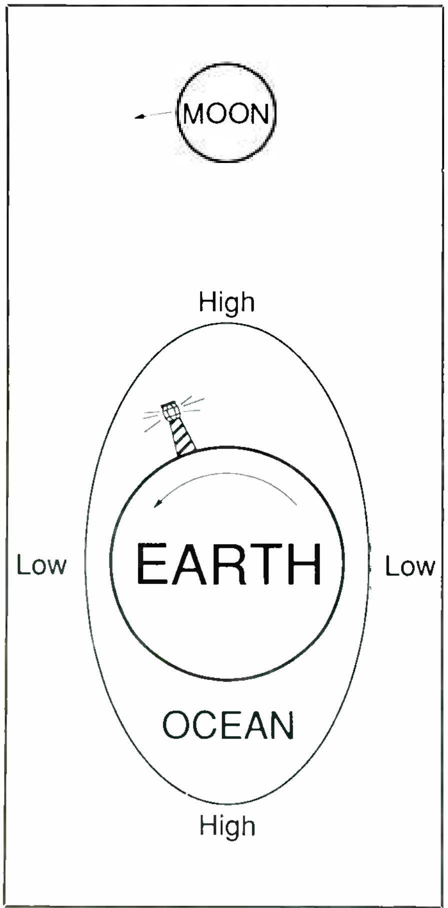


Fig. 1. With every rotation of the Earth relative to the moon, an observer in the lighthouse would see two high and two low tides.

Clock project incorporates both in a single electronics package. As can be seen in the lead photo, the Tide Clock actually consists of two units: a motor-driven clock mechanism with its special dial face and a separate electronics package that powers the motor. Though the project offers both powering options, the 12-volt dc electronic drive approach is likely to be of more widespread interest because it has uses beyond that of a simple Tide Clock application.

The unique characteristics of synchronous motors make this project possible and practical. Synchronous motors are employed in clocks and other electromechanical timing devices because their speed of operation depends on the ac line frequency used to drive them and on their reasonable immunity to wear, uneven loading and wide variations in powering voltage. Although designed to be driven by a 117-volt ac sine-wave signal, synchronous motors can operate satisfactorily with the square-wave drive the power supply in our Tide Clock delivers.

The dependence of synchronous motors on line frequency makes them both reliable in normal applications and easy to control in special applications. One such special application is the Tide Clock project presented here.

A synchronous motor can be thought of as a stepper motor whose output shaft advances a fraction of a revolution for every cycle of the ac drive signal. To complete a single revolution in 12 hours and 25 minutes instead of the 12 hours exactly it would normally require, a synchronous motor must be driven at a slightly slower frequency than normal. The new frequency must complete the same number of cycles in 12 hours and 25 minutes as the standard 60-Hz frequency completes in just 12 hours.

A frequency of 60 Hz completes 2,692,000 cycles in 12 hours. The frequency that completes the same number of cycles in 12 hours and 25 minutes is 57.9865772 Hz. A similar calculation for telescope drive motors reveals that the correct frequency to accurately accomplish sidereal tracking with a solar telescope drive is 60.1643 Hz. The power supply in this project offers more than this range of adjustment to meet a variety of application needs.

About the Circuit

The complete schematic diagram of the project's circuitry, including its ac-operated power supply but not including the drive motor, is shown in Fig. 2. Refer to this for the following explanation of circuit operation.

There are many ways to design an oscillator that will generate the required frequency for our Tide Clock. However, the simplest reasonably accurate approach is to build the circuit around an integrated-circuit oscillator chip. Of the oscillator chips that are commonly available, the Exar XR-2206CP was chosen for this project because it has the best thermal stability, rated at 20 ppm/°C.

The stability of the XR-2206CP chip is more than adequate for a clock with an analog display. This is because the error in reading the position of the hand against the clock dial alone is much greater than the oscillator would accumulate during weeks of worst-case operation.

Another advantage of the XR-2206CP shown for *IC2* in Fig. 2 is the low additional external component count required to configure a square-wave oscillator with this chip. In this circuit, the operating frequency of the oscillator built around *IC2* is determined solely by the capacitance of *C2* and series resistance of *R1* and FINE ADJUST potentiometer *R8*.

With a capacitance value of 1 microfarad, the resistance required is 17,425 ohms. A 16,000-ohm value for *R1* and 2,000-ohm value for the potentiometer permits the operating frequency of the oscillator to be adjusted over a range of 55.5 to 62.5 Hz, enough to allow for trimming purposes and to make up for slight discrepancies in component values.

The square-wave output at pin 11 of *IC2* is directly coupled to the input of *IC3* at pins 5, 7, 9 and 11. The unconnected pins of *IC2* provide a sine-wave output and some other functions that are not of interest here.

Capacitors *C1* and *C3* provide bypassing to ensure stable circuit operation. Their values are not critical to proper operation of the project.

Integrated circuit *IC3* contains six buffered inverter stages. The square-wave output from *IC2* that couples to pins 5, 7, 9 and 11 of *IC3* emerges inverted at pins 4, 6, 10 and 12 of the IC. Note that the output at pin 4 of *IC3* provides a means for monitoring

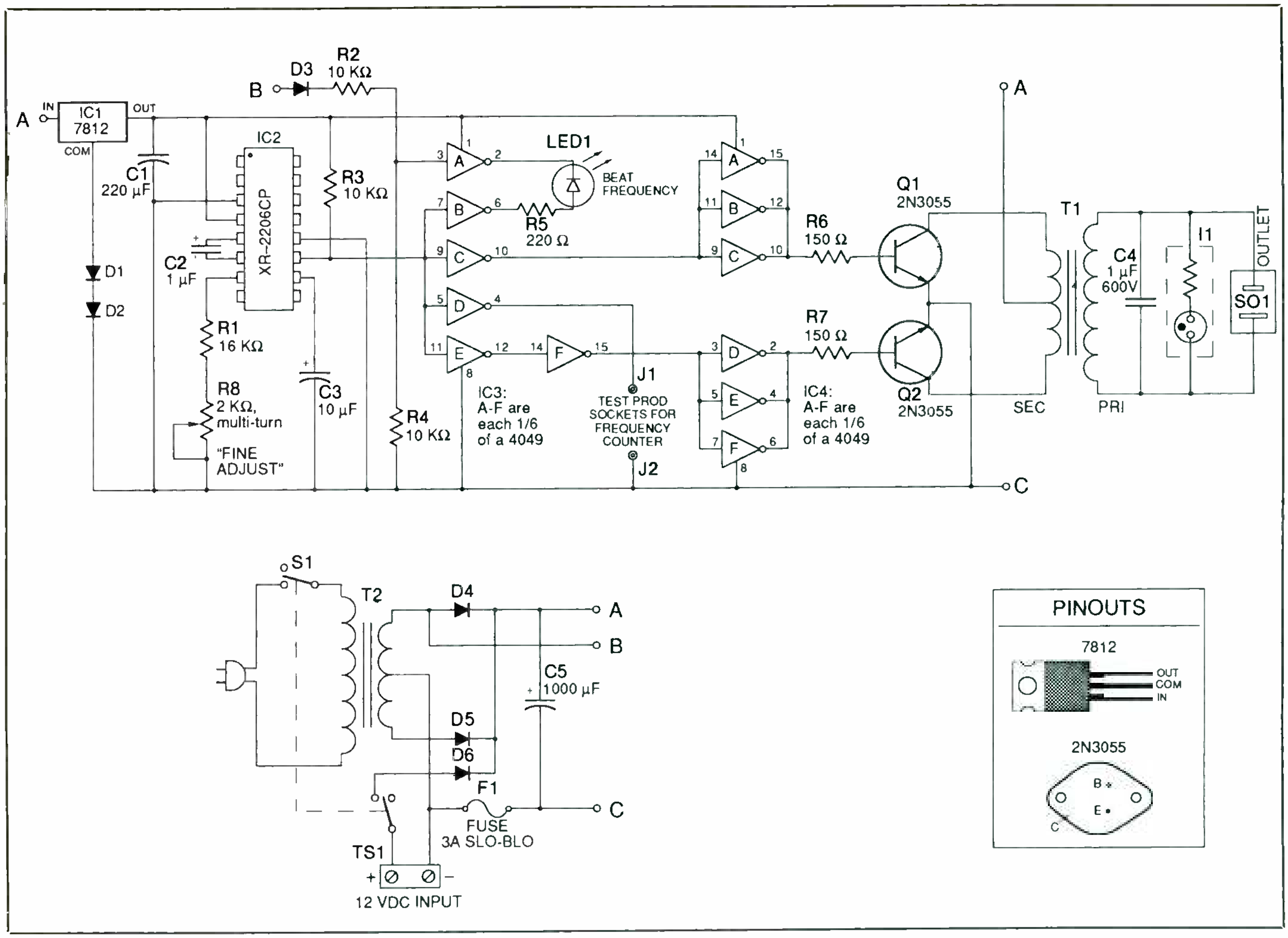


Fig. 2. Complete schematic diagram of Tide Clock electronic drive circuitry.

the frequency of the oscillator with an external frequency counter.

Inverters *IC3A* and *IC3B* drive light-emitting diode *LED1* at the beat-frequency (mathematical difference) of the oscillator and a 60-Hz pulse train obtained from the 117-volt ac line through *D3*, *R6* and *R7*.

The remaining inverters in *IC3* are used to obtain the alternating pulse trains needed to bias transistors *Q1* and *Q2*. One of these pulse trains passes through three such stages to reach *Q2*. This puts the drives to the two transistors out-of-phase with each other so that when one is conducting the other is held in cutoff, and vice-versa.

Integrated circuit *IC4* simply serves as a buffer between *IC3* and the two transistors. Note that there are two groups of three inverters connected in parallel in *IC4*, one for each transistor, to provide enough current to bias the transistors into saturation.

As *Q1* and *Q2* alternately conduct, each allows current to flow in alternating directions through the secondary of transformer *T1*. Capacitor *C4* suppresses switching transients, and the neon lamp *I1* provides visual indication when power is being delivered to ac OUTLET *SO1* into which the Tide Clock's display or other synchronous motor is plugged.

The ac/dc-driven power source, shown schematically at the lower-left in Fig. 2, is of conventional design. It permits operation from either a 12-volt dc or 117-volt ac source. A single double-pole, double-throw switch, *S1*, is provided for powering the project from the ac line and to switch between ac and dc modes.

The power supply provides a 60-Hz pulse train that is used to derive the beat frequency discussed above. During operation from a 12-volt dc source, the beat frequency display does not operate and *LED1* simply remains dark.

Although the power supply drives the inverter section of the main circuit directly, it passes through voltage regulator *IC1* before powering the more delicate timing and switching ICs. Using *D1* and *D2* in the return path of regulator *IC1* as shown increases the output of the chip by about 0.7 volt for every diode used.

PARTS LIST

Semiconductors

D1,D2,D3—1N4001 or any other silicon rectifier diode

D4,D5,D6—50-volt, 3-ampere (or more) silicon rectifier diode

IC1—7812 + 12-volt 3-terminal voltage regulator

IC2—XR-2206CP function generator (Exar Corp.)

IC3,IC4—4049 hex inverter

LED1—Red panel-mount light-emitting diode

Q1,Q2—2N3055 npn power transistor in TO-3 case

Capacitors

C1—220-µF, 16-volt electrolytic

C2—1-µF, 10% or better tolerance nonpolarized Mylar, propylene or polystyrene

C3—10-µF, 16-volt electrolytic

C4—1-µF, 400-volt or better nonpolarized

C5—1,000-µF, 16-volt electrolytic

Resistors (¼-watt, 5% tolerance)

R1—16,000 ohms

R2,R3,R4—10,000 ohms

R5—220 ohms

R6,R7—150 ohms

R8—2,000-ohm multi-turn pc-mount trimmer potentiometer.

Miscellaneous

F1—3-ampere slow-blow fuse

I1—Panel-mount neon-lamp assembly with current-limiting resistor

J1,J2—Panel-mount banana jack

S1—3-ampere or better dpdt toggle switch

SO1—Panel-mount ac receptacle

T1,T2—24-volt center-tapped, 2-ampere power transformer

TS1—Two-position panel-mount, screw-type terminal strip

Synchronous-motor analog clock (see text); printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); suitable enclosure (see text); solder-lug type terminal strip; sockets for all DIP ICs; fuse holder; materials for making clock face (see text); small-diameter heat-shrinkable tubing; suitable machine hardware; hookup wire; solder; etc.

The diodes used in this circuit assure that the power supply voltage for the ICs is at least 12 volts dc, even for a slightly out-of-specification regulator IC. If desired, *D1* and *D2* can be eliminated.

Construction

Most of the construction work for this project is entailed in wiring the Fig. 2 circuit and housing it in a suitable enclosure. What remains after that is taking apart an existing acline-powered analog clock to salvage the drive motor and fabricating a new face and hand to match its new function as a tide clock.

Owing to the fact that only low-frequency digital-level signals are used in this project, you can wire the Fig. 2 circuit on either a printed-circuit board or perforated board that has holes on 0.1-inch centers using suitable Wire Wrap or soldering hardware. A final alternative is to wire together the components on a Universal PC Board like the Radio Shack Cat. No. 276-168.

If you opt for printed-circuit construction, you can fabricate a suitable board using the actual-size etching-and-drilling guide shown in Fig. 3. From here on, we will assume pc construction. Once the board is ready to be populated, orient it as shown in Fig. 4. Begin wiring it by installing and soldering into place sockets for the DIP ICs. (Note that sockets for these chips are optional but highly recommended to ease replacement should any or all ICs fail during the life of the project.) Do *not* plug the ICs into their respective sockets until after preliminary voltage checks have confirmed that you have properly wired the project.

Continue wiring the circuit-board assembly by installing and soldering into place first the fixed resistors and then the diodes and capacitors. Make certain the diodes and electrolytic capacitors are properly oriented before soldering any of their leads into place. Next, install and solder into place multi-turn potentiometer *R8*, regulator *IC1* and the JUMPER wire. Use a cut-off resistor or capacitor lead or a solid bare hookup wire for the jumper.

Strip ¼ inch of insulation from both ends of eight 6-inch-long hookup wires. If you are using stranded hookup wire, tightly twist together the fine wires at both ends of all wires and sparingly tin with solder. Plug one end of these wires into the holes labeled Q1 BASE, Q2 BASE, FROM POWER SUPPLY "A" and "B" (two wires), LED1 CATHODE and LED1 ANODE (two wires), and TO J1 (two wires). Solder all wires into place.

Carefully examine all soldered connections. Solder any connection you missed and reflow the solder on any suspicious connections you encounter. Also, check for solder bridges, especially between the closely spaced pads for the IC sockets. If you locate any solder bridges, remove them with desoldering braid or a vaccum-type desoldering tool.

Now prepare the enclosure in which you will house the circuit-board assembly and power-supply circuitry. Make sure the enclosure you select is large enough to also accommodate POWER switch *S1*, power transformer *T2*, neon-lamp indicator assembly *I1*, power outlet *SO1*, screw-type terminal strip *TS1* fuse *F1* in its holder and a solder-type terminal strip on which to mount diodes *D4*, *D5* and *D6* and capacitor *C5*.

Machine the enclosure as needed to mount the circuit-board assembly, power transformer and diode/capacitor arrangement on a terminal strip and the fuse holder on the floor panel. Through the front panel, drill mounting holes for the LED, banana jacks, neon-lamp assembly and POWER switch. Also drill an access hole for *R8* in a location at the lower-right that provides easy access to the adjustment screw when the circuit-board assembly is mounted in place. Details for machining this panel,

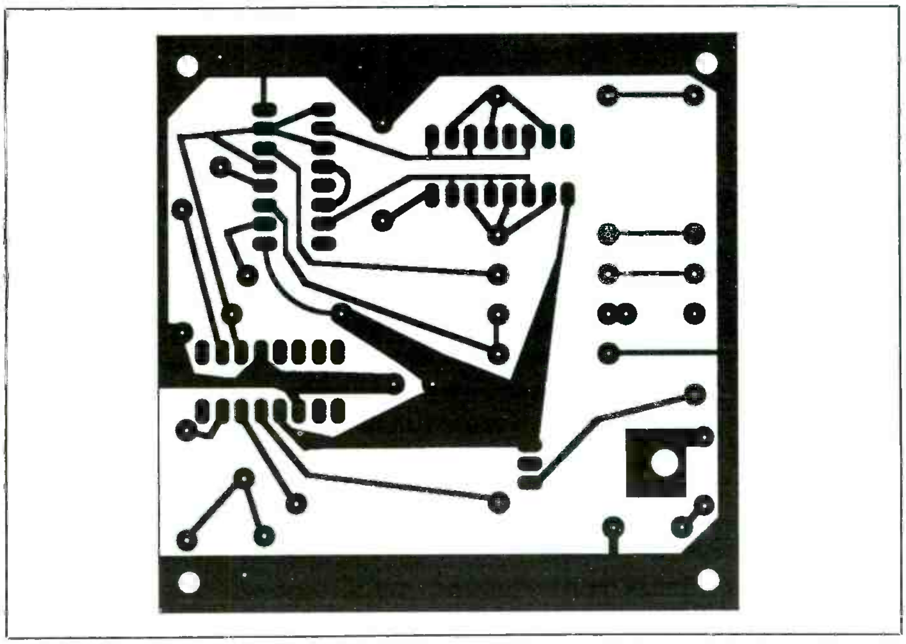


Fig. 3. Actual-size etching-and-drilling guide for project's printed-circuit board.

along with typical lettering, are shown in Fig. 5.

On the rear panel of the enclosure will be mounted the two-position screw-type terminal strip, power transistors *Q1* and *Q2*, transformer *T1* and receptacle *SO1*. Also, drill a hole to provide entry for the ac line cord. Machining details for this panel are shown in Fig. 6.

After all machining is done, deburr all holes and cutouts to remove sharp edges. Then paint the front panel, if desired. When the paint has fully dried, label the front panel with a dry-transfer lettering kit. Protect the lettering with two or more light coats of clear acrylic spray, allowing each to dry before applying the next.

When the enclosure is ready, mount the circuit-board assembly in place with suitable-length spacers and 4-40 machine hardware. Mount the power transformer, solder-type terminal strip and fuse holder into place. Then, referring to Fig. 2, carefully wire the power-supply circuit. Make certain that you do not mistake the primary leads of the transformer for the secondary leads and that the diodes are properly polarized.

Place a rubber grommet in the the ac line cord's entry hole in the rear panel. Then feed the unprepared end of the line cord through the hole and tie a strain-relieving knot in it about 8 inches from the free end inside the enclosure. Tightly twist together the fine wires in each conductor and sparingly tin with solder.

Mount the various components on the front panel. Then crimp and solder one line cord conductor to one lug of the POWER switch. Slip a 1-inch length of small-diameter heat-shrinkable tubing over one primary lead of the power transformer. Crimp the other line cord conductor to this lead and solder the connection. Slide the tubing over the connection to completely insulate it and shrink the tubing into place. Then crimp and solder the other transformer primary lead to the other POWER switch lug on the *same* side of the switch.

Crimp but do not solder the center-tap secondary lead of *T1* to one lug of the fuse holder. Then use a suitable length hookup wire to bridge between the same fuse holder lug and the negative (−) lug of the screw-type terminal strip on the rear panel of the enclosure.

Now wire the other half of *S1* as shown in Fig. 2. If the solder-lug ter-

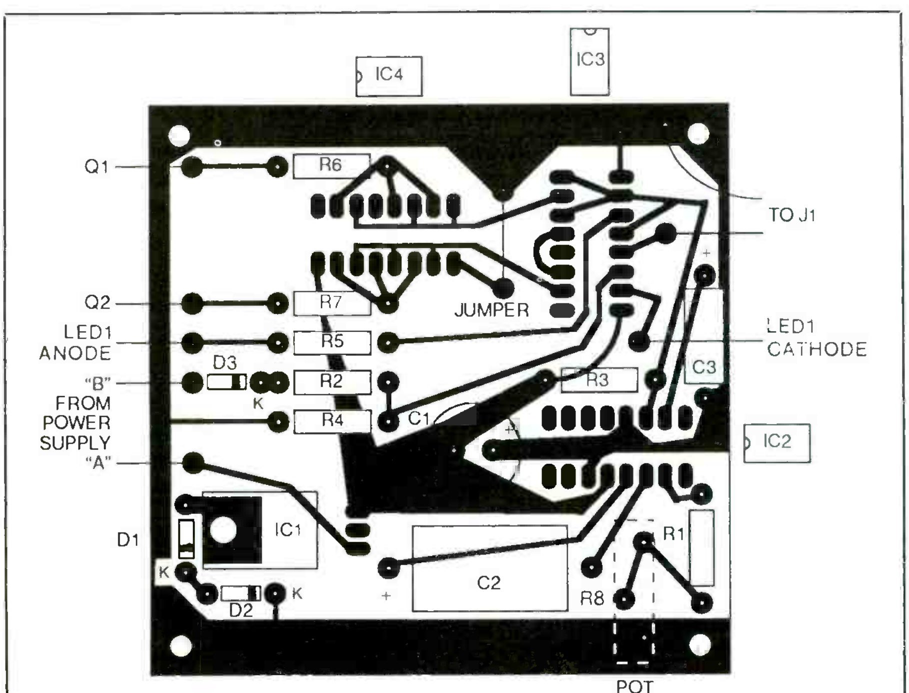


Fig. 4. Component-placement guide for pc board.

minal strip in the power supply is sufficiently close to *TS1*, simply bridge from the switch lug to the terminal strip lug to which the cathodes of all three diodes in the powering section connect. If not, lengthen the anode lead of *D6* with hookup wire (use heat-shrinkable or other tubing to insulate the connection). Make certain *D6* is properly polarized and that you wire the anode lead to *S1* so that when the ac powering option is off, the circuit from *TS1* is closed to *D6*.

Now wire *LED1*, *J1* and *J2* to the circuit-board assembly, using the wires you previously installed on the board. Use small-diameter heat-shrinkable tubing to insulate the connections to the LED, and make certain that the LED is properly polarized. When this is done, wire *I1* and *SO1* into the circuit.

Mount the two power transistors on the rear panel. If you are using a plastic utility box for the project's enclosure, you must use a 7 × 4 × ⅛-inch sheet of aluminum as a heat sink for the transistors. You can bend this into a U shape if the height of the enclosure is less than 4 inches. If you are using an all-metal enclosure, the enclosure itself will provide adequate heat-sinking for the transistors.

Make sure the transistors are insulated from the metal of the heat sink or metal enclosure. Once they are mounted, tie together their emitters with a length of hookup wire and connect them to circuit ground at the lug of the fuse holder to which the negative (−) lead of *C5* is connected. Crimp and solder the wire coming from hole A in the circuit-board assembly and the secondary center-tap lead of *T1* to the solder-lug terminal strip to which the cathodes of *D4*, *D5* and *D6* are connected.

Next, terminate the two wires coming from the Q1 Base and Q2 Base holes in the circuit-board assembly to the bases of the transistors. Mount transformer *T1* and ac outlet *SO1* to the rear wall of the enclosure. Crimp and solder the remaining secondary

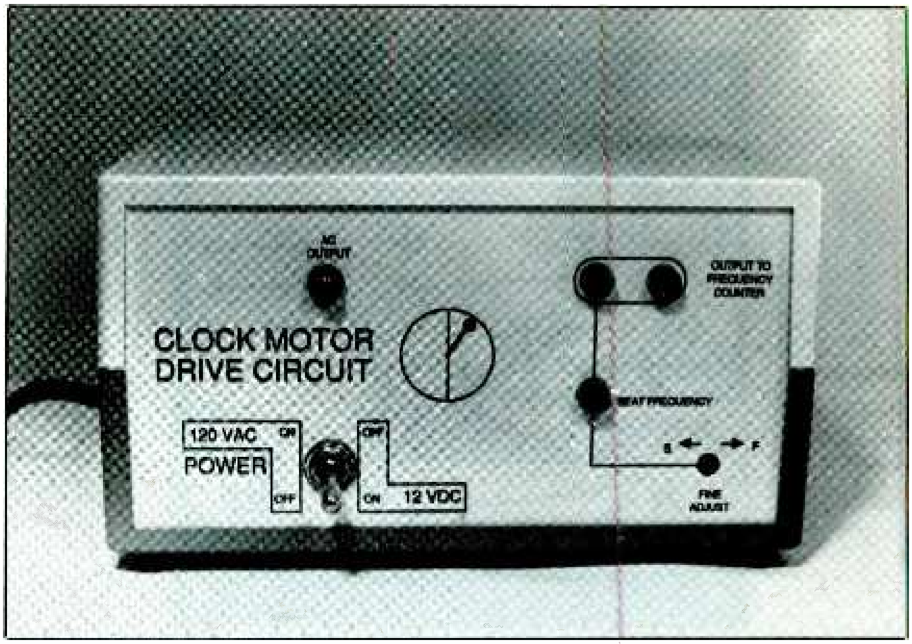


Fig. 5. Machining details for front panel of electronics-package enclosure.

leads of the transformer to the collectors of the transistors.

Mount *T1* and *SO1* in their respective locations on the rear panel of the enclosure. Slide suitable lengths of plastic tubing over the leads of non-polarized capacitor *C4* and crimp but do not solder the capacitor's leads to the lugs of the chassis-mounted ac outlet. Crimp but do not solder the primary leads of the transformer to the lugs of the outlet. Prepare two suitable lengths of hookup wire and crimp one end of each to the lugs of the ac outlet. Solder both connections.

Slide a 1-inch length of small-diameter heat-shrinkable tubing over the free ends of the two wires. Crimp and solder these wires to the leads of neon-lamp assembly *I1* on the front panel. When the connections cool, slide the tubing over them to completely insulate the connections and shrink the tubing into place.

Terminate the free end of the wire coming from hole B in the circuit-board assembly at the junction of *D4* and secondary lead of *T2*. Solder the connection. Then crimp and solder the free ends of the wires coming from holes J1 and J2 to the lugs on the jacks mounted on the front panel (observe polarity). Finally, plug a 3-ampere fuse into the holder.

This completes assembly of the power-supply portion of the project. Set this assembly aside until later and proceed to fabricating the Tide Clock's dial/motor assembly.

Modify an existing ac-operated analog clock is a simple procedure. Simply open the clock's case and remove all hands from the shafts of the drive motor. If you wish, you can save the hours hand for use as the pointer for the Tide Clock's display. The minutes hand (and seconds hand if there is one) can be discarded. Then dismount the synchronous motor from the clock case.

Building the clock hand and face depends on what materials are available. You can go elaborate, as was done for the prototype shown in the lead photo, or you can simply use the clock as-is, just replacing the existing dial face with a new one with appropriate markings to distinguish it from ordinary standard clocks.

If you decide to go the elaborate route, the dial face can be any sheet material—plywood, Masonite, hard-

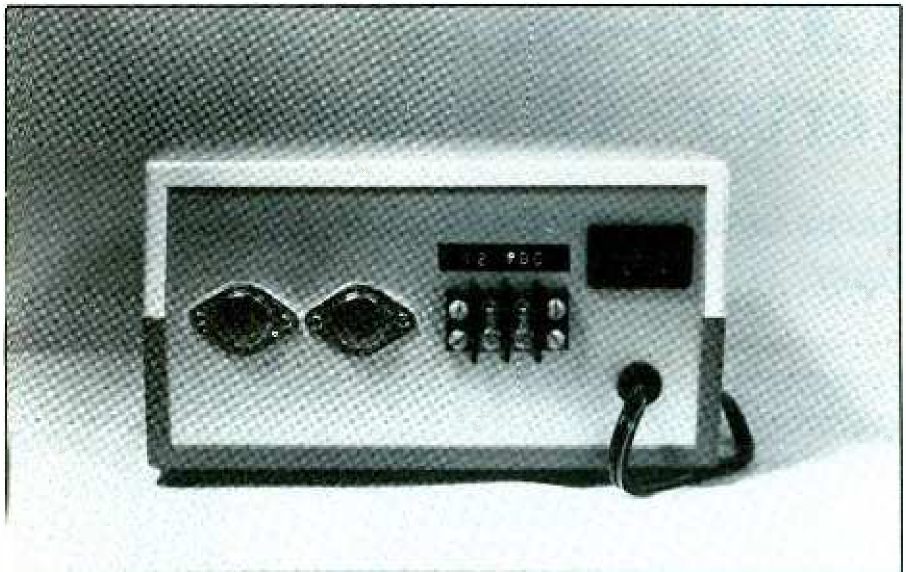


Fig. 6. Machining details for rear panel of enclosure.

board, plastic sheet or metal sheet—you have handy and is thin enough to permit mounting the clock motor in its center with adequate clearance for the hours-hand ring on the motor's shaft to mount the hand. A ⅛-inch or less thickness is about right for most clock motors.

Mark the dial face to easily distinguish it from normal solar clocks. Instead of hours positions, divide the display into two sections, which you can label HIGH and LOW. When the clock face is ready, simply mount the motor mechanism to it, usually with small wood screws. Mount the motor to the clock face in any manner that works for you.

If you are making a large-size Tide Clock display, as shown in the photo of the prototype, the hours hand you removed from the clock mechanism is usually too small to be of use. Making a new hand is usually necessary in a case like this. However, give some thought to the material you will use. This must be light in weight to prevent loading down the clock motor. A thin piece of sheet plastic, brass or even balsa wood should work well here. Other materials may come to mind as well.

A car stereo knob is a good way to mount the new hand to the motor's shaft. An alternative is to use a small cork with a hole of the correct diameter drilled in it. Although the clock-motor shaft will have two to four concentric shafts that different hands were once attached to, only the shaft that formerly held the hours hand is to be used in this project. Fortunately, the shaft for the hours hand is usually the largest in diameter and most accessible since it is the outermost of the group, except for the removable alarm shaft that is featured on some clocks.

Checkout & Calibration

Before attempting to calibrate or put into service your Tide Clock, it is a good idea to check out voltage distribution throughout the system to make sure you properly wired the project. For this, you will need a dc voltmeter or a multimeter set to the dc-volts function.

Clip the meter's common lead to the negative (−) lug of *TS1* and leave it there until voltage measurements are complete. Plug the project's line cord into an ac outlet and set the POWER switch to the 120 VAC ON position. Touch the meter's "hot" probe to pin 16 of the *IC2* and pin 14 of the *IC3* and *IC4* sockets. The readings obtained should all be approximately +12 volts. If they are not, immediately power down the project and unplug it from the ac line. Rectify the problem before proceeding.

Once you are certain that the project has been properly wired, power it down and allow the charges to bleed off the electrolytic capacitors. Then plug the ICs into the various sockets on the circuit-board assembly. Make sure the correct ICs go into the sockets and that no pins overhang the sockets or fold under between ICs and sockets. Handle these ICs with the same care as you would use in handling any other MOS-type device.

Power up the project and calibrate it as follows. The easiest way to accurately calibrate the drive circuit to a particular frequency is with a frequency counter that has adequate resolution. Another method is to use the beat-frequency LED to indicate the difference between the oscillator frequency and the 60 Hz of the ac line. A third method is to use trial and error over a long period of time.

Before calibration, make sure the circuit is actually working by plugging the clock motor into the ac receptacle on the rear panel of the enclosure. Then allow the circuit to stabilize and the case to warm up by running the project for 20 minutes or so under load. If you have a frequency counter, connect it to the Tide Clock via *J1* and *J2*. While observing the counter's display, adjust the setting of the potentiometer for a precise 57.9865772-Hz output. Accuracy to two or three decimal places will be quite sufficient.

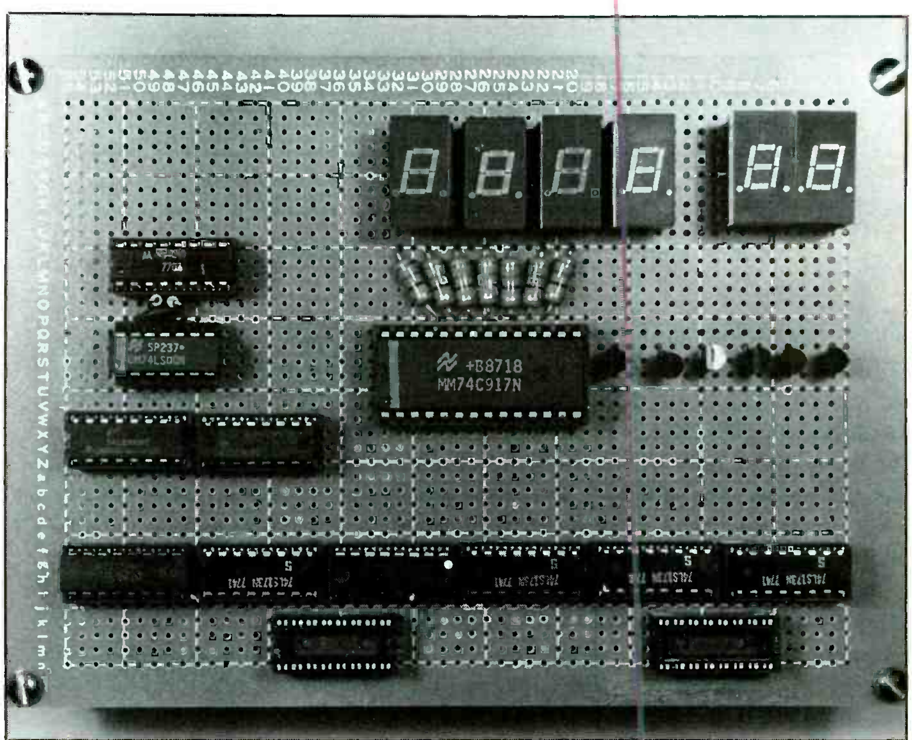
Without a frequency counter, calibration is more difficult but still possible. Using the panel-mounted LED, the output of the oscillator can be compared with the 60-Hz line frequency. The frequency of the flashes of the LED then represents the difference between the drive and ac-line frequency. This method will not tell

(Continued on page 82)

BCD-to-Hex Converter/Display

Easily converts and displays binary-coded-decimal data in hexadecimal format

By Lloyd W. Redman



National Semiconductor makes an integrated circuit that offers an ideal solution to the problem of having to convert binary-coded-decimal (BCD) data into the hexadecimal format. The six-digit hex display controller/driver MM74C917 chip decodes and displays, on separate numeric display devices, 24 bits of hex data from a BCD-format source. This gem of a chip is just what you need to relieve you of the headache of having to laboriously make BCD-to-hex conversions, either mentally or with a special type of calculator.

The BCD-to-Hex Converter/Display project described here takes full advantage of the National chip. It offers a full six digits of display that requires no interpreation. Just feed in BCD data and numeric displays automatically show its hex equivalent. The project can be used to convert and display up to 24 bits of BCD data from any source, as long as the data is latched (temporarily stopped) to provide a stable display.

About the Circuit

When designing a decoder/display driver circuit, several functions must be performed. The sequence of events is illustrated by the block diagram shown in Fig. 1.

To begin with, the BCD data to be displayed must be latched (temporarily stopped) at the Data Source. Next, the latched data must be switched, four bits at a time, by the Electronic Switch to a BCD-to-7-Segment Decoder/Driver. This section decodes the binary data to hexadecimal format and routes it to the appropriate decade in the display string (DISP1 through DISP4). Finally, the proper segments of the appropriate display decade must be turned on, which is accomplished with another Electronic Switch under control of the Electronic Switch Control & System Clock block.

Normally, the same segment turn-on information is sent to all displays simultaneously. Using a multiplexing technique, only one decade in the display is switched on a any given instant. The multiplex switching is accomplished at a rapid enough rate that the eye perceives all display decades to be on simultaneously, each with its appropriate segments lit, to display the correct data.

The 74C917 six-digit hex display controller/driver chip is the workhorse of this project. It performs nearly all the functions illustrated in Fig. 1. To accomplish this, the chip has on-board a number of circuits, which are diagrammed in Fig. 2.

Referring to Fig. 2, BCD data (except the decimal point) is presented at inputs a, b, c and d of the Input

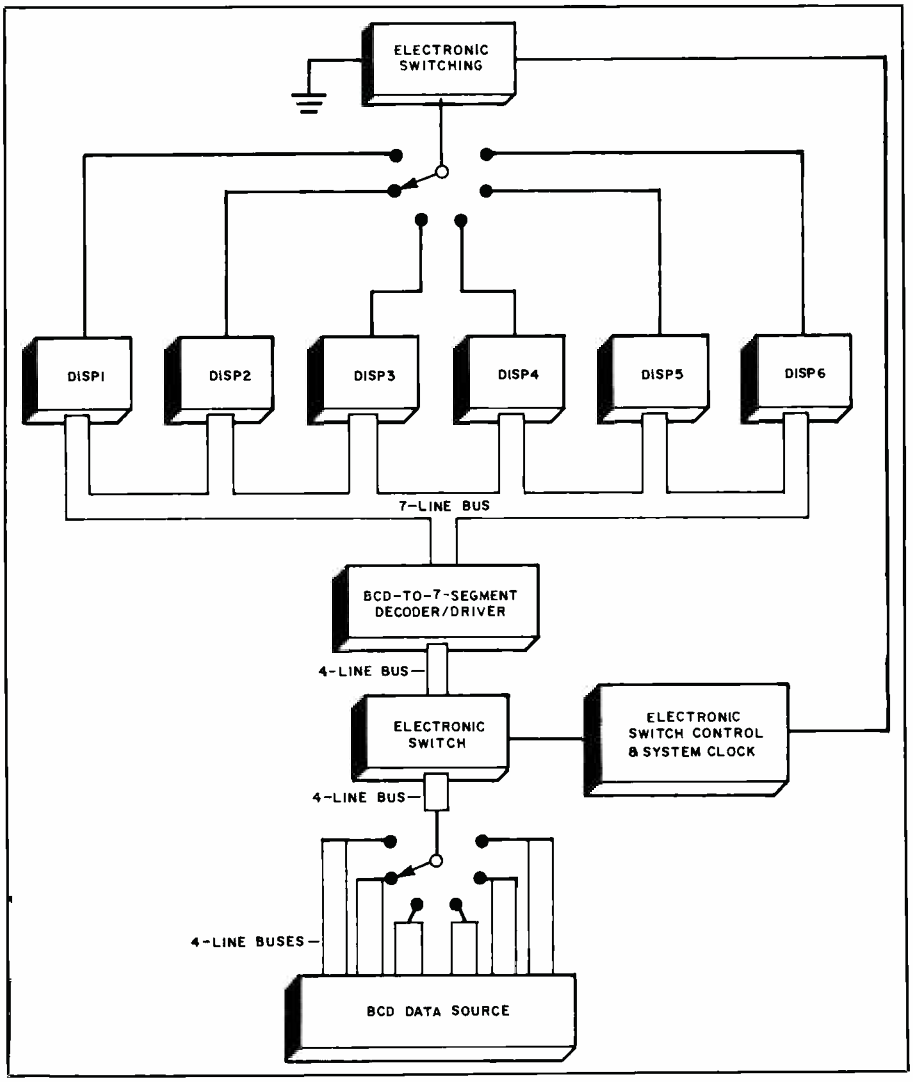


Fig. 1. Block diagram of the subsections that make up the project.

Data Buffers. This data is written into internal registers M1 through M6 when $\overline{WE}$ (write enable) and $\overline{CE}$ (chip enable) are low. (When implemented in the project presented here, $\overline{CE}$ is permanently wired low.)

When WE goes from low to high, the data written into the registers is latched. Address information is furnished the 74C917 from a 74LS390 (*IC4* in Fig. 3 complete schematic diagram of project) dual decade ripple counter. An internal oscillator running at about 350 Hz switches the BCD data from the internal registers to the 16 × 7 ROM where it is decoded to hexadecimal format. When SOE goes low, segment drive data is switched to the proper decade in the display and turns on that decade.

Referring now to Fig. 3, the display system clock generator consists of two stages in 4049 CMOS hex inverting buffer *IC2*, wired here as an astable or free-running multivibrator. Clock frequency is determined by the values of *R9* and *C1*. Ideally, operating frequency of the clock generator is calculated using the formula f = 1/2.2RC. The main objective in selecting the values of the resistor and capacitor was to have a digit-select frequency that was high enough to obviate perceptible flicker of the lighted segments in the display.

The output at pin 2 of *IC2* goes to the input at pin 1 of counter *IC4*. The internal counter to which pin 1 of *IC4* connects operates as a BCD decade counter. The output at pin 3 of this counter furnishes the clock signal that is fed to pins 8 of 74LS173 quad D-type flip-flops *IC6* through *IC11*. The output at pin 5 of *IC4* goes to the pin 10 clock-enable inputs of the same ICs.

The output at pin 6 of *IC4* provides the clock input to pin 15 of the second counter inside this chip and the write-enable ($\overline{WE}$) signal to pin 2 of 74C917 display controller/driver *IC1*. The output at pin 7 of *IC4* connects to segment output-enable ($\overline{SOE}$) pin 15 of *IC1*.The duty cycle of the pulse train fed to the *IC1* pin 15 input determines the segment on/off time and, subsequently, the brightness of the lighted segments in the display.

If you wish to temporarily reduce power dissipation, you can do either of two things to extinguish the display. You can switch off the +5 volts to the entire circuit. Alternatively, you can install an spdt switch in the line that goes from pin 7 of *IC4* (one switch throw, or stationary contact) and pin 16 of *IC1* (the switch pole, or toggle) and run a line from the +5-volt bus to the remaining switch throw. With this arrangement, when you want to extinguish the display, you simply set the switch to its +5V position.

If you want to be able to adjust the brightness of the display, you can drive pin 1 of *IC1* with a variable-frequency pulse generator. Such a generator can easily be assembled around a commonly available 555 or other timer chip. Schematic diagrams for building a variable-frequency pulse generator can be found in a wide variety of electronics magazine articles and books.

The second ripple counter inside *IC4* is also wired as a BCD decade counter. Its pins 10 and 11 outputs go to the inputs of one gate inside

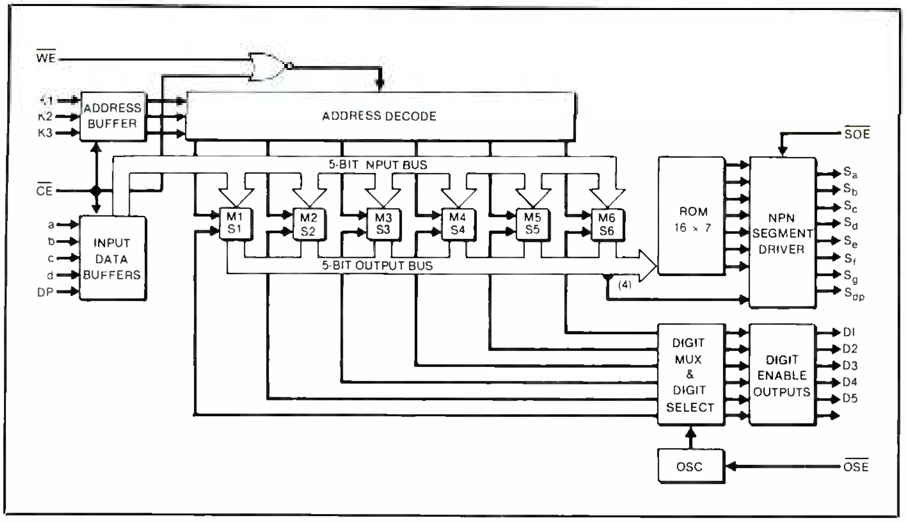


Fig. 2. The 74C917 six-digit hex display controller/driver chip around which project is built contains circuitry that performs nearly all functions diagrammed in Fig. 1.

84LS00 quad NAND gate *IC3* at pins 9 and 10, respectively. The output of the second counter inside *IC4* is inverted by a second gate inside *IC3* and is available at pin 11. This inverted signal is fed back to master-reset pin 14 of *IC4*.

The second ripple counter inside *IC4* counts from 0 to 5 and resets to 0. The outputs at pins 13, 11 and 10 generate the address code for internal registers of *IC1*. These outputs also connect to 74LS138 1-of-8 decoder *IC5* at pins 1, 2 and 3 , respectively. Though *IC5* is in reality a 1-of-8 decoder, it is wired here as a 1-of-6 decoder.

BCD data is temporarily stored in *IC6* through *IC11* before it is switched from pins 6, 5, 4 and 3 of these flip-flops to the A, B, C and D inputs of *IC1* at pins 3, 4, 5 and 6, respectively. Notice in the schematic that the clock enables (E1) pins 9 of *IC6* through *IC11* are wired to ground (logic low).

When the E2 clock enables at pins 10 of *IC6* through *IC11* are low, the next low-to-high transition of the clock signal, connected to pin 7 of each of these flip-flops, loads the BCD data into the chips. When the E2 pin is high on any flip-flop, the next high-to-low transition of the clock signal latches the BCD data into that flip-flop.

Outputs of *IC6* through *IC11* operate independently of the inputs. Output-enable ($\overline{OE2}$) pin 2 in all six cases is wired to ground (logic low). When output-enable ($\overline{OE1}$) pin 1 goes low, the data latched into the flip-flops appears at output pins 3, 4, 5 and 6. The signal on pin 2 is generated by *IC5* operating as a 1-of-6 decoder/demultimplexer. When this signal is high, the pins 3 through 6 outputs are in high-impedance state. Thus, all flip-flop outputs can be connected to a common bus feeding the inputs of *IC1*.

Power for the project is supplied by a suitable 5-volt dc power supply. If you do not have one handy, you can build the one shown schematically in Fig. 4. This is a common full-wave supply with built-in voltage regulation provided by *IC12*.

Construction

You can assemble this project using any of a number of traditional wiring techniques. If you wish, for example, you can design and fabricate a printed-circuit board on which to mount and wire together the various

PARTS LIST

Semiconductors

D1 thru D4—1N4003 or similar silicon rectifier diode
DISP1 thru DISP6—Common-cathode LED numeric displays to mount in 14-pin DIP socket
IC1—74C917 six-digit hex display controller/driver
IC2—CD4049 hex inverting buffer
IC3—74LS00 quad two-input NAND gate
IC4—74LS390 dual decade ripple counter
IC5—74LS138 1-of-8 decoder/ ultiplexer
IC6 thru IC11—74LS173 Quad D-type flip-flop with three-state outputs
IC12—7805 +5-volt regulator
Q1 thru Q6—2N3904 or similar silicon npn transistor

Capacitors

C1—47-pF ceramic disc
C2—0.1-µF ceramic disc
C3—2,500-µF, 16-volt electrolytic
C4—1-µF, 9-volt electrolytic

Resistors (¼-watt, 5% tolerance)

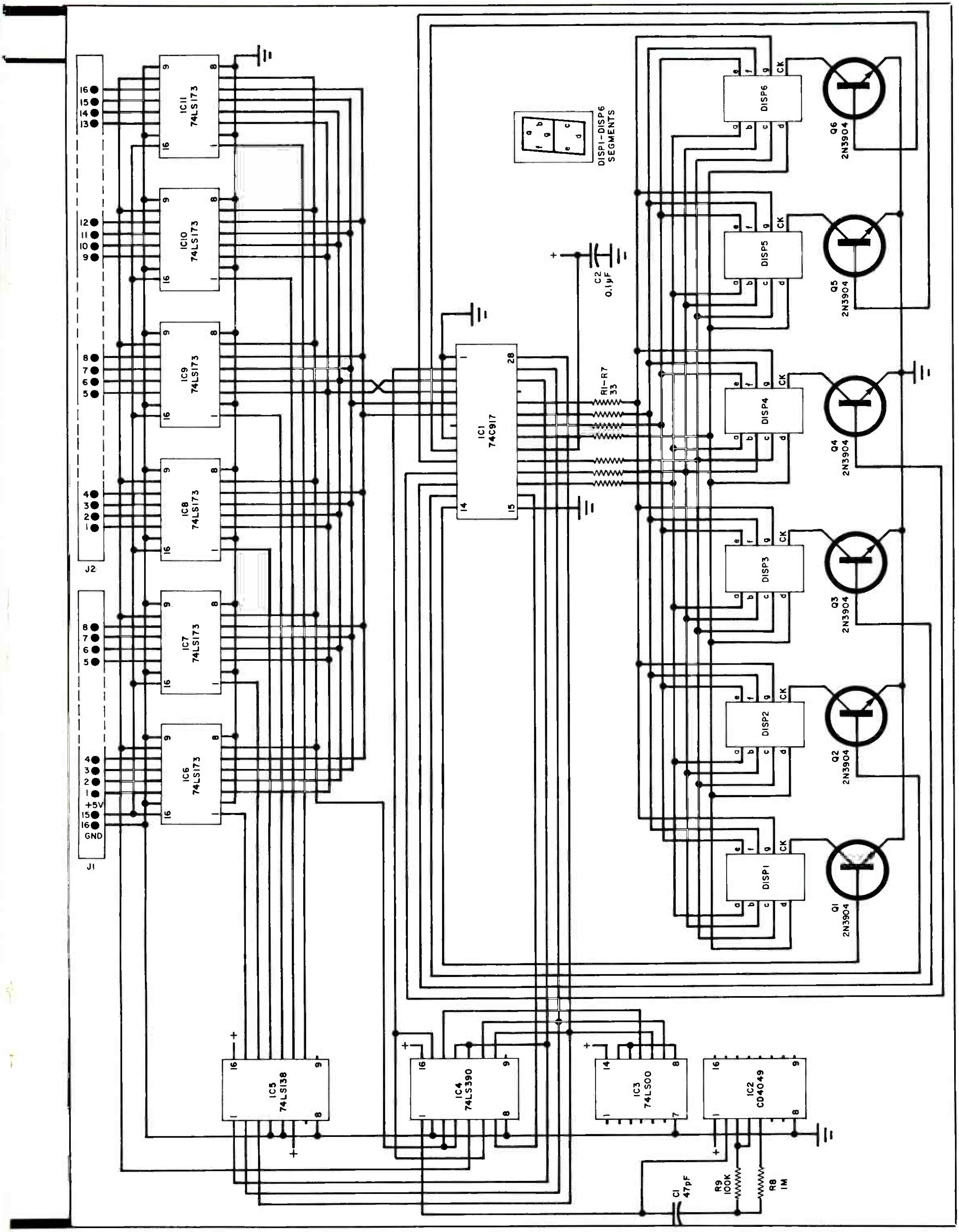
R1 thru R7—33 ohms
R8—1 megohm
R9—100,000 ohms

Miscellaneous

J1,J2—16-pin DIP IC socket
T1—12.6-volt, 1-ampere power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); sockets for all DIP ICs and LED displays; two 16-conductor ribbon cables with 16-pin headers; suitable enclosure; LEDs, 330-ohm resistors, CD4060 divider chip and spst switch for testing purposes (see text) machine hardware; hookup wire; solder; etc.

Note: The 74C917 display controller/driver is available by mail order from Digi-Key, P.O. Box 677, Thief River Falls, MN 56701-9988 or Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002.

Fig. 3. Schematic diagram of all circuitry, except power supply, used in the project.


IC11 74LS173
IC10 74LS173
IC9 74LS173
IC8 74LS173
IC7 74LS173
IC6 74LS173
J2
J1
+5V
GND
IC1 74C917
R1-R7 33
C2 0.1µF
DISP1-DISP6 SEGMENTS
DISP6
DISP5
DISP4
DISP3
DISP2
DISP1
Q6 2N3904
Q5 2N3904
Q4 2N3904
Q3 2N3904
Q2 2N3904
Q1 2N3904
IC5 74LS138
IC4 74LS390
IC3 74LS00
IC2 CD4049
C1 47pF
R9 100K
R8 1M

Master Wiring List

IC1 (74C917)

From Pin	To
1	Ground
2	IC4 pins 6,15
3	IC6 thru IC11 Pin 3
4	IC6 thru IC11 Pin 4
5	IC6 thru IC11 Pin 5
6	IC6 thru IC11 pin 6
7	No Connection
8	Ground
9	Q6 Base
10	Q5 Base
11	Q4 Base
12	Q3 Base
13	Q2 Base
14	Q1 Base
15	Ground
16	IC4 Pin 7
17	R1
18	R2
19	R3
20	+ 5 Volts
	C2
21	R4
22	R5
23	R6
24	R7
25	No Connection
26	IC4 Pins 12,13
	IC5 Pin 1
27	IC3 Pin 9
	IC4 Pin 11
	IC5 Pin 2
28	IC3 Pin 10
	IC4 Pin 10
	IC5 Pin 3

IC2 (CD4049)

From Pin	To
1	+ 5 Volts
2	C1
	IC4 Pin 1
3	IC2 Pin 4
	R9
5	R8
6	No Connection
7	No Connection
8	Ground
9	No Connection
10	No Connection
11	No Connection
12	No Connection
13	No Connection
14	No Connection
15	No Connection
16	No Connection

IC3 (74LS00)

From Pin	To
1	No Connection
2	No Connection
3	No Connection
4	No Connection
5	No Connection
6	No Connection
7	Ground
8	IC3 Pins 12,13
11	IC4 Pin 14
14	+ 5 Volts

IC4 (74LS390)

From Pin	To
1	IC2 Pin 2
	C1
2	Ground
	IC4 Pin 8
3	IC4 Pin4
	IC6 thru IC11 Pins 7
5	IC6 thru IC11 Pin 10
6	IC4 Pin 6
7	IC1 Pin 16
9	No Connection
16	+ 5 Volts

IC5 (74LS138)

From Pin	To
4	Ground
5	Ground
6	+ 5 Volts
7	No Connection
8	Ground
9	No Connection
10	IC11 Pin 1
11	IC10 Pin 1
12	IC9 Pin 1
13	IC8 Pin 1
14	IC7 Pin 1
15	IC6 Pin 1
16	+ 5 Volts

IC6 (74LS173)

From Pin	To
2	Ground
	IC6 Pins 8,9,15
	IC7 thru IC11 Pins 2, 8,9,15
	J1 Pin 16
10	IC7 thru IC11 Pin 10
11	J1 Pin 4
12	J1 Pin 3
13	J1 Pin 2
14	J1 Pin 1
16	+ 5 Volts
	IC7 thru IC11 Pin 16
	J1 Pin 15

IC7 thru IC11 (74LS173)

From			To		
IC7	Pin	11	J1	Pin	8
		12			7
		13			6
		14			5
IC8	Pin	11	J2	Pin	4
		12			3
		13			2
		14			1
IC9	Pin	11	J2	Pin	8
		12			7
		13			6
		14			5
IC10	Pin	11	J2	Pin	12
		12			11
		13			10
		14			9
IC11	Pin	11	J2	Pin	16
		12			15
		13			14
		14			13

Miscellaneous

From		To
IC12	IN	C3 +
		Bridge +
	COM	C3 – ,C4 –
		Bridge –
		Ground Bus
	OUT	C4 +
		+ 5-Volt Bus
DISP1-DISP6		
	Pin a	DISP2-DISP6 Pin a
		R1
	b	DISP2-DISP6 Pin b
		R2
	c	DISP2-DISP6 Pin c
		R3
	d	DISP2-DISP6 Pin d
		R4
	e	DISP2-DISP6 Pin e
		R5
	f	DISP2-DISP6 Pin f
		R6
	g	DISP2-DISP6 Pin g
		R7
	CK	Q1 Collector
DISP2	Pin CK	Q2 Collector
DISP3	Pin CK	Q3 Collector
DISP4	Pin CK	Q4 Collector
DISP5	Pin CK	Q5 Collector
DISP6	Pin CK	Q6 Collector
Q1-Q6	Emitter	Ground
C2		Ground
C1/R9		R8

components. Alternatively, you can use perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware to mount and wire together the components. Whichever way you go, though, be sure to use sockets for all ICs and the LED numeric displays.

As shown in the lead photo, the prototype of the project was assembled on perforated board. Measuring 6⅝ × 4½ inches, the Radio Shack Cat. No. 276-147 has a copper pad for each hole on the wiring side of the board. You can use this or any other similar board or even perforated board that has no pads around the holes if you go this route. To provide stability, assuming pad/hole board and the point-to-point wiring technique, it is suggested that you solder at least the corner pins of each IC socket to the pads surrounding them.

Begin construction by installing the IC and display sockets. Also mount into place between the edge of the board and the six sockets for *IC6* through *IC11* 16-pin DIP sockets *J1* and *J2* (shown unoccupied in the lead photo). If you are using a pc board or pad/hole perforated board, solder the pins of the sockets into place. If you are point-to-point wiring the circuit, it is a good idea to mark the pin 1 position for each socket on the wiring side of the board. Alternatively, you can place a commercial plastic ID label on which the pin numbers are printed for each socket location. Do *not* plug any ICs or displays into the sockets until after you have performed initial voltage checks and are certain that all wiring is correct.

Again assuming you are using a pc board or pad/hole perforated board, install the resistors and then the capacitors in their respective locations and solder both leads of each into place. Having come this far, you are ready to proceed with wiring together the sockets and components. (If you are using a pc board, they are already wired together.)

A fairly foolproof method of wiring any project using the point-to-point technique is to make up a Wiring List that details every wire run and connection and check off each as it is made. The complete Wiring List for this project is shown elsewhere in this article. Carefully following each step as detailed in it should yield a working project the first time out.

Next, using the Wiring List and an ohmmeter or audible continuity tester, check all runs and connections for continuity. When you obtain the proper indications in all cases, assemble the power-supply circuit (if there is room for them, you can mount the rectifier diodes, two capacitors and regulator *IC12* on the circuit-board assembly. Do not attempt to mount the power transformer on the board. If you wish, you can incorporate a POWER switch and 1-ampere slow-blow fuse in a holder into the primary side of the power transformer in the traditional manner.

Select a suitable enclosure for the project. It can be all plastic, all metal or a combination of the two. The enclosure must be large enough to accommodate the circuit-board assembly and power transformer without crowding and have sufficient front-panel room for the POWER switch and a bayonet-type fuse holder if you decide to use these two components.

Machine the enclosure as needed. That is, drill mounting holes in the floor panel for the circuit-board assembly and power transformer and an entry hole for the ac line cord through the rear panel. Determine exactly where in the top panel to make the cutout for the six-decade numeric display's window and cut a suitable slot for it. Then cut narrow slits through the rear wall panel near *J1* and *J2* through which to route the two input cables. Make these slits only wide enough to pass through the ribbon-type input cables. If you are using the POWER switch and fuse, also drill holes in which to mount them through the front panel.

If you drilled the holes or cut the display slot through metal panels, deburr them to remove sharp edges. Then mount the power transformer in place with suitable machine hardware, sandwiching the mounting tab of a two-lug terminal strip (neither lug connected to the mounting tab) between the nut and one tab of the transformer. Connect and solder the two secondary leads of the transformer to the appropriate points in the bridge rectifier arrangement in the power supply.

Crimp but do not solder the primary leads of the power transformer to the lugs of the terminal strip. If the line-cord entry hole is through a metal panel, line it with a rubber grommet. Pass the unfinished end of the line cord through the hole and into the enclosure. Tie a strain-relieving knot in it about 6 inches from the unfinished end inside the enclosure.

Tightly twist together the fine wires in each line-cord conductor and sparingly tin with solder. Crimp and solder one line-cord conductor to one lug of the terminal strip, and solder the primary lead of the transformer already in place on this lug.

Mount the fuse holder and POWER switch (if you are using them) in their holes on the front panel. Connect and solder a suitable length of hookup wire from one lug of the switch to one lug of the fuse holder. Similarly, connect and solder a hookup wire to the other lug of the fuse holder, route the other end to the unsoldered lug of the terminal strip. Crimp the free end of this wire to the lug and solder it and the primary lead already occupying the same lug. Then separate the line cord conductors inside the enclosure to within 1 inch of the strain-relieving knot. Crimp and solder the unattached conductor to the unoccupied lug of the POWER switch.

The input cables for the project consist of standard 16-conductor ribbon-cable assemblies terminated in 16-pin DIP headers. Two separate input cables are needed. Cut off and discard one header from each cable.

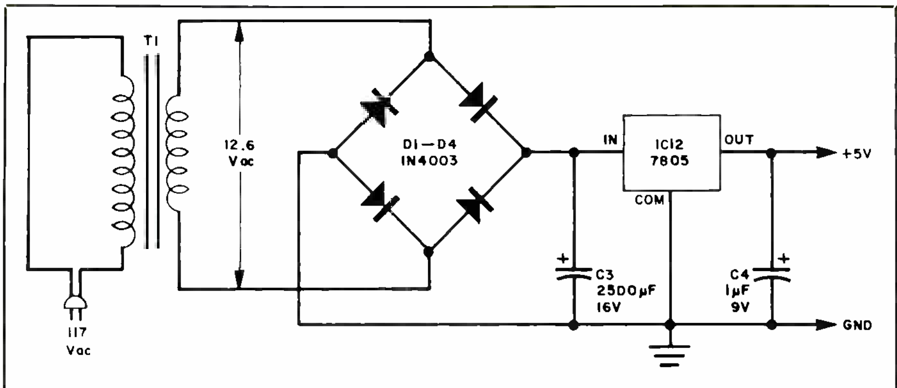
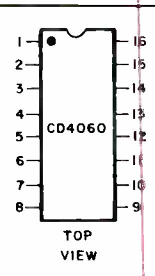


Fig. 4. Schematic diagram of a suggested 5-volt regulated dc power supply for use with project.



OUTPUTS		
PIN NO.	CLOCK DIVISION	OUTPUT IN Hz
1	4,096	5
2	8,192	2
3	16,384	1
4	64	325
5	32	650
6	128	162
7	16	1,300
13	512	40
14	256	80
15	1,024	20

Fig. 5. A CD4060 divider chip can be used to slow down project's clock oscillator for easy observance of signal activity via a logic probe or discrete LEDs.

Then carefully separate the conductors at the cut ends a distance of about 3 inches. Strip ¼ inch of insulation from the ends of all cut-end conductors, tightly twist together the exposed fine wires in each case and sparingly tin with solder. Use heat judiciously to minimize charring the insulation.

Pass the unprepared ends of the cables through the narrow slots you cut through the rear panel from the *inside* of the enclosure. Plug the headers at the ends of the cables into the *J1* and *J2* IC sockets. Leaving about 1 inch of slack in each cable inside the enclosure, apply a liberal bead of silicone adhesive on both sides of the cables to secure them in place against the rear panel. Allow the adhesive to fully cure, at least overnight, before proceeding.

When the adhesive has cured, terminate the unfinished ends of the conductors in suitable connectors for your expected applications.

System Checkout

If you incorporated the POWER switch and fuse into your project, place a fuse into its holder. Clip the common lead of a dc voltmeter or a multimeter set to the dc-volts function and set the meter's range selector to a position that will easily display 5 volts. Bear in mind that no ICs (except regulator *IC12* in the power supply) or LED numeric displays should be plugged into the sockets on the circuit-board assembly for preliminary voltage tests.

Plug the line cord of the project into an ac outlet. As you perform voltage checks with the meter, make absolutely certain that you do not touch or otherwise come in contact with the primary circuit of the power transformer. Potentially lethal 117 volts will be present at the terminal-strip lugs and the lugs of the POWER switch and fuse holder.

Turn on power to the project by setting the POWER switch to its "on" position, assuming you are using this switch. If you are not using the switch, dc power is automatically delivered to the various points in the circuit when you plug in the line cord.

With power applied, touch the "hot" probe of the meter to pin 20 of the *IC1* socket and note the reading obtained. It should be approximately +5 volts. If you obtain this reading, touching the "hot" probe to pin 1 of the *IC2* socket should also yield a +5-volt reading. Touching the "hot" probe to pin 14 of the remaining 14-pin and pin 16 of the remaining 16-pin IC sockets should yield the same +5-volt reading.

If you fail to obtain the proper reading at any of the indicated IC socket pins, immediately power down the circuit and pull the line cord from the ac outlet. Rectify any wiring error(s) or reverse-polarity diode or/and filter capacitor connections you might have made in the power-supply section or errors in wiring you might have made in the rest of the circuit before proceeding to operational checks.

Once you are certain of your wiring, power down the project by pulling the plug from the ac outlet. Allow sufficient time for the charges to bleed off the filter capacitors in the power supply. Then carefully plug the CD4049 into the *IC2* socket. Make sure that no IC pins overhang the sockets or fold under between devices and sockets.

To accurately check clock generator *IC2*, you should use an oscilloscope or frequency counter. If you have access to neither, you can use a CD4060 divider chip to slow down the output signal from *IC2* so that it can be verified with a logic probe.

Plug the CD4060 chip into a small solderless breadboarding socket. Using suitably long flexible wire leads, connect pins 8 and 12 to circuit ground and pin 16 to the +5-volt buses in the project. Similarly, connect a lead from output pin 11 to pin 1 of the *IC4* socket in the project.

Power up the project. If you have a scope or counter, monitor the output of the clock generator at pin 2 of *IC2*. You should obtain a frequency reading at this point of approximately 20.8 kHz. If you are using the

CD4060 circuit, refer to the table in Fig. 5 for details of where to pick off the divided signal for monitoring with a logic probe.

The most-accurate reading obtained is with an accurately calibrated frequency counter. Of slightly lesser accuracy is scope monitoring, while use of a logic probe simply gives an indication of signal activity. If you obtain any signal activity, regardless of which monitoring method you employ, you can assume that the clock oscillator is working.

Having verified that the clock oscillator is working, pull the project's line cord from the ac receptacle, allow the charges to bleed off the filter capacitors in the power supply and then install a 74LS390 in the *IC4* socket and a 74LS00 into the *IC3* socket. Again, make sure the pins of the ICs (and all subsequent ICs and LED numeric displays) engage the socket pins.

Connect separate light-emitting diodes through 330-ohm current-limiting resistors to the outputs of *IC4* at pins 2, 5, 7, 10, 11 and 13. The cathodes of the LEDs go to the specified pins on the IC, while the anodes go to the +5-volt bus through the current-limiting resistors.

Leave the CD4060 still connected to the project as described above. Then temporarily connect one of the slow outputs (see Table in Fig. 5) to input pins 1 and 15 of *IC4*.

Power up the project and observe the LEDs for activity. If you selected a low enough frequency out of the CD4060, you should observe the LEDs flashing on and off to show the BCD count. Having verified that both counters inside *IC4* are operating properly, disconnect the project from the ac line and allow time for the charges to bleed off the capacitors.

Plug a 74LS138 into the *IC5* socket. Remove the LEDs you installed for *IC4* and temporarily connect them to pins 10 through 15 of *IC5* in the same manner as you did for *IC4*. Leave the CD4060 connected as before. Power up the project and observe the activity of the LEDs. If you selected a low enough frequency through the CD4060, you should observe the LEDs counting in a repeating 0-to-5 sequence.

With operation of *IC5* confirmed, pull the plug of the project from the ac outlet and allow the charges to bleed off the capacitors. Then temporarily tack-solder suitable lengths of hookup wire to the +5-volt or ground buses in the project and terminate the other ends at pins 1 of *IC6* through *IC11* to represent BCD data to these input pins. Disconnect the LED/resistors from *IC5*.

Carefully plug 74LS173s into the *IC6* through *IC11* sockets. Temporarily connect four of the LED/resistor combinations between pins 3 through 6 of *IC6* and the +5-volt bus in the same manner as above.

Power up the project and observe the LEDs, which should flash on and off in BCD sequence. Once you obtain LED activity, power down the project and move the LED/resistor combinations to between pins 3 through 6 of *IC7* and the +5-volt bus and repeat the test. Do this for *IC8* through *IC11* in turn to verify operation of all six latches. Once you verify operation of each stage, power down the project and remove the wires from the +5-volt bus and pins 1 of *IC6* through *IC11* and remove the LED/resistor combinations.

Plug the six LED displays into a solderless breadboarding socket to precheck all seven segments of each before installing the displays in their sockets. Connect the common cathodes of the displays to the ground bus in the project. Tack solder a suitable length of hookup wire to the +5-volt bus in the project and terminate the other end of the wire in a 330-ohm resistor. Use this test lead to check each segment in each display by plugging the free lead of the resistor into the appropriate holes for the pins that connect to segments *a* through *f* of each display.

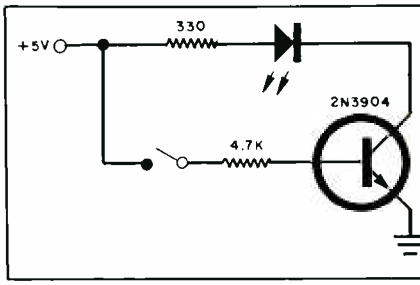


Fig. 6. A circuit for testing operation of project's transistors out-of-circuit.

You can also check each of the *Q1* through *Q6* transistors out-of-circuit. To do this, breadboard the circuit shown in Fig. 6. The transistor shown here is the one that will be installed in the project. This test circuit is designed to prevent exceeding the maximum allowable base current for the transistors.

You verify operation of the transistor under test by powering up the project, closing the switch and observing the LED. If the LED lights with the switch closed, the transistor is good. If the LED does not light, discard the transistor and replace it with a new one.

Now that you have tested all the subsystems in your project (and corrected any wiring errors you have detected during this operation), it is time to connect the output of the clock generator to the first counter. With power turned off and no charges on the filter capacitors in the power supply, install the 74C917 chip in the *IC1* socket, employing the same precautions you would use for handling any other MOS-type device.

Power up the project and check operation of the complete system. Change the BCD inputs to flip-flops *IC6* through *IC11* and verify that the LED numeric displays show the corresponding hex signals.

To use the project, simply clip the leads of its input cables to the appropriate points in the circuit under test. Power up the circuit being tested and the project and observe the numeric displays. That is all there is to it!

Using an Oscilloscope in Electronics Troubleshooting

Testing overshoot and ringing in square waves; shock excitation of RLC circuitry; and transient waveforms in pseudo-inductive circuits

By Robert G. Middleton

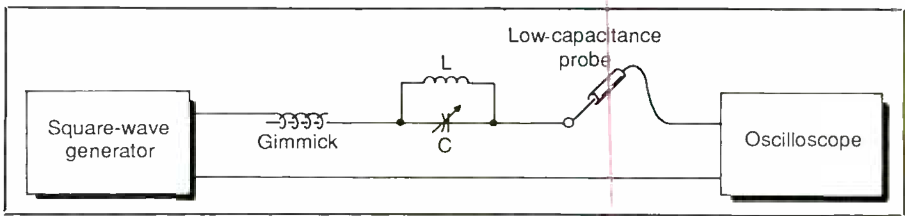


Fig. 1. Test setup that minimizes circuit loading for displaying a ringing waveform.

In previous issues of *Modern Electronics*, we've discussed using an oscilloscope in various troubleshooting applications. (See "How to Read Oscilloscope Waveforms," July and August 1988 and "Waveshaping Circuit Action," January 1989.) This article is actually a continuation of those already published. Here we discuss overshoot and ringing in square-wave tests, shock excitation of RLC circuitry and transient waveforms in pseudo-inductive circuits.

Basic Ringing

Shown in Fig. 1 is a basic test setup for displaying a ringing waveform in an electronic circuit. It uses a "gimmick" that consists of two or three turns of insulated wire wound around the lead to the inductor and capacitor. This provides a small amount of capacitive coupling from the square-wave generator to the LC network and minimizes circuit loading.

Similarly, a low-capacitance probe is used with the oscilloscope to minimize circuit loading. The square-wave generator must have a fast rise time to assure that sufficient harmonic energy is applied to adequately shock-excite (ring) the LC network.

With the inductance and capacitance values specified in Fig. 1, the LC network will ring at approximately 1 MHz. The scope will display a ringing waveform like that shown in Fig. 2. If *L* has considerable distributed capacitance, the effective total capacitance in shunt to *L* will be significantly greater. The result will be that the network will ring at a lower frequency—as low as 0.5 MHz.

As illustrated in Fig. 2(B), this basic ringing waveform has a decaying (damped) sine-wave shape and the damping is exponential. An exponential waveform represents the natural physical law of growth and decay. The rate of decay is determined by the winding resistance of the inductor and effective shunt resistances, such as eddy currents and radiation resistance.

Transient Response of Tuned Transformers

Let us now consider the ringing waveforms provided by a transformer with tuned primary and tuned secondary, such as an AM i-f transformer. Frequency-response curves for a typical transformer with three degrees of coupling are shown in Fig. 3. Here, *M* denotes the mutual inductance that exists between the primary and secondary windings of the transformer, and *k* denotes the coefficient of coupling. Note that the equivalent circuit shown in Fig. 3(A) shows the series-parallel RLC primary circuit as its Thevenin equivalent series RLC network, which simplifies analysis of transformer action.

The key to understanding tuned-transformer ringing waveforms is recognition of the double-humped frequency responses in Fig. 3 as the equivalent of two RLC networks tuned to slightly different frequencies. Observe in Fig. 4 that when a tuned transformer with double-humped frequency response is shock-excited by a square wave, a more complex ringing waveform is produced than by a single network. The tuned transformer is ringing at two slightly different frequencies, and the ringing pattern is a beat resultant of two decaying sine waves that have slightly different frequencies.

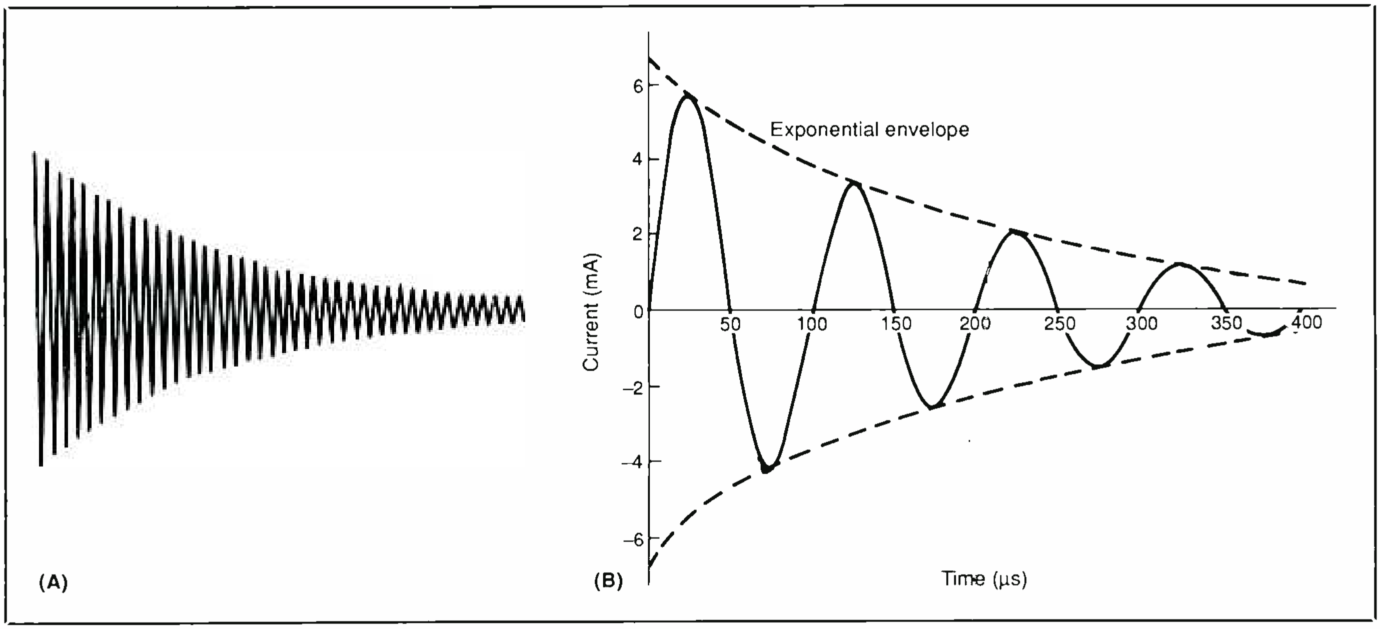


Fig. 2. Example of a ringing waveform with exponential decay. (A) is the pattern of the waveform as it would appear on the screen of an oscilloscope; (B) is the graphed plot of the waveform parameters versus time.

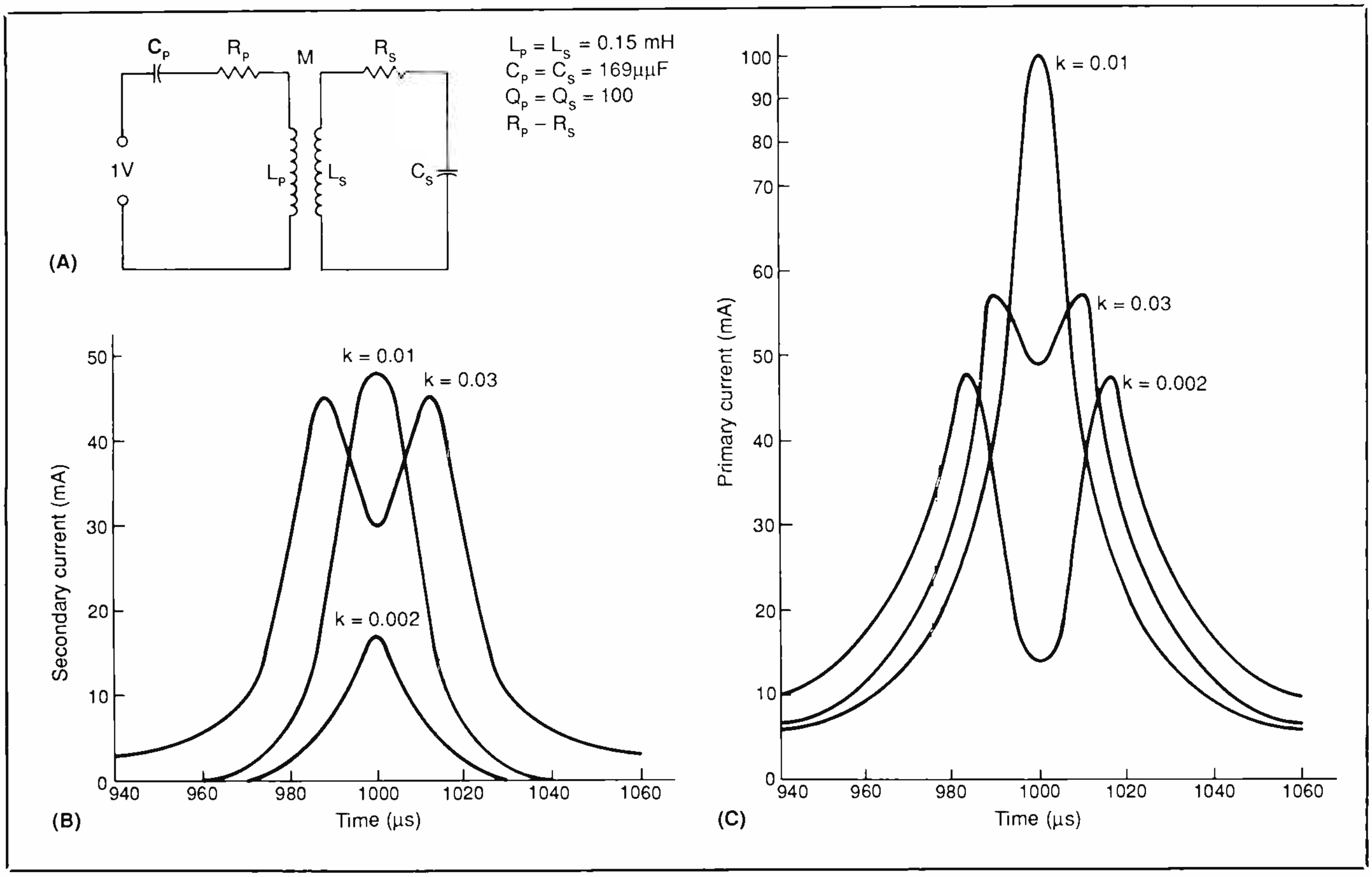


Fig. 3. Details of an AM i-f transformer: (A) Thevenin representation; (B) plots of primary signal-current flow of three degrees of coupling; (C) plots of secondary current flow of three degrees of coupling.

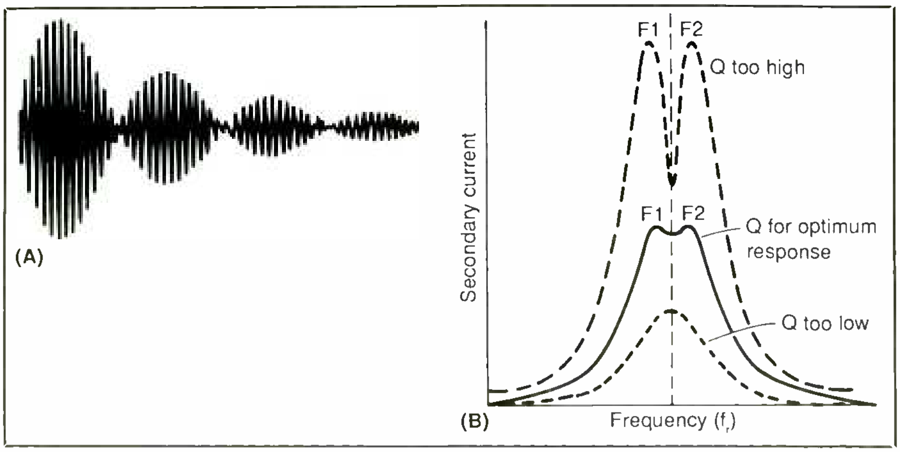


Fig. 4. Example of a ringing waveform for a tuned i-f transformer illustrating the effect of two ringing frequencies: (A) as it would appear on the screen of an oscilloscope; (B) graph of ringing frequencies F1 and F2.

Transient Ringing Waveforms

All ringing waveforms are transient in nature and eventually decay to zero. However, some decay slowly, others rapidly. This decay rate is a function of the circuit's "Q" value. When Q is high, *R* is small and the I^2R resistive loss is correspondingly slow.

With reference to Fig. 5, when *R* is comparatively large and the circuit bandwidth is large, a square wave will be reproduced with overshoot and ringing evident for only brief intervals following the leading and trailing edges of the square wave. The Q value of a parallel-resonant circuit (or equivalent parallel-resonant circuit) is equal to XL/R. Since XL = XC at resonance, the Q value of the circuit is also equal to XC/R.

It is helpful to note that a definitive value of circuit resistance is called the "critical resistance," abbreviated R_c. This critical resistance is equal to $2\sqrt{L/C}$. Under this operating condition, the overshoot is a single surge without subsequent ringing, as illustrated in Fig. 6(A). By way of comparison, the Q value under this condition is 1.

If the Q value is reduced to 0.25, there will be no overshoot. However, the corner of the reproduced square wave will be substantially rounded off. This is just another way of stating that the rise time of the waveform is considerably faster if overshoot is permitted by increasing the Q value from 0.25 to 1.

Next, if the Q value of the circuit (or equivalent circuit) is slightly greater than 1, the overshoot will be followed by a "dip," as illustrated in Fig. 6(B). That is, the initial single surge is followed by one recognizable half-cycle of ringing. Under this condition, the rise time of the waveform is also improved to some extent.

If the Q value is much greater than 1, the initial overshoot is followed by prolonged ringing, as demonstrated in Fig. 6(C). A practical example of this condition is seen in a defective TV sweep system described as "ringing all the way through the picture."

Rising High-Frequency Response

Although an RC amplifier does not contain inductance per-se, the amplifier will overshoot and ring on a square-wave test if it has rising high-frequency response. This is exemplified in Fig. 7. In this case, the amplifier rings because the rising high-frequency response is equivalent to a basic "flat" amplifier plus a high-frequency RLC peaking network. In turn, the amplifier overshoots and rings because it "sees" a moderately high-Q RLC network.

It does not make any difference what the cause of the rising high-frequency response may be. For example, it can be caused by deteriorated emitter-bypass capacitors. The practical result is that the amplifier network now contains pseudo-inductance, which evaluates as an RLC peaking network.

As a helpful rule of thumb, any RLC network that contains more than one section with Q values that are greater than 1 will ring most prominently at the sectional frequency that has the highest Q value. If a multiple-stage amplifier has stages that have uniform frequency response, the overall frequency response will be "flat," and the amplifier will have little tendency to overshoot and ring on a square-wave test. However, even when overall frequency response is uniform, the amplifier will overshoot and ring if it has a rapid high-frequency rolloff char-

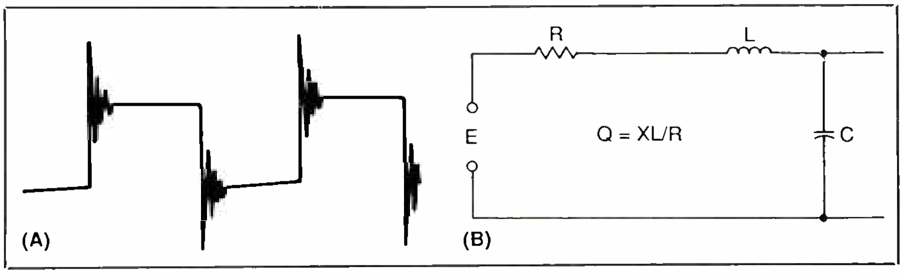


Fig. 5. Example of ringing reproduced square wave with rapid decay interval: (A) as it would appear on the screen of an oscilloscope; (B) rapidly of decay depends on the Q value of the equivalent RLC network.

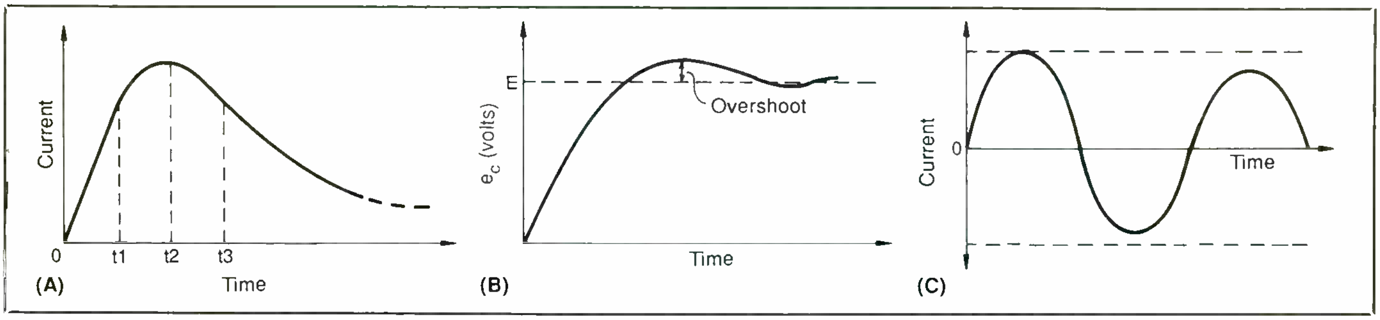


Fig. 6. Square-wave overshoot and ringing modes: (A) critical damping where Q is 1 and overshoot is a single surge; (B) where Q is slightly greater than 1 and overshoot is followed by a half-cycle of ringing; (C) where Q is comparatively high and overshoot is followed by a substantial ringing sequence.

acteristic. This is a consequence of nonlinear phase response.

It is not difficult to understand why an amplifier that has a very nonlinear phase characteristic is rapidly curved at high frequencies. Envelope delay distortion—also known as phase distortion—is the inevitable result. This is just another way of stating that the higher harmonics in the square wave are not equally delayed from one harmonic to the next in passage through the amplifier. Instead, the rapid curvature in the phase characteristic "bunches up" the high-frequency harmonics with respect to time. In turn, the sum of the higher-frequency harmonics becomes abnormal with accompanying overshoot.

If an amplifier has a comparatively slow rolloff characteristic in its frequency response, it will also have a comparatively linear phase characteristic. In the case of an ideal linear phase characteristic, all harmonics in a square wave will be equally delayed from one harmonic to the next and the reproduced square wave will be undistorted.

In practice, no amplifier has an ideal phase characteristic. However, when reasonably slow high-frequency rolloff is provided, square-wave distortion becomes negligible or, at the very least, tolerable. It is not ordinarily feasible to display the phase characteristic of an amplifier on the screen of an oscilloscope. However,

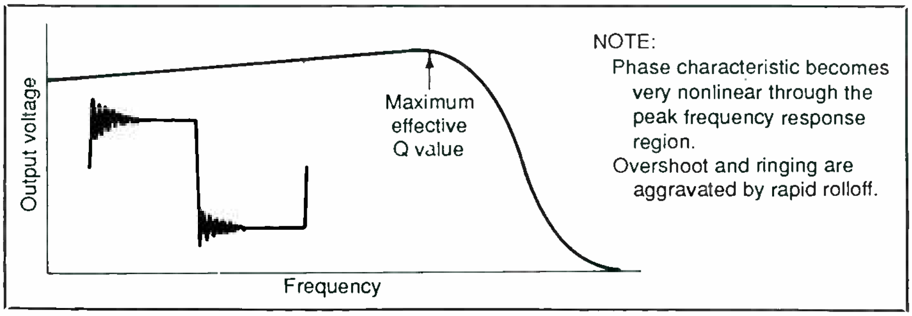


Fig. 7. Plot of an RC amplifier that has rising high-frequency response is equivalent to a basic amplifier plus an RLC peaking network that has a moderately high Q.

a square-wave test provides essentially the same data in another form—the reproduced square wave is easily "read out" for evidence of nonlinear phase conditions.

From the viewpoint of test procedures, the optimum square-wave frequency depends upon the location of phase linearity. Thus, if there is significant 100-Hz phase nonlinearity, low-frequency square waves will be reproduced with tilt, but no visible distortion will occur at 1 kHz or 10 kHz. On the other hand, if there is significant phase nonlinearity at 3 MHz, a high-frequency square wave will be reproduced with overshoot and ringing, but no visible distortion will appear at 100-Hz or 1-kHz repetition rates.

Note that a direct-coupled amplifier in normal operating condition shows no phase distortion at any low square-wave repetition rate. However, phase distortion will always become apparent as the high-frequency cutoff point is approached.

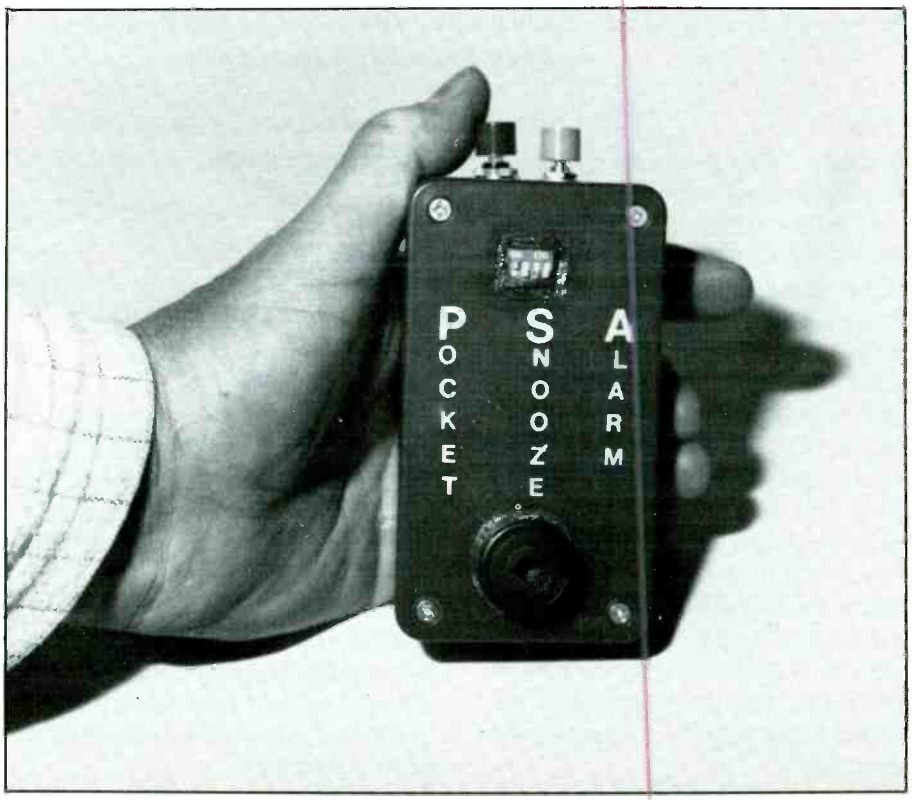
When troubleshooting electronic equipment with transient distortion, it is desirable to make comparison waveform tests, if possible, with reference to a similar unit that is operating normally. Comparative frequency-response and square-wave response tests can be made using a function generator at the signal source.

Although dc-voltage and resistance measurements are basic and valuable, they do not "spot" open capacitors and do not indicate the presence of shorted turns or layers in inductors. To cite a familiar procedure, a yoke with a few shorted turns can be effectively checked with a pulse generator and oscilloscope, though the yoke on a TV picture tube will appear to be okay if only resistance tests were made. ME

A Pocket Snooze Alarm

Lets you catnap for selected periods of 5, 10, 15 or 30 minutes before being awakened by the battery-powered alarm

By Homer L. Davidson



Taking a short nap after lunch or whenever you feel dragged out can do wonders in keeping you alert later when it counts. Sometimes just closing your eyes for 10 or 15 minutes can let you relax enough to speed through your next job. And pulling off the road during a long haul to relax for a vital few minutes can prevent an automobile accident. There are any number of situations in which a short nap can be beneficial.

One way to help you get your short nap but not sleep through several hours is to have handy a small Snooze Alarm like the one described here to wake you. This pocket-size, battery-powered Snooze Alarm can be used anywhere—on a driving trip, to your office and even at home. It can be set to sound an audible alert at the end of a preprogrammed period lasting 5, 10, 15 or 30 minutes.

About the Circuit

As shown in Fig. 1, thanks to the ubiquitous 555 integrated-circuit timer used for *IC1*, only a few readily available components are needed to build this Snooze Alarm. Small DIP switch assembly *S2* permits you to select the duration of your snooze period. When the snooze period has timed out, piezoelectric buzzer *PB1* sounds an audible tone to wake you.

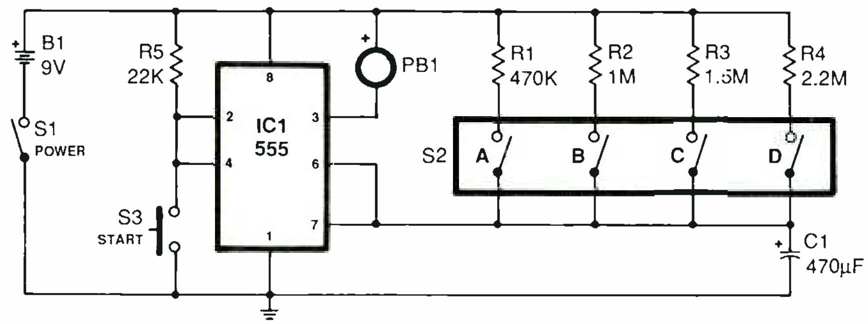
Pressing and releasing START switch *S3* starts the timing cycle. The timing period depends upon the RC time constant generated by the values of any one of resistors *R1* through *R4*, depending on which is selected by *S2*, and capacitor *C1*. With the values specified for *R1* through *R4*, snooze periods of approximately 5, 10, 15 and 30 minutes, respectively, are available with the 470-microfarad value specified for *C1*.

Once the countdown period has begun, the Snooze Alarm remains silent for the selected period of time. Upon completion of the countdown, OUTPUT pin 3 of *IC1* powers *PB1* to sound the alarm. When you awaken at this point, you shut off the audible alert simply by turning off power to the project by opening switch *S1*.

The timing circuit is powered by common 9-volt transistor battery *B1*. The timing circuitry draws only 8.25 milliamperes of current from the battery. So if you use a heavy-duty alkaline battery for *B1*, you should obtain a long life from the battery.

Construction

Owing to the simplicity of this project in terms of component count and the fact that nothing is critical about component location and conductor runs, you can build the Pocket



PARTS LIST

B1—9-volt alkaline battery
C1—470-µF, 16-volt electrolytic capacitor
IC1—LM555 timer
PB1—PC-mount 2.8-kHz piezoelectric buzzer (Radio Shack Cat. No. 273-065A)
(All resistors ¼-watt, 5% tolerance)
R1—470,000 ohms
R2—1 megohm
R3—1.5 megohms
R4—2.2 megohms
R5—22,000 ohms
S1—Spst push-push, slide or toggle switch
S2—4-position DIP switch assembly
S3—Normally-open, momentary-action spst pushbutton switch

Misc.—Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable Wire Wrap or soldering hardware (see text); 4⅜" × 2⅝" × 1" plastic enclosure (see text); snap-type connector and holder for 9-volt battery; spacers; lettering kit (see text); clear spray acrylic; fast-setting epoxy cement or silicone adhesive (see text); machine hardware; hookup wire; solder; etc.

Fig. 1. Complete schematic diagram of the project's circuitry.

Snooze Alarm using any traditional wiring technique that suits you. If you wish, you can wire the circuitry on a small printed-circuit board you make yourself or on perforated board that has holes on 0.1-inch centers using appropriate Wire Wrap or soldering hardware. Whichever technique you choose, though, it is a good idea to use a socket for the timer chip.

If you wish to use a printed-circuit board, use the actual-size etching-and-drilling guide shown in Fig. 2 to fabricate one. When the board is ready, drill a hole in each of its four corners in locations where they will not interfere with any conductor runs and place the board on you work surface oriented as shown in Fig. 3. (Note: Use the layout shown in Fig. 3 as a rough guide to component placement if you wire the circuitry on perforated board.)

Install and solder into place the IC socket, but do *not* plug the 555 in the socket until after you have conducted a voltage check upon completion of assembly of the project. Then install and solder into place the piezoelectric buzzer (observe polarity!), resistors and the DIP switch assembly. Plug the leads of the capacitor into the C1 holes in the board from the conductor trace side of the board and solder them into place. Be sure you properly orient the capacitor before soldering its leads to the copper pads on the bottom of the board.

Strip ¼ inch of insulation from both ends of three 4-inch-long hookup wires. If you are using stranded wire, tightly twist together the fine conductors at both ends of all wires and sparingly tin with solder. Plug one end of two of these wires into the holes labeled S3 from the solder side of the board and solder into place. Similarly, plug one end of the remaining wire into the hole labeled S1 from the solder side of the board and solder this into place.

Tightly twist together the fine wires at the ends of the 9-volt battery snap connector leads and sparingly tin with solder. Plug the red-insulated lead of the battery connector into the hole labeled B1+, again from the solder side of the board, and solder it into place. Temporarily set aside the circuit-board assembly.

Now prepare the enclosure that will house the circuitry. You can use any type of small enclosure you may have around or can locate in your local electronics parts store. An all-plastic enclosure, like the one shown in the lead photo, is ideal. However, if you wish, you can use a plastic enclosure that has an aluminum cover plate as well.

Machine the enclosure to permit mounting of the circuit-board assembly to the cover plate, switches *S1* and *S3* on the top wall and battery holder to the floor. Note also that you must cut a rectangular slot in the cover plate through which the toggles on the DIP switch will be accessible.

The 1-inch-diameter hole for the piezoelectric buzzer can begin as a ¼-inch-diameter hole that can be enlarged with a tapered reamer.

The dimensioned drawing shown in Fig. 4 gives machining details for the cover panel if you use the size enclosure specified in the Parts List. Not shown are the mounting holes for the circuit-board assembly. These must be located according to where you drilled them in the circuit-board assembly.

After machining the enclosure, use a dry-transfer lettering kit or tape labeler to label the switch functions and, if you wish, the name of the project. If you use dry-transfer letters,

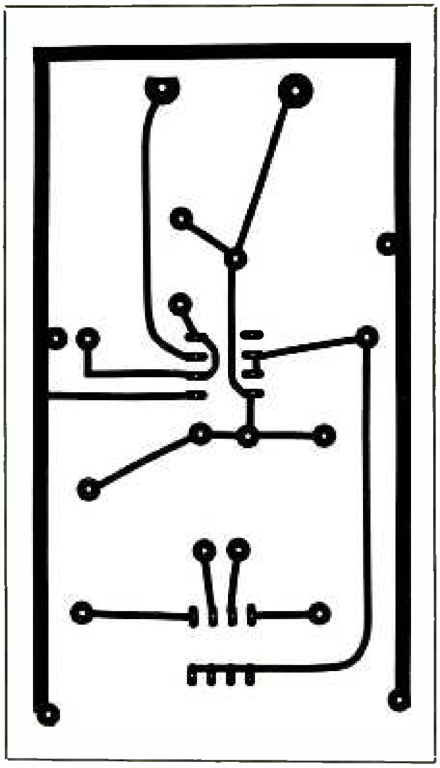


Fig. 2. Actual-size etching-and-drilling guide for printed-circuit board for project.

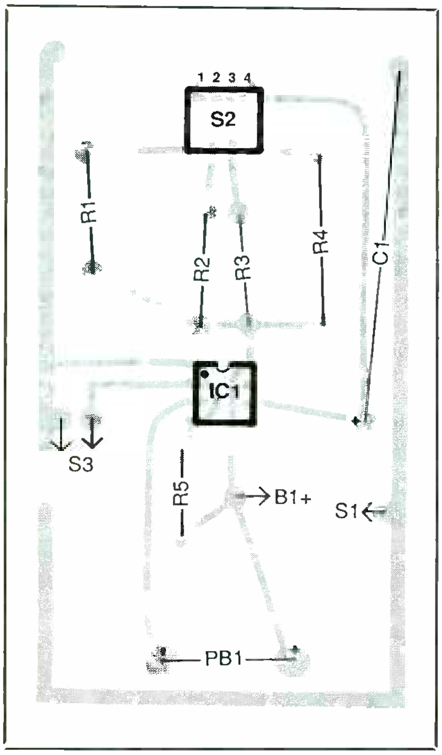


Fig. 3. Wiring guide for pc board.

protect them from scratching with two or more light coats of clear spray acrylic. Allow each coat to dry before spraying on the next.

Mount *S1* and *S3* in their respective holes in the end panel and the battery clip to the floor of the enclosure. Then mount the circuit-board assembly to the panel with suitable length spacers and 4-40 machine hardware. Apply a thin bead of black silicone adhesive around the perimeter of the DIP-switch assembly and piezoelectric buzzer to give the project a more finished appearance.

Locate the wires coming from the holes labeled S3 and crimp and solder these to the lugs of the momentary-action pushbutton switch. Then crimp and solder the free end of the remaining wire to one lug of the slide, toggle or push-push switch. Crimp and solder the black-insulated lead of the battery snap connector to the other lug of the latter switch.

Checkout & Use

With the 555 timer chip still not plugged into its socket, snap a fresh 9-volt battery into the connector and place the battery in its holder. Connect the common lead of a dc voltmeter or multimeter set to the dc-volts function to the negative (−) lead of the capacitor. Set *S1* to "on." Touch the "hot" probe of the meter to pin 8 of the IC socket and observe the reading obtained on the meter. If it is not +9 volts, power down the circuit and rectify the problem.

Once you are certain that the project has been correctly wired, turn off the power. Then install the 555 timer chip in the IC socket. Make certain that the timer is properly oriented in the socket and that no pins overhang the socket or fold under between IC and socket.

Now select the shortest-duration snooze period by setting switch 1 in the DIP switch assembly to "on." Upon power-up of the project, you should immediately hear a loud beeping from the buzzer. Press and re-

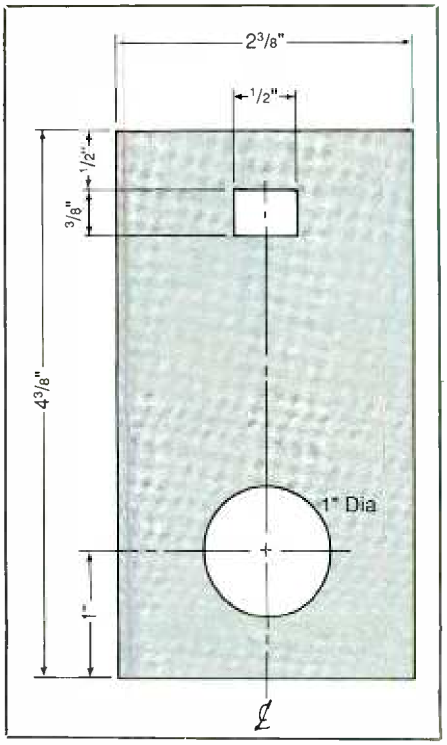


Fig. 4. Fabrication details for front panel of specified enclosure. If you use an enclosure that has different dimensions, make suitable adjustments in machining details.

lease the START pushbutton switch to begin the timing interval countdown of 5 minutes. At the end of the countdown interval, the buzzer should again sound and continue to do so until you set *S1* to "off."

If the project operates as described for the shortest timing interval, you might want to ascertain operation for the other intervals. This will take a bit of time to accomplish because each successive switch in the DIP-switch assembly increases the snooze timing period. Also, each DIP switch should be set to "off" when another time is selected. For example, if switch 2 is selected, switches 1, 3 and 4 should all be off so that only a 10-minute countdown period is selected by switch 2.

Bear in mind that times stated are only approximate. If you want more accurate timing, it may be necessary to add to or subtract from the resis-

(Continued on page 82)

BOOKS

Modern Television Service and Repair. *By Stan Prentiss (Prentice-Hall. Hard cover. 356 pages. $33.)*

Written by one of the most prolific expert authors of television servicing articles and books, this volume is a font of useful information. It bridges the history of TV receivers, starting with the 1950s and working up to the most up-to-date topics in the technology. Starting with a catch-all "Then and Now" chapter that contrasts the old with the new, the book moves on to an analysis of modern TV receiving systems.

Following the two introductory chapters are ten more chapters. Chapter 3 discusses digital receivers as they are now and what can be expected in the foreseeable future. Surface-mount and LSI technologies are treated in depth in the next chapter. Chapter 5 deals with the art, science and practice of TV servicing. Here is where the test instruments specific to TV troubleshooting and repair are identified and their utilization discussed.

The next five chapters dissect the TV receiver, devoting individual chapters to mono and stereo sound, tuner types, luma/chroma/sync processing circuits, power supplies, and antennas, transmission lines and MATV systems. Projection TV and cathode-ray tubes are dealt with in Chapter 11. The book closes with a look at the near future of TV with a discussion on high-definition television (HDTV) and the steps that might lead up to this ultimate goal, which is expected to be the next wave in improved-performance reception.

From the foregoing, it should be obvious that this book provides a well-rounded overview of modern TV receiving equipment and the techniques required to service and repair it while at the same time giving an insight into where the technology began and where it is heading. Excellently rendered schematics, drawings and photos are liberally distributed throughout the book to support the easy-to-understand text.

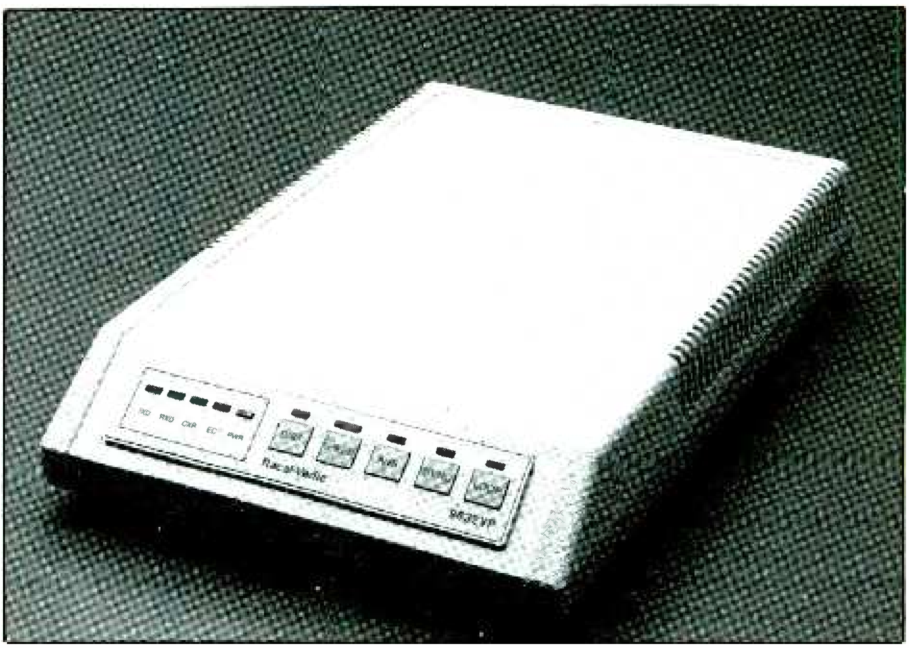
NEW LITERATURE

Computers & Electronics Catalog. Jameco Electronics' new 1990 catalog of computer kits and electronic components is now available. The 84-page catalog lists and fully describes a wide variety of computer kits and related products, as well as integrated circuits and other semiconductors. It also lists capacitors, resistors, switches, connectors, project enclosures, tools and tool kits, and more. A separate section is devoted to test instruments and includes listings for oscilloscopes, meters, logic probe and 1-GHz frequency counter.

Included in the computer products line-up are an 80286 laptop computer, 80386 and 80286 computer kits, 80386 and 80286 full-size and baby-AT motherboards, expansion cards, monitors and floppy- and hard-disk drive systems. Accessory products include internal and external modems; desktop and tower computer cases; power supplies; printers; software; handheld scanners; printer and monitor stands; keyboards and keyboard drawers; etc. For a free copy, write to: Jameco Electronics, 1355 Shoreway Rd., Dept. ME, Belmont, CA 94002.

The Racal-Vadic V.32 Modem: High-Speed Data Communication on a "Budget"

By TJ Byers



In an age when you can fly from Los Angeles to New York in 4 hours, you might reasonably ask why you should you have to wait nearly 2 hours for your 2,400-baud modem to transmit the contents of a single 1.44MB, 3.5-inch floppy diskette from one PC to another. The answer is that you shouldn't have to wait so long, and now you don't. A new generation of V.32 modems, like the Racal-Vadic Model 9632VP, solves the problem by offering data throughput at speeds up to 19,200 bps (bits per second) over standard telephone lines. Although the V.32 standard is rated at 9,600 bps, the Model 9632VP is able to double the data rate using MNP 5 data compression, allowing you to send those 1.44MB in well under 15 minutes.

In addition to V.32 operation, the Model 9632VP can also function as a 1,200/2,400-bps or 300-baud modem for connecting with electronic bulletin boards and other low-speed user devices. The Model 9632VP does this by querying the responding modem as to its type at the beginning of the session, then adjusting its speed to match that of the other modem. Which means the Model 9632VP is a one-stop source for all your modem needs at standard speeds.

The V.32 Story

Modems communicate by first generating and then modulating a carrier signal that is subsequently transmitted over telephone lines. The method of doing this is identical to the way radio and TV stations send their messages over the airwaves, except that the frequencies are different.

Modems are currently restricted to the 2,700-Hz bandwidth of the Public Switched Telephone Network (PSTN) dial-up phone channel (until ISDN becomes commonplace), which ranges between the audio frequencies of 300 Hz and 3 kHz. Consequently, you don't have a lot of room to work with, and the carrier frequency is pretty much limited to 2,400 Hz. For full duplex (two-way) communications you need two carriers, however, one coming and one going, leaving only 1,200 Hz of bandwidth (600 baud) per channel.

Modems overcome this inherent speed limitation by using phase-shifted keyed (PSK) modulation to send data in excess of the baud rate. PSK modulation uses two oscillators running at 90 degrees apart for its digital encoding. According to the value of the binary bit, the encoder chooses between one of the two oscillators at predetermined intervals to produce a waveform like the one you see in the waveform drawing. A phase-locked loop (PLL) detector in the receiving modem decodes the phase information.

As the speed of the modem increases, so does the complexity of the carrier waveform because the phase must be changed more times per cycle to accommodate the faster data rate. At 2,400 bps, each 1,200-Hz carrier cycle experiences four phase changes, which is simple enough to decipher. However, when a 1,200-Hz carrier is encoded for 9,600 bps, it's nearly impossible to distinguish the 16 phase changes per carrier cycle from the random background noise commonly found on telephone lines. The only recourse is to make the carrier waveform simpler by increasing the carrier frequency. But if this is done, there isn't enough bandwidth for two separate carriers, which means that a new approach must be found.

The V.32 standard forged by the Cooperative Committee for International Telephone and Telegraph (CCITT) meets the challenge using a technique called "echo cancellation." In echo cancellation, two modulated 2,400-Hz carriers are put on the phone line at the same time. One carries your data and the other carries the data from the other modem. Although the two signals clash and interfere with each other, the method works because your modem knows what it is sending. All you do is subtract your signal from the total to hear what the other modem is saying.

This is done by creating an inverted signal of your modem's output (using an operational amplifier) and feeding it to your receiver's input. When the transmitter's output voltage goes positive, the receiver's input voltage goes negative, resulting in a zero voltage at the input of the receiver for that signal. Once your signal is canceled, all that remains is signal coming from the other modem.

Data Compression

The other half of the Racal-Vadic Model 9632VP success story is built-in MNP Class 5 data compression. Data compression doesn't change the way the modem works, only the way the data is packaged before it is sent. MNP 5 has a 2-to-1 data compression ratio, which allows the Model 9632VP to communicate at 19,200 bps.

MNP 5 data compression (created and licensed by Microcom) works by looking for repeated characters or patterns in the data string, such as spaces or tabs in a table, and replacing them with unique control characters. It also counts the number of times a character appears in a document, like the letter "e," and renames those that are frequently used with a code that's shorter than its ASCII equivalent.

Compressed data is then sent over the phone line at a speed of 9,600 bps. At the receiving end, the MNP 5 control characters are expanded back into their original sequence, resulting in data throughput speeds up to twice the modem's data rate. Of course, the actual rate increase depends on the type of data being sent. Text files compress the best because they have very predictable patterns, while graphics files gain the least. Furthermore, if you use MNP 5 to compress a file that has already been compressed by another method, you actually *lose* data throughput because the modem wastes time looking for patterns that no longer exist.

Model 9632VP Features

While the Racal-Vadic Model 9632VP isn't unique in its support for V.32 protocol or MNP 5 data compression (nearly all 9,600-bps modems support both), its price is. At $1,195 list, the Model 9632VP is one of the lowest-cost V.32 modems available. But low price doesn't mean that this modem is shy on features. In fact, just the opposite is the case.

Racal-Vadic 9632VP Modem Facts

Maximum data rate	19,200 bps (with MNP 5 data compression)
Supported data rates	
V.32	9,600/4,800 bps
V.22	2,400 bps
Bell 212	1,200 bps
Bell 103	300 bps
Data compression	MNP 5
Error correction	MNP 2-4, V.42 compliant
Command languages	Hayes AT, Racal-Vadic ATPlus
PC interface	25-pin RS-232
Weight	2.4 lbs. (with power transformer)
Power	6 watts
Warranty	1 year
List price	$1,195
Manufacturer	
Address	Racal-Vadic, 1525 McCarthy Blvd., Milpitas, CA 95035
Telephone	(408) 432-8008

Among the features of this modem is support for five error correction methods: MNP Classes 2 through 4, V.42, and optional V.32 trellis encoding. With MNP and V.42 error correction, the data packet is checked for accuracy using a parity bit (MNP Class 2) or a CRC checksum (MNP Classes 3 and 4 and V.42). If an error occurs, the faulty data is discarded and a replacement data packet is sent. Trellis coding, on the other hand, adds a special forward-correcting data bit to the byte that tells the receiver how to correct errors in the data packet by itself, thus saving time and further improving throughput because data re-transmission isn't needed.

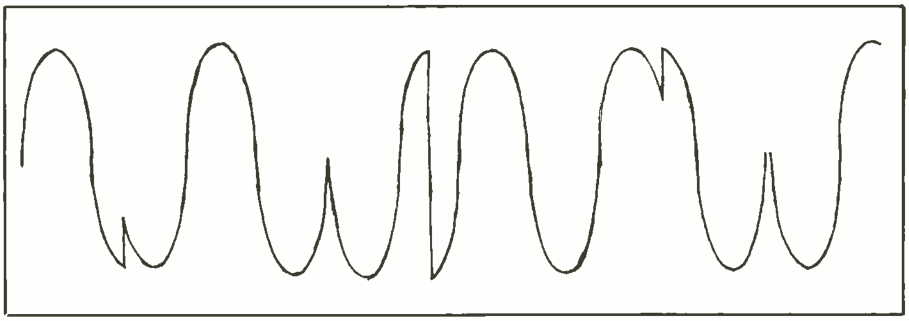
With either method, the Model 9632VP constantly monitors the phone line for quality. If line conditions are so poor that there are more errors than data coming down the pipe, V.32 automatically throttles the modem back to 4,800 bps. During the fall-back period, the modem makes periodic attempts at re-establishing 9,600 bps communications.

Unlike most modems, the Model 9632VP doesn't use mechanical DIP switches for its hardware configuration. Instead, the hardware instructions are entered from the keyboard and stored in nonvolatile memory. However, the front panel does sport a unique assortment of manual override switches that provide one-touch access to functions that include manual or auto-answer, self-test diagnostics, changing data rate, switching between voice and data, and a Sync switch that selects between asynchronous communications and a special Racal-Vadic synchronous communications mode.

All the above functions can be used individually or in combination to establish a modem communication link without the need of a software communications package. This makes the unit suitable for stand-alone mainframe and terminal use. The status of the switch settings and modem operation are displayed via 11 LEDs.

The Model 9632VP also has an MI/MIC (Mode Indicator/Mode Indicator Common) connection that allows you to add an external Bell 801-type device, such as a dial-back security system that prevents unauthorized persons from gaining access to your system, to the modem.

The Model 9632VP uses the AT command set, which was invented by Hayes



Waveform of phase-shift-keyed (PSK) modulation.

and supported by virtually all popular communications programs like *CrossTalk* and *Procomm Plus*. In addition to the Hayes AT command set, the Model 9632VP also supports a Racal-Vadic proprietary command set called ATPlus that is a superset of Hayes AT. With ATPlus, you can control modem capabilities not available in AT, like manual synchronous operation. A nice feature of the ATPlus command set is a user-friendly interface that tells you in plain English what's happening with your connection or what the modem needs in the way of input. ATPlus commands can be entered into the modem using a software package that has a script language, like *Procomm Plus*, or by typing in the commands from the keyboard while in DOS.

Automatic dialing of telephone numbers that contain up to 36 digits and auto log-on are supported by both command sets. In the AT command mode, the Model 9632VP can store up to four phone numbers in nonvolatile memory. In the ATPlus mode, up to 15 phone numbers can be saved.

User Comments

Installing the Racal-Vadic Model 9632VP modem is about as simple as it gets. Altogether, there are four back-panel connectors to fill, three of which are signal and one for the power. The connection to the PC or terminal is via a standard 25-pin RS-232 port. Power comes from a remote supply that has two 6-foot cords emanating from its plastic box: a low-voltage cable that plugs into the modem and a standard power cord that plugs into a 117-volt ac power outlet.

The two remaining outlets are phone jacks—one to connect the modem to the telephone line, the other (labeled TELSET) to be used to connect a standard telephone through the modem to minimize the number of phone connections in your system. When you use the "telset" option, a relay in the modem disconnects the handset when the modem is in service. You can override the disruption using the voice/data switch.

Basically, that's all there is to installation. If by some remote chance your communications software program requires special hardware settings, you'll have to make them from the keyboard. Unfortunately, the user's manual doesn't explain the procedure in lay terms; so the process may be confusing to some users.

Of the many software communications packages tested on the Model 9632VP, the modem showed no hardware or software problems. The only quirk noted was that the speaker didn't turn off when switching from voice to data when used with *Smartcom III* or *HyperAccess*. But it's not a life-threatening problem. If you find it bothersome, there's a volume control within easy reach on the rear panel.

Conclusions

There has never been a better time to buy a modem than now. Today's modems offer more features and better reliability and are easier to use than modems of the past. With the adoption of V.32 as the international 9,600-bps standard, the modem has taken a quantum leap forward in performance.

Versatility is a must with high-speed modems if they're to be anything more than a luxury. An important requirement is the multi-speed feature supported by the Racal-Vadic Model 9632VP that lets the modem operate at 1,200 and 2,400 bps for use with dial-up services and other users who haven't upgraded to V.32. Without the ability to shift gears, the user is limited to just sending files back and forth between another V.32 modem.

Another Model 9632VP key feature to keep in mind is MNP 4 error correction and MNP 5 data compress. Both are finding widespread use among V.32 modems and the new generation of 2,400-bps modems. When talking to a 2,400-bps modem using MNP 5 data compression, actual data throughput is at speeds up to 4,800 bps. When talking to another V.32 modem using MNP 5 data compression, you'll hit speeds of 19,200 bps.

High-speed V.32 modems are likely to find wide appeal among heavy PC users because of the time and phone charges they save. Desktop publishing and CAD/CAM users should find V.32's high-speed ideal because of the size of the files their applications generate. Financial analysis and mainframe links are also prime targets for V.32 performance.

Until recently, though, V.32 modems (with list prices topping $2,000) have been out of reach for most PC users. This is why the $1,195 Racal-Vadic Model 9632VP (under $1,000 on the streets) modem with its many features and 19,200-bps performance is perhaps your best V.32 dollar value today. ME

CIRCLE NO. 117 ON FREE INFORMATION CARD

Glossary of Popular Modem Terms

ASCII—7-bit code for text encoding
AT mode—Hayes AT command set
Bell 103—300 bps, full-duplex
Bell 208—4,800 bps, half-duplex
Bell 212A—1,200 bps, full-duplex
Bps—bits per second
CCITT—Cooperative Committee for International Telephone and Telegraph
CRC—Cyclic Redundancy Check error correction method
Full duplex—two-way communication
Half duplex—one-way communication
ISDN—Integrated Services Digital Network
MNP 4—Microcom Networking Protocol error correction method
MNP 5—Microcom Networking Protocol data compression method
PLL—Phase-Locked Loop
PSK—Phase-Shifted Keyed modulation
PSTN—Public Switched Telephone Network
V.21—300 bps, full-duplex
V.22—1,200 bps, full-duplex
V.22—2,400 bps, full-duplex
V.27—4,800 bps, half-duplex
V.29—9,600 bps, half-duplex for use with fax
V.32—9,600 bps, full-duplex
V.42—CCITT error correction method, compliant with MNP 4

Experimenting With an r-f Spectrum Analyzer

By Forrest M. Mims III

Testing and alignment of a radio-frequency (r-f) transmitter is considerably simplified if an r-f spectrum analyzer is used. This valuable instrument also permits you to survey your environment for the presence of r-f radiation and check equipment for unwanted r-f emissions.

This time around, I'll begin by describing a new kind of r-f spectrum analyzer that costs considerably less than conventional analyzers. Then I'll detail how this instrument can be used to check for r-f signals. Finally, I'll show how a spectrum analyzer can be used to aid testing and aligning a miniature r-f transmitter.

Spectrum Analyzer Basics

A radio-frequency spectrum analyzer is similar in principle to an audio spectrum analyzer. Both instruments provide a graphical display on which signals are plotted as a function of both frequency and amplitude. Serious audiophiles find an audio spectrum analyzer indispensable for observing the nature of an audio signal and for equalizing the frequency response of a system to best match the acoustics of a particular room or auditorium. An r-f spectrum analyzer is even more important since, unlike audio signals, r-f signals ordinarily cannot be sensed by the human body.

An r-f spectrum analyzer can be used to measure the absolute frequency and amplitude of a signal. It can also be used to compare the relative frequencies and amplitudes of two or more signals. The signal can be generated by a circuit under test or from an unknown source. In any case, a quick glance at the analyzer's screen will reveal if the signal has a narrow bandwidth or if it is noisy.

An analyzer greatly simplifies alignment of an r-f source because harmonics, noise and spectrum broadening are easily visible. It's also a valuable tool for finding and correcting unwanted r-f leaks and signals.

All these features and advantages can be very expensive. Consider, for example, Hewlett-Packard's Model 3585 20-Hz-to-40-MHz spectrum analyzer. This high-performance instrument provides up to 100 dB of dynamic range and a resolution of 3 Hz. The CRT display gives a comprehensive readout of the instrument's settings. These and many other features of the Model 3585 can be had for a whopping $24,200!

An instrument like the H-P Model 3585 is totally beyond the financial reach of most electronics experimenters, of course. Fortunately, an inexpensive alternative is now available.

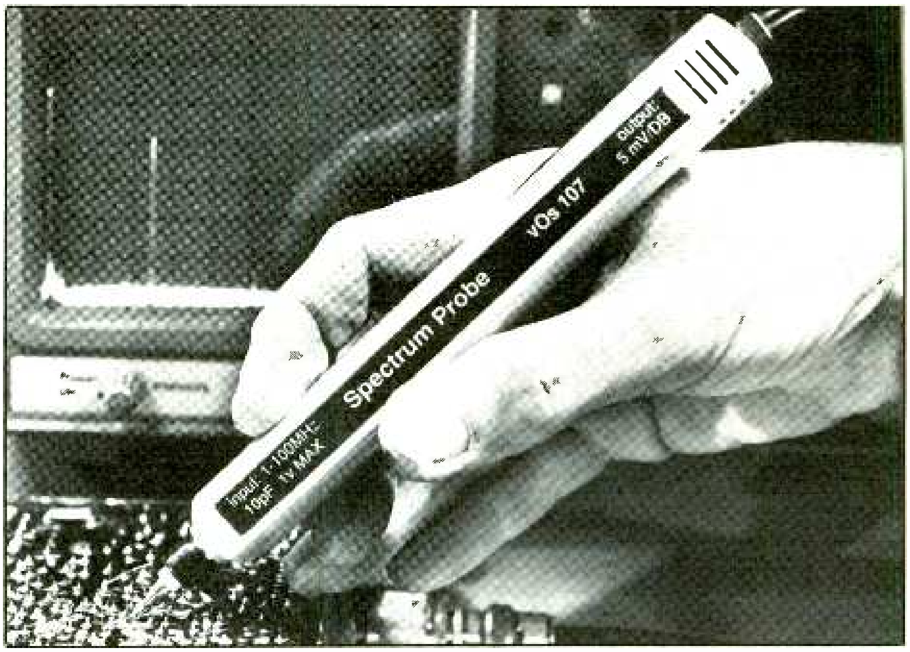


Fig. 1. The Spectrum Probe spectrum analyzer in operation with an oscilloscope.

An Economical Analyzer

I recently had the opportunity to evaluate the Spectrum Probe, a miniature probe-like device that transforms almost any oscilloscope into a 1-to-100-MHz spectrum analyzer. Shown in Fig. 1, the Spectrum Probe is manufactured by Smith Design (1324 Harris Rd., Dresher, PA 19025) and sells for only $199, plus a nominal shipping charge. (The company accepts charge-card orders at 215-643-6340.) While the $199 price of the Spectrum Probe might seem rather steep for such a small instrument, particularly since it can be used only in conjunction with an oscilloscope, this instrument is considerably less expensive than a conventional spectrum analyzer.

Before proceeding, I must point out that the Spectrum Probe shouldn't be considered as a replacement for a conventional spectrum analyzer. It doesn't provide the calibrated, high-resolution display of such professional instruments. Nevertheless, in many applications, the Spectrum Probe does provide a usable substitute for considerably more expensive instruments.

The Spectrum Probe is easy to use. Its male BNC connector goes to the input of the oscilloscope, and its plug-in wall transformer connects to a source of 117-volt ac household current. The oscilloscope is then initialized. Horizontal sweep is set to 0.5 millisecond per division to give a frequency response of about 10 MHz per division and total frequency range of 1 MHz to slightly beyond 100 MHz. The vertical scale is then set to 50 millivolts per division to give a sensitivity of 10 decibels per vertical division, for a total dynamic range of more than 50 dB. Logarithmic linearity of the vertical scale is ±3 dB.

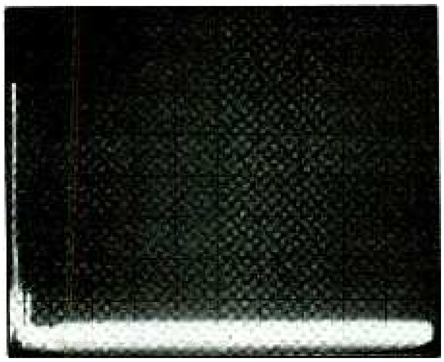
Shown in Fig. 2(A) is a typical oscilloscope display, produced when the Spectrum Probe is operated in my rural office in South Texas without the presence of any incoming r-f signals. In operation, the oscilloscope trace is adjusted to be near the bottom of the screen. The vertical spike shown at the extreme left side of the sweep is a zero marker that indicates the beginning of the sweep at about 1 MHz. Just to the immediate left of the zero spike is a negative synchronizing pulse. The next arrival of this pulse is sometimes visible on the extreme right end of the trace.

Figure 2(B) shows the display when a short clip lead is attached to the input of the Spectrum Probe. Notice the presence of distinct signals and areas of what appear to be noise. The spikes that occupy the first one and a half divisions immediately to the right of the zero marker represent broadcast signals from several AM radio stations in my area. The spikes that occupy the next few divisions are signals from more-powerful shortwave radio stations. These signals become more powerful and numerous at night.

Two of the three spikes shown at the right end of the screen are signals from two television stations in San Antonio, TX. The first is TV Channel 4, the third TV Channel 5. The small spikes just discernible near the 100-MHz point at the extreme right end of the screen are signals from FM radio stations. The amplitudes of these signals is increased when a longer antenna is connected to the device.

When comparing relative amplitudes of the r-f signals displayed on the oscilloscope screen, keep in mind that the vertical scale is logarithmic at 10 dB per division. Thus, a signal with an amplitude of 100 millivolts is stronger than one with an amplitude of 50 millivolts.

You can use the oscilloscope controls to expand a particular portion of the trace for more detailed examination. For example, it's possible to examine only the cluster of signals from nearby AM-broadcast stations to determine which


(A)

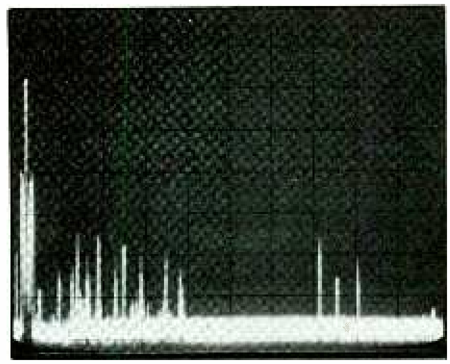

(B)

Fig. 2. Spectrum Probe oscilloscope display (A) without presence of an input signal and (B) showing ambient r-f signals received with a short wire antenna.

come from specific stations. This provides a convenient means of comparison of the relative signal levels of the stations at your location.

Though Fig. 2(B) shows the signals received by the Spectrum Probe when a short wire is attached to its input, you can obtain a very similar result simply by touching the Probe's input with a finger. This provides a convincing demonstration of the ability of your body to function as an r-f antenna.

Experimenting With The Spectrum Probe

I've learned a good deal about the r-f signals in my office with the help of the Spectrum Probe. What follows is a summary of some of the many measurements and experiments you can conduct with this versatile instrument.

You can use the Spectrum Probe much like a conventional oscilloscope probe to trace various kinds of circuits. For example, you can inspect digital circuits that have clock speeds in excess of 1 MHz. As pointed out in literature from the manufacturer of the Spectrum Probe, the harmonics that may be present on a digital line can be rather surprising.

The probe is especially useful for tracing the r-f sections of radio transmitters. Since the input of the probe has a very low capacity, it has little effect on the circuit being monitored. The probe can also be used to optimize the lengths of antennas and to study the efficiencies of various kinds of antennas and antenna terminations.

Simultaneous signals transmitted by two CB transceivers are shown in Fig. 3(A). One transceiver transmitted at a frequency near 27 MHz, the other on a frequency near 49 MHz.

Figure 3(B) shows the simultaneous signals received by the Spectrum Probe when a cordless telephone is being operated. The two separate signals are required so that full duplex communication can take place.

Figure 3(C) is particularly interesting because it shows the rash of r-f noise spikes that are generated by a small dc motor. This screen photo reveals a sharp drop in the amplitudes of noise spikes just beyond the midpoint of the display at around 55 MHz. Nevertheless, there's still plenty of noise out to and presumably beyond the 100-MHz limit of the display. Similar noise spikes are produced when mechanical switches and relay contacts are opened and closed in a circuit in which a current is flowing.

It's possible to expand the Spectrum Probe display by means of the oscilloscope's horizontal sweep controls, especially the 10× multiplier and delayed-sweep controls. For example, Fig. 3(D) shows an expanded view of the index marker and several AM broadcast-band radio signals. In Fig. 3(E), the sweep is further expanded to show a magnified

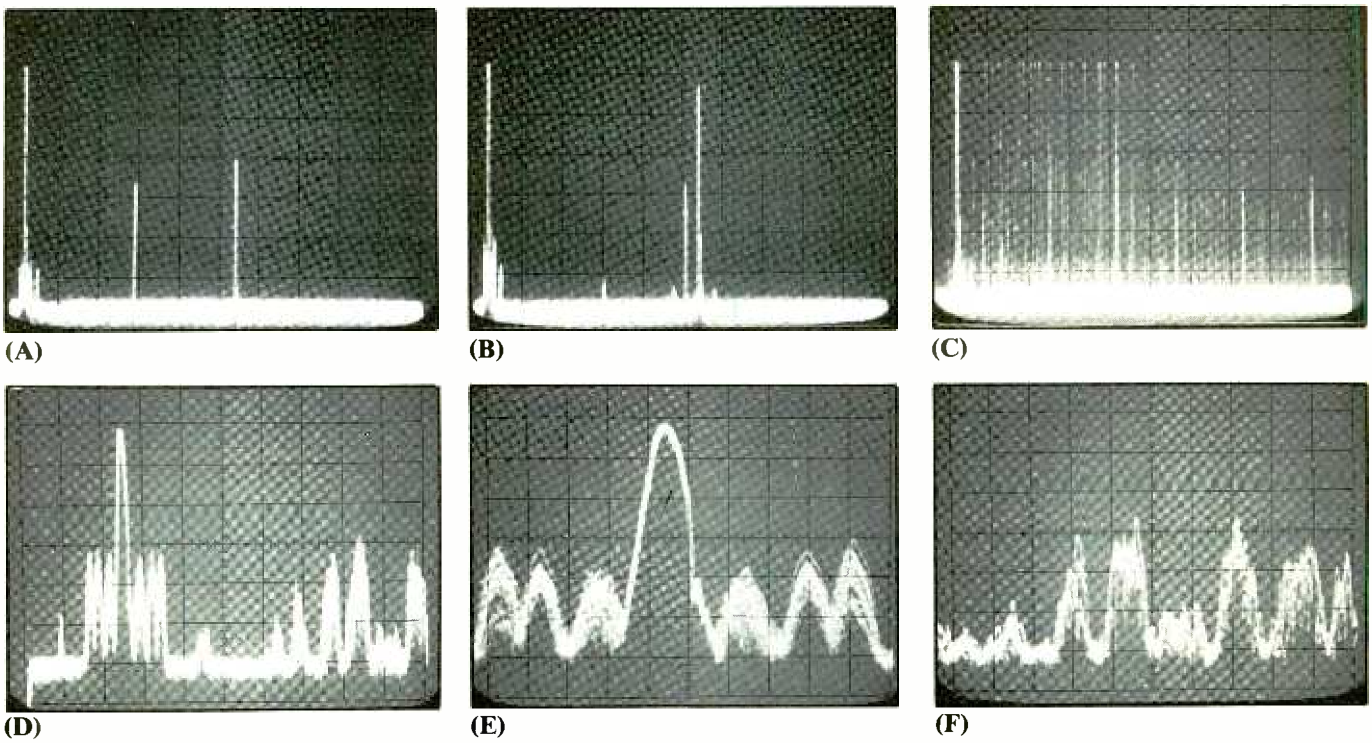


Fig. 3. Spectrum Probe oscilloscope displays showing: (A) simultaneous 27- and 49-MHz CB transmitter carrier signals; (B) two closely spaced signals of a cordless telephone system; (C) broad-spectrum noise produced by dc motor; (D) expanded view of index marker and received local AM radio station; (E) highly expanded view of index marker generated by Spectrum Probe; and (F) expanded portion of trace showing signal from AM radio broadcast-band stations.

view of just the index marker and its accompanying side lobes.

An expanded view of the signals from several AM radio stations is shown in Fig. 3(F). The apparent fuzziness of these signals is a direct result of the fact that they are amplitude-modulated and bounced up and down during exposure of the oscilloscope camera. An interesting experiment is to tune a radio to a station that the Spectrum Probe clearly shows on the screen of the oscilloscope. You can watch the crest of the wave bounce up and down in direct proportion to the audio signal. When the audio signal is momentarily quiet, the displayed wave will settle down.

Miniature Part 15 Vhf Transmitter

During the many hours I've spent designing and testing miniature transmitters, I've often longed for an r-f analyzer. Therefore, one of the most interesting experiments I've performed with the Spectrum Probe was evaluation of a miniature vhf transmitter, which I described in the April 1987 installment of this column.

Shown in Fig. 4 is the schematic diagram of the circuitry for this transmitter. The transmitter can be switched on by a pressure- or light-sensitive switch to notify you when mail has been placed in your mailbox. It can also be used as part of a wireless doorbell or intrusion-alarm system. By replacing *R1* with a suitable variable-resistance detector, it can even be used as a telemetry transmitter that transmits temperature, light-intensity or other physical analog data.

The transmitter depicted in Fig. 4 was designed to meet the requirements of Part 15.122 of Title 47 in the Code of Federal Regulations. This regulation permits periodic low-power transmission at any frequency beyond 70 MHz. In the band from 70 to 130 MHz, maximum field strength of the fundamental frequency is restricted to 500 microvolts/meter at a distance of 3 meters. This permits a transmission range on the order of hundreds of feet.

Part 15.122 permits a maximum transmission time of 1 second and minimum interval between transmissions of 10 seconds. The silent interval must be at least 30 times the duration of the transmission. Therefore, if a pulse is transmitted once every 10 seconds, its duration must not exceed 0.33 second.

The Fig. 4 circuit transmits a 0.24-second burst once every 10 seconds at a frequency within the 88-to-108-MHz FM broadcast band. In operation, *Q1*, *L1* and *C5* make up the transmitter's oscillator. Configured as an oscillator, *IC1* modulates the r-f carrier with an audio tone that has a frequency that's controlled by the values of *R1* and *C1*. Interval timer *IC2* enables the r-f oscillator for 0.25 second at 10-second intervals.

Each time the transmitter broadcasts a tone burst, the LED glows. The principal purpose of this LED is to drop the voltage applied to the r-f oscillator to around 1.5 volts to keep the output power from the transmitter within guidelines set forth in Part 15.122.

Oscillator coil *L1* is the most important component in the Fig. 4 circuit. This is an air-core coil that's made by wrapping five turns of solid wire around a ⅜-inch form. When the form is removed, the coil springs outward slightly and assumes a diameter of about ½ inch. The tap in my original transmitter was merely a wire soldered at the midpoint of the coil. As a result of the tests that follow, I replaced the soldered tap with the small clip lead shown in Fig. 5.

Connected to the junction of *L1* and the collector of *Q1*, the length of the transmitter's antenna shouldn't exceed 7 inches. A longer antenna violates Part 15.122 field-strength restrictions.

The transmitter can be tuned with the help of a vhf receiver, a Spectrum Probe or both. Firstly, temporarily disconnect the collector of *Q2* from the circuit to permit the r-f oscillator to operate continuously in CW (continuous-wave) mode. Then apply power to the transmitter and tune the radio receiver until a strong, continuous tone is heard. If the signal frequency is near that of a local radio station, alter the transmission frequency of the transmitter. Transmission frequency can be altered by varying the position of the tap or by slightly compressing or stretching the coil.

Another way to tune the transmitter is to slightly increase the value of *C5*. This can be done by adding one or more 1-picofarad capacitors in parallel with *C5*. Alternatively, you can replace *C5* with a miniature variable capacitor like those used in digital watches and miniature r-f gear. If you use a variable capacitor, it's imperative that you use an insulated

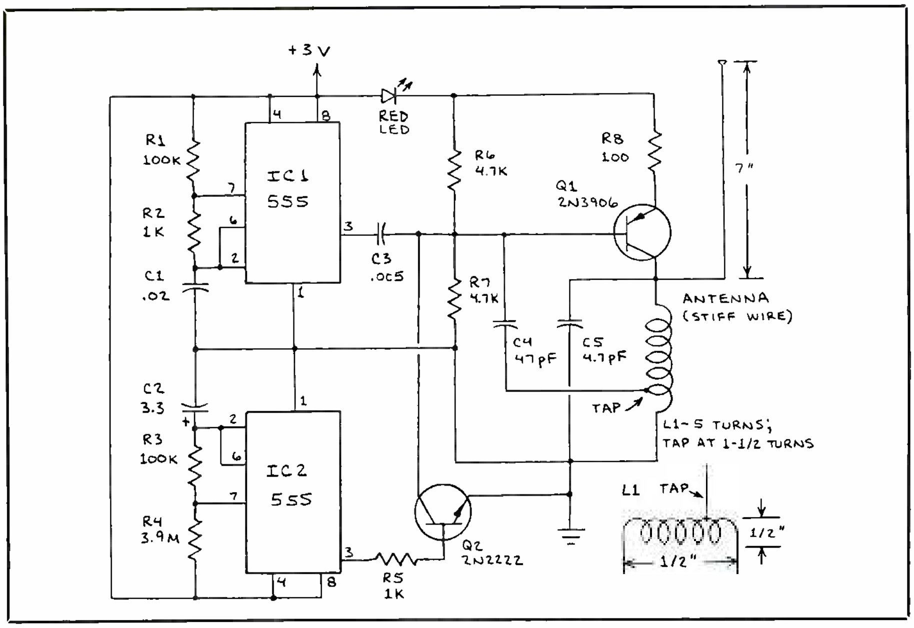


Fig. 4. Schematic diagram of circuitry for a miniature Part 15 vhf radio transmitter.

alignment tool to change its setting.

Still another way to tune the transmitter is to replace *R6* and *R7* with a 10,000-ohm potentiometer. Adjust the setting of the pot to center of rotation. Slight changes in position of the wiper change the oscillation frequency slightly. (See "Electronics Notebook," April 1987 for more details about the transmitter.)

Testing the Transmitter With the Spectrum Probe

Figure 6(A) shows the signal from the transmitter as displayed on an oscilloscope screen when the Spectrum Probe was located about 1 foot or so away. To avoid interfering signals from local radio stations, the Spectrum Probe was not connected to an antenna. The digital frequency readout of a communications receiver indicated that the transmitter signal peaked at 84 MHz. The half-power points of the signal were located at 83.3 and 84.1 MHz.

The signal shown in Fig. 6(A) was obtained when the clip lead tapped the coil at its center point. Fig. 6(B) is a triple exposure scope photo that shows how the frequency can be altered by moving the position of the tap. Moving the center tap one turn toward the antenna end of the coil, raised the frequency to 93.75 MHz. Moving it one turn toward the ground end of the coil, dropped the frequency to 76.4 MHz. These three frequencies are clearly displayed in Fig. 6(B). To make this photo, I simply moved the clip lead to the three points on the coil mentioned above and made an exposure of the screen each time.

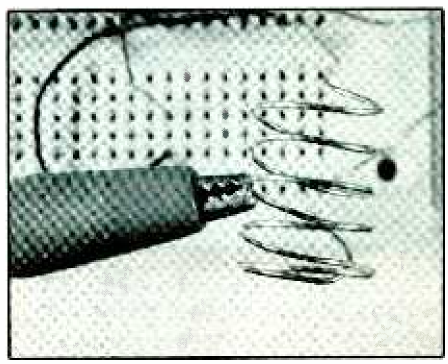
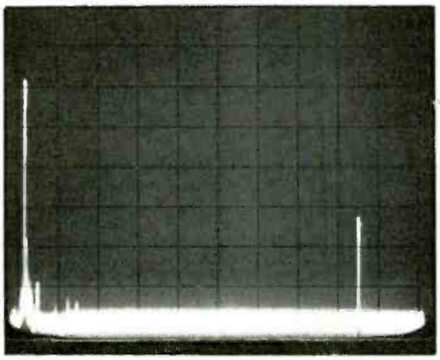
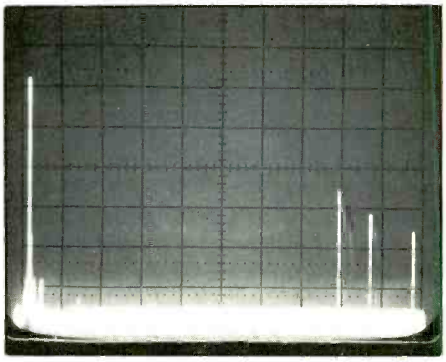


Fig. 5. Four-turn oscillator coil for Fig. 4 circuit showing center-tap clip lead.

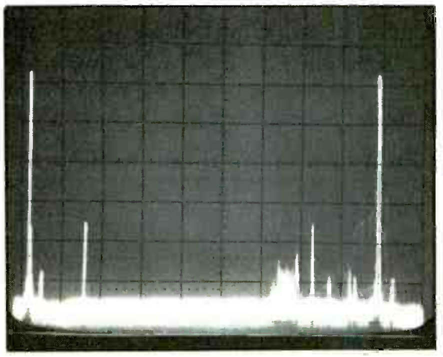
ELECTRONICS NOTEBOOK . . .



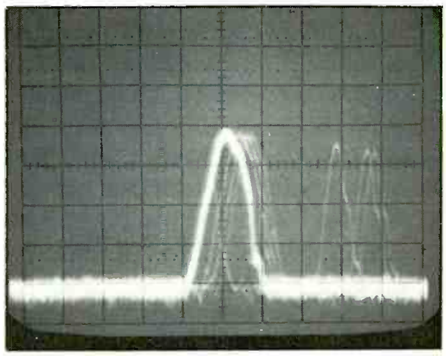
(A)



(B)



(C)



(D)

Fig. 6. Spectrum Probe oscilloscope displays of: (A) 84-MHz signal generated by Fig. 4 transmitter; (B) multiple exposure showing signals emitted by transmitter for three different oscillator-coil taps; (C) signal from transmitter (high-amplitude spike at right), along with local broadcast-band and TV-station signals; and (D) expanded view of (C).

Adding a short wire antenna to the Spectrum Probe greatly increased the amplitude of the displayed signal from the transmitter on the screen of the oscilloscope. Figure 6(C) shows the signal when the coil was center-tapped and when a 1-foot-long antenna was connected to the Spectrum Probe. Note that the amplitude of the transmitted signal was nearly 40 dB greater than that of the strongest signal from nearby TV and FM broadcast stations.

Figure 6(D) is an expanded view of the signal from the transmitter when it was center-tapped. This photo shows some undesirable spurious oscillations.

With the Spectrum Probe in operation, you can instantly see the results of adjustments to the transmitter. Place a finger next to the coil and observe what happens. Then try squeezing and stretching the coil in the transmitter. Another interesting experiment you can perform is to replace *C5* in Fig. 4 with a variable capacitor and *R6* and *R7* with a potentiometer as described above. Changing the settings of these two adjustable components will produce significant changes in oscillation frequency.

Summing Up

The Spectrum Probe represents a major breakthrough for low-cost r-f spectrum analysis. While it doesn't possess many of the refinements and features of more-sophisticated spectrum analyzers, its sensitivity, bandwidth and compact size make it a test instrument that's well worth its reasonable cost. **ME**

SOLID-STATE DEVICES

Analog-to-Digital Converters

By Joseph Desposito

Many applications require that an analog input signal be converted to digital form for processing. Naturally, to do this, you use an analog-to-digital converter. In this month's column we'll examine A/D converters that use a technique called successive approximation.

Device Backgrounder

One way to convert information from analog to digital form is by successive approximation. A typical A/D converter (ADC) of this type (see Fig. 1) is the ADC-912 from Precision Monolithics Inc. (Santa Ana, CA). It consists of a voltage reference, a D/A converter (DAC), a comparator, a successive approximation register, a clock and an output latch. The three-state bus interface is for logic compatibility.

The functional diagram shows that the device uses a 12-bit DAC. It also shows a voltage reference at pin 2 that connects to the DAC (the reference is −5V, according to the specifications for this particular device). During system power-up, the ADC comes up in a random state. Once the clock (running at 1 MHz) is operating, the first valid conversion begins with the application of a high-to-low transition on both CS (chip select) and RD (read). The next 13 negative clock edges complete the first conversion, producing valid data at the digital outputs.

Now, suppose we wanted to convert an analog potential of 6.3 V to digital form. High-to-low transitions on both CS and RD initiate the conversion sequence; the HBEN (high-byte-enable) input must be low, too, or coincident with the RD input edge. The start of conversion resets the internal successive-approximation register (SAR) to 0000 0000 0000 and enables the three-state outputs. The BUSY line is active-low during the conversion process.

During conversion, the SAR sequences the voltage output DAC from the most-significant bit (MSB) to the least-significant bit (LSB). In other words, it successively tests each bit to see if it should remain at zero or be changed to 1. The analog input, A_{in}, which can vary between 0 and 10 V for this device, connects to the comparator via a 5 k-ohm resistor. The DAC, which has a 2.5 k-ohm resistance, connects to the same comparator input, as shown in Fig. 2. Notice that the DAC voltage can vary over a range between 0 and −5 V ($-V_{REF}$).

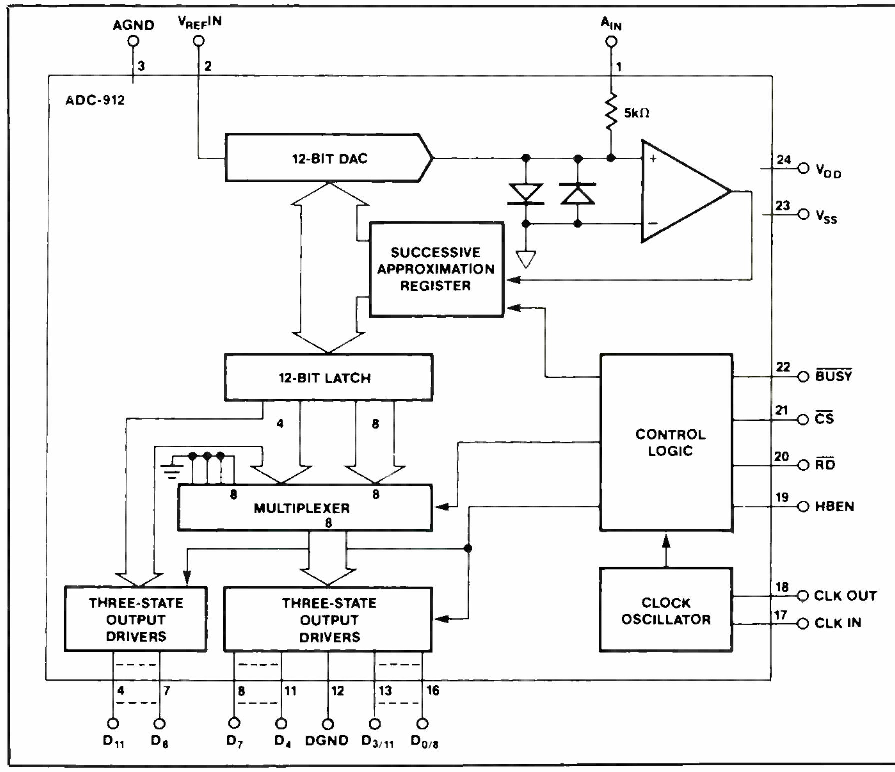


Fig. 1. Precision Monolithics' ADC-912 A/D converter offers successive-approximation conversion.

The first test occurs for the number 1000 0000 0000, which makes the DAC voltage −2.5 V. An analog input of 6.3 V would cause a positive potential of 0.4 V to appear at the positive input to the comparator. Since the negative input of the comparator is tied to analog ground (AGND), the comparator output is driven high. This leaves the MSB high for the remainder of the conversion. The process continues with the next bit raised high (1100 0000 0000) and then tested. If the voltage at the comparator is positive, the bit is kept high; if not, it is changed to a zero and the next bit is tested. This continues until all bits are tested.

Once a conversion cycle is started, it cannot be stopped or restarted without upsetting the remaining bit decisions. Every conversion cycle must have 12 negative CLK IN edges. At the end of conversion, the comparator input voltage is zero. The SAR contains the 12-bit data word representing the analog input voltage. The BUSY line returns to logic high, signaling the end of conversion. The SAR transfers the new data to the 12-bit latch. When the negative edge of RD is aligned with the positive edge of CLK IN, the conversion takes 12.5 microseconds.

Key Parameters

Let's now look at some of the key parameters of the ADC-912:

- *Conversion Time.* The time required to convert the analog input voltage to a digital output code.
- *Resolution.* The number of digital output lines. A 12-bit ADC has 12 digital output lines. Twelve lines allow the ADC to have 4,096 steps or analog voltages that can cause the LSB to change from 0 to 1 or vice-versa.
- *Gain Error.* The deviation of the actual analog input voltage from the ideal when the digital output is at full-scale (1111 1111 1111).
- *Offset Error.* The deviation of the analog input voltage from zero when the digital output is at all zeros (0000 0000 0000).
- *Integral Nonlinearity (INL).* The amount that the actual analog input voltage deviates from the ideal analog input voltage for any digital output code after

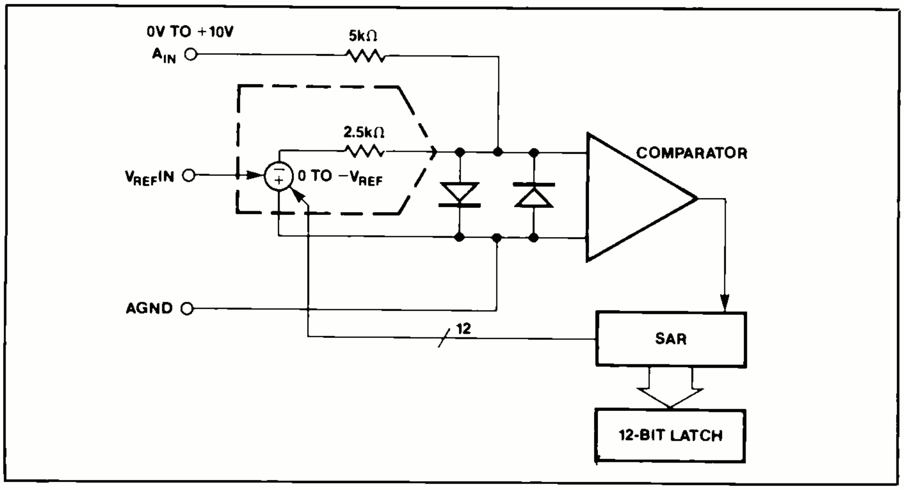


Fig. 2. The ADC-912 has a 2,500-ohm input resistor that connects to the same comparator input as the external 5,000-ohm resistor that couples the input signal into the device.

the gain and offset errors have been adjusted to zero. This number is expressed in LSBs or fraction of LSB. For example, a maximum INL of + ½ LSB is equivalent to 1.22 mV for a 12-bit ADC with an input range of 0 to + 10 V.

• *Differential Nonlinearity (DNL).* This is the difference between the actual change required to cause a digital output to change 1 LSB and the ideal change. For example, for a 12-bit ADC with a 0-to +10-V range, an analog output change of 2.44 mV should cause the output to change from 0000 0000 0000 to 0000 0000 0001. If it actually took 4.88 mV, the DNL would be + 1 LSB.

• *No Missing Codes.* As the analog input is increased from 0 to + 10 V, the digital output is supposed to increase from 0000 0000 0000 to 1111 1111 1111 by 1 LSB at a time without skipping any codes (for a 12-bit ADC with an analog input range of 0 to + 10 V).

Layout Guidelines

As with any high-speed A/D converter, good circuit layout practice is essential. Wire Wrap boards are not recommended due to stray pickup of the high frequency digital noise. A pc board offers the best performance. Digital and analog grounds should be separated even if they are ground planes instead of ground traces. Don't lay digital traces adjacent to high-impedance analog traces. Avoid digital layouts that radiate high-frequency clock signals. That is, don't lay out digital signal lines and ground returns in the shape of a loop antenna. Shield the analog input if it comes from a different printed-circuit board source.

For the ADC shown in Fig. 1, you would set up a single point ground at AGND (pin 3). Tie all other analog grounds to this point. Also, tie the logic power supply ground, but no other digital grounds, to this point. Low-impedance analog and digital power supply common returns are essential to low-noise operation of the ADC. Their trace widths should be as wide as possible. Good power-supply bypass capacitors located near the ADC package insure quiet operation. Place a 10-μF capacitor in parallel with a 0.01-μF ceramic capacitor across V_{DD} to ground and V_{SS} to ground.

In applications where the ADC data outputs and control signals are connected to a continuously active microprocessor bus, it is possible to get LSB level errors in conversion results. These errors are due to feed-through from the microprocessor to the internal comparator. This problem can be minimized by forcing the microprocessor into a WAIT state during conversion. An alternate method is isolation of the data bus with three-state buffers, such as the 74HC541.

A/D Converter Selection

Precision Monolithics' ADC-912 is a low-noise, precision 12-bit high-speed CMOS A/D converter. A major objective in designing the ADC-912 was to reduce transition noise. Some 12-bit

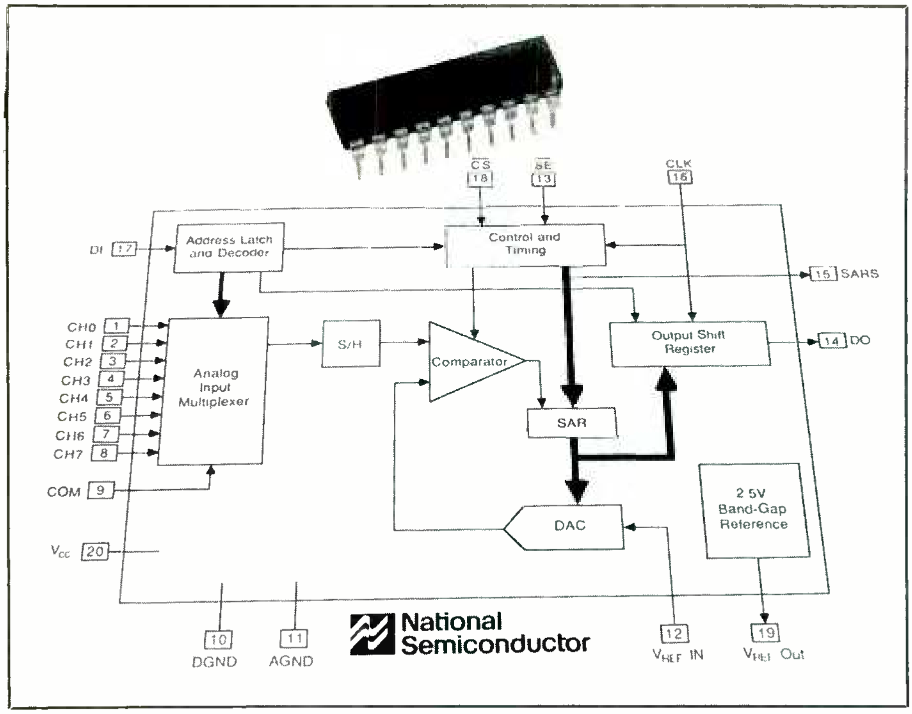


Fig. 3. National Semiconductor's ADC080xx A/D converter series include on-board reference, multiplexer and track-and-hold functions.

CMOS A/D converters exhibit ¼ to ¾ LSB of transition noise, which is often misinterpreted by users of this device as a circuit layout problem.

The ADC-912 is designed with a low-noise comparator that results in A/D converter operation that is quieter than ⅙ LSB. This improved noise performance has immediate application in DSP (digital signal processor) processing, resulting in improved signal-to-noise ratios. Servo positioning systems also benefit from the low transition noise of the ADC-912.

The fast 12-microsecond conversion time of the ADC-912 makes it well suited for data-acquisition systems. Also, battery-operated equipment can take advantage of the ADC-912's 95-mW maximum power consumption.

The half-width 24-pin skinny DIP and 24-lead SOL packages permit production of compact portable equipment. The ADC-912's fast 90-ns access time allows direct interface with no wait states to high-speed processor systems. The ADC-912 (0° to 70° C) is available at $19.95 for 100-piece quantities.

ADC08031 Family

National Semiconductor Corp. (Santa Clara, CA) recently introduced a family of eight-bit serial I/O analog-to-digital converters that include on-board reference, multiplexer and track-and-hold functions (see Fig. 3). The family, called the ADC08031 series, features a conversion time of 8 microseconds, four times faster than National's earlier series of ADC0831 devices.

The new devices include the ADC-08031, ADC08032, ADC08034 and ADC-08038, which offer one, two, four and eight analog input channels, respectively, and are pin-compatible upgrades for the earlier ADC0831, ADC0832, ADC0834 and ADC0838. The new components offer high-speed digital interface and on-board track-and-hold. Track-and-hold allows the analog input to vary during the conversion process. A reference is also provided on the ADC08034 and ADC-08038 that is not available on the ADC-0834 and ADC0838.

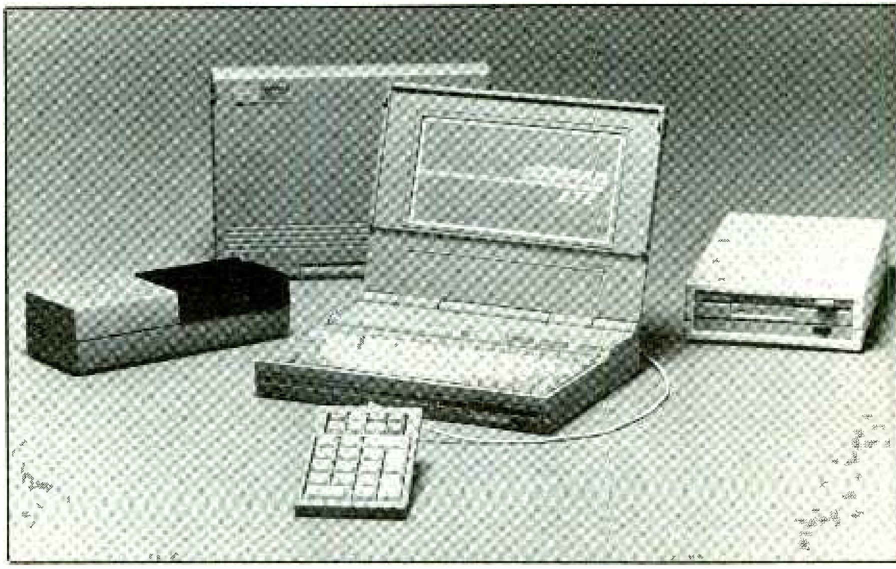
All converters in the ADC08031 series are guaranteed over temperature and 100 percent tested for no missing codes and total unadjusted error of ± ½ LSB or ± 1 LSB. Total unadjusted error includes offset, linearity, full-scale, multiplexer and track-and-hold errors. Power consumption is only 20 mW at +5V, and maximum conversion and digital interface times are both 8 microseconds. The ADC08031 series features easy interfacing with a wide variety of microprocessors and microcontrollers and supports National's MICROWIRE interface.

The new converters use a successive-approximation conversion technique. Track-and-hold permits signal sampling at rates up to 100 kilosamples per second on the ADC08031 and 80 kilosamples per second on the ADC08038. Input voltage range for all devices is from 0 to 5 V, using a +5 V reference and operating on a +5 V supply. Digital I/O lines are TTL and CMOS compatible.

The ADC08031 and ADC08032 are available in a choice of eight-pin plastic DIP and CERDIP packages. The ADC-08034 and ADC08038 are available in 14-pin and 20-pin wide-body SO packages, respectively, in addition to plastic DIP and CERDIP packages. All devices in the ADC08031 series are available in extended industrial (−40° to +85° C) and military temperature range (−55° to +125° C), and in two electrical grades providing ± ½LSB or ± 1 LSB maximum total unadjusted error. **ME**

The Winter 1989 COMDEX Report

By Ted Needleman



Compaq's LTE notebook computer comes in two versions: the PC compatible 8086 LTE and the 80286 286/LTE versions. Key options include (left to right) external Fast Charger/ac Adapter, numeric keypad and 5¼-inch floppy-disk drive or 40-MB hard disk.

While you're reading this in March, it's the beginning of December as I'm writing it. And I've just returned from another one of the computer industry's bi-annual circuses—COMDEX. This was the largest yet; 120,000 attendees and 1,740 exhibitors. Needless to say, I didn't get to see all of them.

The big news this time out was the number of i486 machines being shown. Almost every major vendor of PCs was showing one, and quite a number of unknown vendors had one, too. This was especially interesting, as few companies can actually deliver. There is an acute shortage of the i486 CPU chips, and quite a number of those already delivered have a problem with certain floating-point operations. Intel is in the process of swapping out these flawed chips, which should further slow down shipment of the i486 PCs.

Nevertheless, the quick embracing of this CPU means that prices on 486 systems should fall much more rapidly than they did with its predecessor, the 80386. While I am skeptical that very many users actually need the power of this CPU, it doesn't really matter. All users, myself included, want the most powerful PC they can get, whether or not they will ever put this power to full use. Even with falling prices, though, the i486 will be out of the range of affordability for many of us for some time to come.

The other interesting trend I noticed is towards smaller, lighter, and (sometimes) more affordable laptops. A couple of columns ago, I provided a quick look at the Atari Portfolio. The "star" of COMDEX was a similar sized unit from Poquet. The Poquet, while still only slightly larger than a VHS cassette, has a very usable keyboard, a much larger screen than the Portfolio, much more RAM and a several thousand dollar price tag. Also in evidence were new "notebook" sized laptops, such as the Toshiba 1000SE, the Panasonic 150 and the one possibly destined to be the most popular of them all, the Compaq LTE.

Compaq 286/LTE

The 286/LTE is a "notebook" PC. It's called that because it is almost the exact size of a thin three-ring notebook. Within its small 8.5 by 11-inch package is a complete PC—including a minimum of 640K of RAM and a 1.44-MB 3.5-inch floppy-disk drive. Available options allow the LTE (an 8086-based system) and 286/LTE to be internally expanded with up to 2 MB of additional RAM and a 20 or 40 MB hard-disk drive.

The 286 version of the notebook can also accept a 12-MHz 80C287 math coprocessor. And both the 8086 and 80286 versions have provisions to accept a second serial port or internal 2,400-baud modem. My review unit was the 286/LTE equipped with the 2-MB RAM upgrade, a 20-MB hard disk and the internal 2,400-baud modem. This configuration is a very usable one, and carries a fairly hefty price tag ($6,247).

The LTE, which is missing only the letter "i" to spell "lite," is supposed to invoke a certain image in your mind, one that suggests ease of transporting. At between 6 and 7 pounds, depending on which model you choose, and its small size, the image is a fairly true one.

Very little, however, is sacrificed in the way of usability to provide this portability. The LTE contains a battery that provides up to 3.5 hours of use, a very readable backlit LCD screen and an 80-key keyboard. This keyboard has keys that are just slightly smaller than those on a standard keyboard and an embedded keypad. I found it to be as usable as those found on most laptops. If you do much numeric work, though, you will almost definitely want to purchase the optional external numeric keypad.

The Control and Alt keys are also a bit awkward to use. There are two of each, located on the left and right of the space bar. Once you get used to their locations, you can find these keys fairly easily. But until you do, it's easy to hit the wrong keys by mistake.

LTEs also have an extra key, labeled "Fn," in the lower-left corner of the keyboard. This key is used to access function keys F11 and F12 (physically located on the F1 and F2 keys), as well as the cursor movement keys and HOME, PgUp, PgDn, INS, DEL and END functions located on the embedded cursor pad. These functions, as well as cursor movement, are also available on a set of four arrow keys on the bottom-right of the keyboard. Again, the locations of these keys takes getting used to.

Aside from having to get used to some of the key locations, the 286/LTE is a very usable system. Running at the same 12-MHz clock speed as the DeskPro I normally use at work, I noticed no difference in speed in performing the same word-processing, spreadsheet, or other applications usually run on the desktop system. The two most noticeable differences are the screen, which is an electroluminescent backlit supertwist LCD with CGA resolution, rather than the color VGA on the desktop, and the hard disk.

In an effort to conserve battery power, the disk is turned on and off as needed. When you perform a disk operation, such as loading a file or saving, the disk is turned on. It takes several seconds to come up to speed and runs on for a while after the disk operation is performed. If you are doing disk-intensive tasks, the drive will be on almost constantly; otherwise, it will cycle on and off as needed, prolonging the useful battery charge.

The LTE also has several other ways to prolong battery life, such as a standby mode that shuts down the system after 10 minutes of non-use. There is also a standby pushbutton that, when pressed, also puts the LTE into this mode. To bring the system back to life, just press the standby button again. The battery pack, incidentally, is replaceable, and the 286/LTE has non-volatile RAM. This means that when the battery runs out in the middle of a task, you can pop in another fully charged pack (if you buy a second battery and keep it charged) without losing any data. The battery takes about eight hours to fully recharge, and the system can be used on ac power (with the ac adapter) while this is taking place.

Compaq also offers an optional external Fast Charger that can recharge the battery in just an hour and a half. This optional Fast Charger also features a deep-cycle charge that minimizes the memory effect that plagues Ni-Cd batteries. In addition, the LTE and 286/LTE use the low-power CMOS version of the 8086 and 80286 (80C86 and 80C286) CPUs to make best use of available battery power.

Even though it's small and lightweight, the LTE and 286/LTE offer the same connectability that you'd expect from a larger system. There is a fold-down panel in the back of the PC that covers the serial and parallel ports. Also located on this back panel are a connector for attaching an external CGA monitor, external keypad, connector for the ac power supply/charger and a connector for the available external disk drives. These external drives are 5.25-inch units and are offered in either 360-KB or 1.2-MB capacities.

The Compaq 286/LTE is more important for what it represents than what it is. Except for its small size, it functions almost exactly the same as my desktop Compaq. It does this while being small enough to fit in an attache case. This amount of power presently carries a hefty price tag. At almost $6,500 as configured for this review, the Compaq 286/LTE is more expensive than many 386 desktops. If you don't need all of the power that this model offers, the 8086-based LTE with a single floppy and no hard disk costs considerably less at $2,399. It's also almost a pound lighter (at 6 pounds versus 6.7 pounds for the 286/LTE). Yet, the last decade shows us that where there is a need, eventually the market will meet it at a reasonable price.

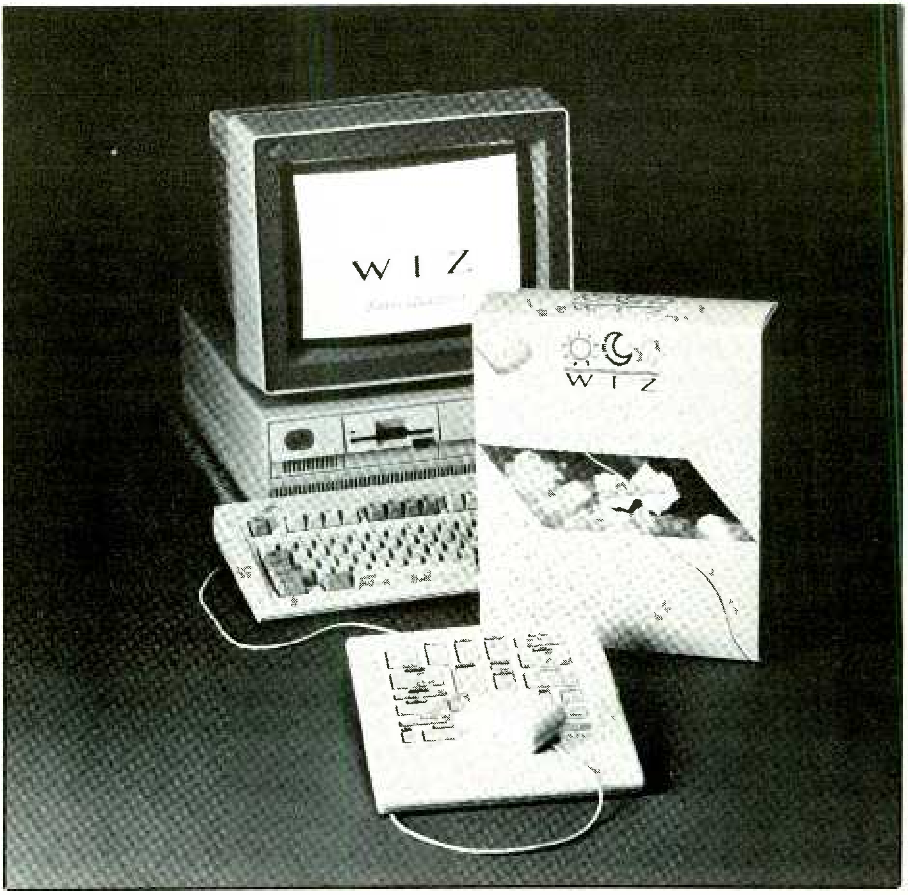
Standard-size laptops can now be purchased for less than $1,000. Notebook-sized PCs, such as the Compaq LTE and 286/LTE, make even more sense to many of us who need portable computing power. Given the ready availability of "lunchbox" clones of Compaq's Portable II and Portable III, it wouldn't surprise me much if next year there were a whole slew of affordable notebooks. Whether these are disk-based systems like the LTE or RAM-based ones like the NEC UltraLite doesn't make much difference to me. I only ask that they be small, powerful and affordable. Chances are that they not only will be, but will be available fairly soon.

The WIZ

Back about a year-and-a-half ago, I reviewed a device called Felix, which was a replacement for a mouse. It was an interesting device that failed to garner much interest among purchasers and seems to have passed on to the category of "devices that never quite made it." The mouse has become an almost universal pointing device, spurred on to a large extent by software, such as desktop publishing, CAD and even Graphical User Interfaces (called GUI, or "gooey"), which make good use of its ease of cursor positioning function.

This year's COMDEX featured several trackballs, which are essentially stationary upside-down mice. I find this development interesting and, in a sense, counter-evolutionary, because trackballs were used first. This "back to the future" development seems to indicate that as popular as mice are, they aren't the preferred device for everyone.

One interesting development that I came back from COMDEX with is called WIZ—a refinement and extension of the mouse. Developed by CalComp, best known for plotters, WIZ is a combination mouse and digitizer pad. The WIZ looks pretty similar to other mice, except for the pad it is attached to and the clear plastic reticle at the top of the mouse. This reticle contains cross-hairs in the center of a sensing coil and is what allows the device to be used as a graphics tablet. The pad the mouse is attached to contains additional circuitry and is about the same size as a standard mouse pad.



WIZ by CalComp combines ease-of-use features of a mouse and power of an intelligent graphics pad.

Completing the WIZ package are six mouse buttons (each of the three buttons is a rocker switch—different codes are generated if you push the top or bottom), and a series of removable templates that fit on the sensing pad.

The WIZ can be used in several ways. Once its drivers for DOS and/or Windows are installed, it will function as a standard mouse. Pressing button 5 (the bottom position of the center button) brings up the WIZ Manager utility. Among other functions, such as redefining the button functions, this utility allows you to set the mode that WIZ works in. This can be to emulate a standard mouse, or you can set the WIZ so that the pad boundaries correspond to the boundaries of the screen. As the active area of the sensing pad is about 7.5 by 7.5 inches, this mode works well for many drawing applications.

The other two modes WIZ can be used in are drawing and template. In drawing mode, the WIZ is used with a CAD or paint program. The line will follow the movement of the mouse on the pad. If you place a picture on the pad and use the reticle's cross-hairs to follow the lines, they will be reproduced on the screen. This is the same way expensive digitizing tablets work, except that their tracing devices often resemble hockey pucks, rather than a mouse with a monocle.

By loading in a software template and placing a plastic overlay onto the WIZ's pad, you can also use the device as a menu selector. Just place the cross-hairs over your choice on the plastic overlay, and click the button 1 on the mouse to select. The WIZ comes with Templates and overlays for DOS and Windows. By returning the registration card, you can get an additional template for free. A number of templates (and their corresponding plastic overlays) are available for many CAD, word-processing and other programs. These additional templates cost $49.95 each.

Installing the WIZ gave me a little trouble. The device is powered from the keyboard connector but must also be hooked up to a serial or mouse port. There is a Y connector that pulls power from the keyboard connector, though if this doesn't supply enough power to run both your keyboard and the WIZ, you can buy an optional power supply.

Once this hookup is made, you need to plug both the cable from the mouse device and from the PC's serial port into the tablet. These connectors aren't keyed, and the documentation doesn't really show how they get plugged in. It is possible to plug the cable in the wrong way—in fact, it seems to go in easier the wrong way—though doing this did not seem to damage the unit.

Another area in which the documentation falls short is in performing the software installation for Windows. It just tells you to reinstall Windows, selecting "other device" for the pointing device choice and inserting the WIZ utility disk when prompted. What is not stated is that the Windows SETUP utility requires 512K of free RAM to work. If you are using a 640K system and have installed the DOS drivers for WIZ, you won't have enough memory to complete SETUP—it just dies in the middle with an error message.

The solution is simple. You have to rename the CONFIG.SYS file the DOS setup routine creates, reboot the PC and complete the Windows SETUP. Then go back and rename CONFIG.SYS so that it loads the correct drivers for the WIZ. A better way would have been to just warn the user to do the Windows SETUP first.

Once installed, though, the WIZ worked the way it's supposed to. It's a lot of fun to use. At a price of $249.95, it's a bit more expensive than a standard mouse, though it is quite a bit less expensive than a digitizer. If you do much drawing and/or CAD work, the WIZ is something you will want to look at. ME

Products Mentioned

Compaq 286/LTE
Compaq Computer Corp.
Box 692000
Houston, TX 77269
713-370-0670

WIZ
CalComp
2411 West La Palma Ave.
Anaheim, CA 92801
800-CALCOMP or 714-821-2000

 (from page 24)

corded messages, enter/leave answer-only mode, rewind, etc.

To use beeperless units, you call the answering machine and let it pick up the line. It is usually necessary to listen to the OGM and let the machine enter the ICM cycle. After the beep that signals the record-incoming-message cycle, you enter the access code from the keypad of the calling telephone. You then use the keypad to key in the access code, which may be one, two, or three digits, depending on the particular machine. When entering the code, each key must be pressed for about 2 seconds to obviate the possibility of a casual caller accidentally gaining access to your recorded messages.

When the machine accepts the access code, it will stop, rewind, and play back any recorded messages. Alternatively, the machine may await another code to use one of the machine's other remote functions.

• *Extension Pick-Up.* This is a function of the Call-Screening capability that automatically stops and resets the machine when any extension is lifted. Once a ringing line is answered, many machines will proceed through its cycles of outgoing and incoming messages. If you decide to speak to the caller, you press a STOP or POWER button to disengage the machine manually.

Extension pickup detects when a local extension is lifted. When it does, it automatically shuts down the machine cycle and disconnects from the line to await the next caller when the user hangs up.

• *Remote Room Monitor.* This is a function of beeperless remote control that allows a user to call in and listen to any sounds in the vicinity of the answering machine via its built-in speaker. To use the room monitor, you call the machine and enter the access code. The machine then waits for an additional code to select the desired function (the code is usually one or two digits, depending on the machine). Now you enter the proper code, at which point the machine connects the microphone to the line and allows you to listen to any sounds within the machine's range. After a certain period of time (usually 30 seconds), the machine disconnects from the line and awaits a new function command.

• *Private Coded Messages.* A few answering machines have a second OGM that can be activated by a Touch Tone code entered by the caller. For example, if an expected caller needs special instructions or information that is not to be available on the regular OGM, he can enter a code (usually two digits) to initiate playback of an alternate OGM that can be left just for that particular caller. Of course, the caller will have to know the code in advance to reach the private message.

• *Answer-Only.* This mode plays back only an OGM and then hangs up. It is used to provide information to a caller but not to take any messages. This mode may be activated by beeperless remote control or by a switch on the machine itself.

• *High-Speed Erase.* Any time an ICM tape is rewound and positioned at its beginning, any new messages will be recorded over messages previously recorded on it. Some machines have an Erase function that cycles the ICM tape from end to end at high speed and erases the entire contents of the tape. This very useful function protects personal or sensitive messages from unauthorized playback after they have been reviewed.

• *Multiple-Line Capability.* Most machines are built to handle only one incoming telephone line. However, more sophisticated machines will handle two incoming telephone lines, which is ideal for businesses run in a home where one line is for private use, the other for business use. With such machines, a personal message can be left for the private number and a professional message can be left for the business number.

• *Power-Failure Protection.* If power should fail, an answering machine normally loses count of the number of recorded messages and its current ICM tape position. When power is restored, the machine will ignore any previous recordings and start from a "no-message" state. To protect the message count, tape position and any other memory-related functions, some machines use a power failure protection scheme.

Batteries are typically used to provide this power-failure protection in answering machines. The machine may still function properly without its battery, but a power failure will

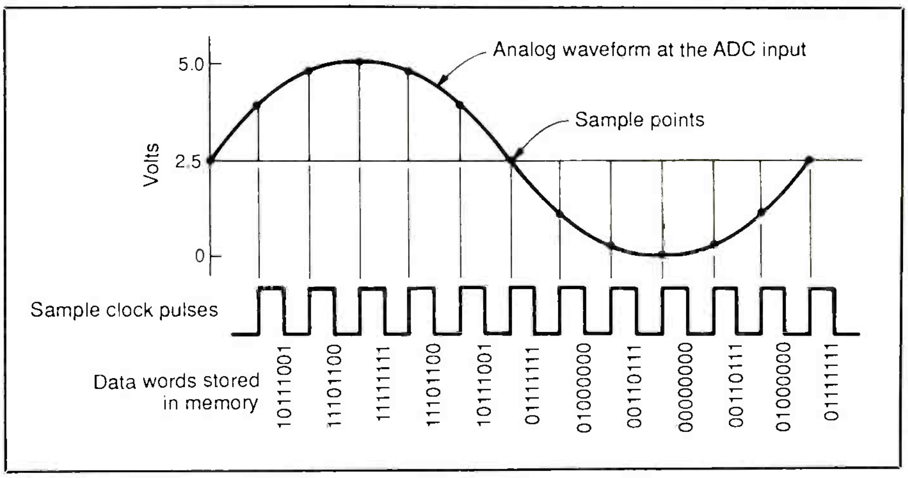


Fig. 9. An example of an analog waveform (upper) and its pulse equivalent and data word codes (lower) after digital conversion.

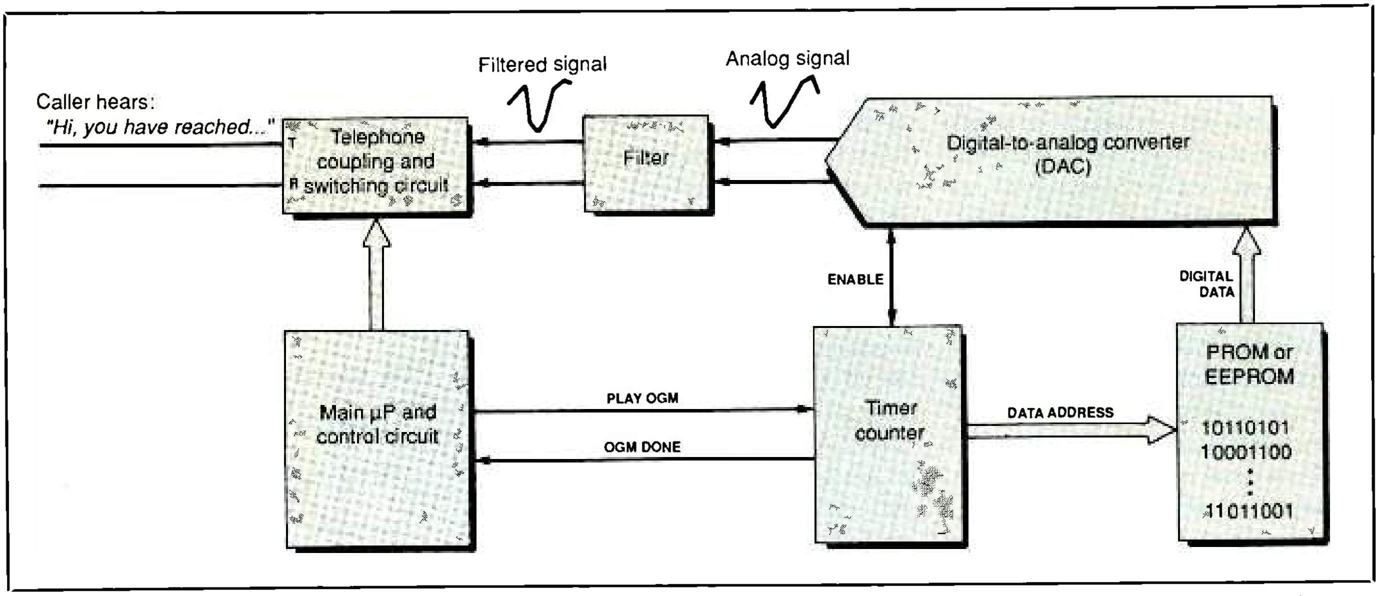


Fig. 10. To generate the outgoing message, a DAC in the voice synthesizer converts EEPROM data into analog form for transmission over the telephone line.

reset the entire machine. In other machines, the telephone line voltage can be used to maintain the memory contents instead of a battery.

• *Follow-Up Message.* Although second messages are usually reserved for more sophisticated voice-mail systems, some top-of-the-line machines may support a brief second, or follow-up message after the caller has stopped speaking. Such a message might be "Thank you for calling. I'll get back to you very soon." This is a very rare feature in answering machines, since most callers will hang up immediately after leaving their messages, but it is ideal in business use where an extra measure of courtesy is important.

• *Digitized Speech.* The techniques and components for synthesizing digital speech have come a long way in the last few years. New machines incorporate a digitizer and a memory chip to make up a DROGM (Digitally Recorded Out-Going Message) instead of using an OGM tape.

Shown in Fig. 8 is one possible approach for assembling a voice digitizer/recorder. Pressing the OGM record button erases the existing contents of the EEPROM (Electrically Erasable Programmable Read-Only Memory), and then starts a timer that sequentially loads digital words from an Analog-to-Digital Converter (ADC). The timer circuit also supplies an enable signal and clock pulses to the ADC.

When speech reaches the microphone, the analog voltage is amplified and sent to the input of the ADC, where it is sampled at a very rapid rate. Each sample is converted to an equivalent digital word, which is taken from the output of the ADC when each conversion is complete. A strobe pulse records the digital word in an EEPROM address and then advances the counter to the next EEPROM address (Fig 9).

There is a time limit with digital recordings (usually in the range of 30 seconds), since rapid sampling consumes a great deal of memory space. At the end of the recording period, the digitizer is disabled and the counter resets to be ready to play the digitized OGM when the answering machine picks up on an incoming call.

When the machine using DROGM picks up a ringing telephone line, the Control Circuit switches in a Digital-to-Analog Converter (DAC) network. The counter cycles through its sequence of EEPROM addresses. The digital data words stored in the EEPROM by the recording process are now available at the EEPROM's output and coupled to the DAC's input. In turn, the DAC converts the digital data back into a proportional analog signal at its output (Fig 10). By stepping through each EEPROM address at the same rate at which it was recorded, data entering the DAC generates an analog signal that resembles the voice of the user. The analog low-pass filter in the output circuit of the DAC smoothes out sudden changes in the DAC output to improve the quality of the signal (Fig. 11).

The primary advantage of this system is reliability. There are no OGM motor linkages or moving parts and no OGM tape to wear or break. Limited recording time is its major disadvantage. A fast sampling rate consumes a great deal of memory to ensure a suitable quality of speech; so OGM times are short. The DROGM method is also much more complex electrically, but new machines use a single digital chip with built-in digitizing circuits and memory storage.

Digital recording quality can vary from one manufacturer to another, depending on how much memory is provided for storage. A small amount of memory (16 kilobytes, for example) will not hold enough digital data to reproduce good-quality speech. Larger memory, like 32 kilobytes or more, will hold more data to reproduce a more faithful copy of the user's voice. It is usually a good idea to test several machines in the store before purchasing one to make sure that reproduction quality of the digitized voice is acceptable.

Instead of using a digitizer to record data in an EEPROM, pre-digitized outgoing-message data can be stored on a factory-programmed PROM and installed in an answering machine built for SSOGM (Speech Synthesized Out Going Message). This simplifies machine electronics by eliminating the need for the digitizer/recorder network (Fig 8) and uses only a reconstruction network (Fig 10). A simple, less expensive, prerecorded PROM holds the fixed message—usually generic, such as: "Hello—no one is available at the moment. Please leave your name, number, and message after the tone. Someone will get back to you. Thank you." The digitized voice can be either male or female, but the lower frequency components of the male voice can usually be digitized with less memory.

• *Date & Time Stamp.* Another application of digital speech synthesis is the Date and Time Stamp feature of some machines. When an incoming call is recorded, the voice synthesizer announces the current date and time and records it on tape along with the ICM. During playback, the recorded date and time are announced after its corresponding message. This feature is handy in business use when it is important to know the exact date and time of every call, or whenever it is necessary to discriminate the date and time of messages that are collected over a period of days or weeks.

This concludes Part I. Next month, we will finish up with selecting a location for your telephone answering machine, hints on making connections between telephone line and telephone instrument(s), maintaining your answering machine, and selecting the best model for your particular needs. ME

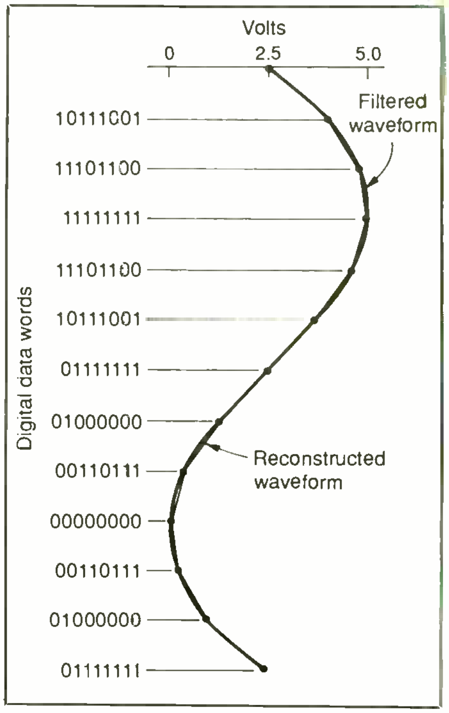


Fig. 11. An analog filter at the output smoothes out the sudden changes in the DAC's converted waveform to improve the quality of the regenerated audio signal.

Dual-Polarity Power Supply *(from page 28)*

try hole for the line cord with a rubber grommet.

Mount the circuit-board assemblies in their respective locations, using ½-inch spacers and suitable machine hardware. Then mount the transformer(s), fuse holders, switches, controls and binding posts in their respective locations. Place control knobs on the shafts of the POSITIVE and NEGATIVE adjust controls.

Referring back to Fig. 1, wire together all components and assemblies. Make certain that you observe proper polarities for the LEDs and that you insulate all connections. When you are done, carefully go over the entire project to make sure all components (except *IC4* and *IC5*) are in their proper locations, that all connections are soldered and that all wire runs are correct.

The only real difficulty you may encounter in wiring together the circuit is wiring to switches *S1* and *S2*. The best and surest way to wire to these four-pole double switches is with the aid of an ohmmeter or audible continuity tester. Use the meter or tester to determine the switching action as you go along.

With all the circuitry wired together, there remains only to apply legends to the front panel of the enclosure near the controls, as shown in the lead photo. Use a dry-transfer lettering kit to apply these legends. Remove the knobs from the POSITIVE and NEGATIVE control shafts to ease this task.

Not shown in the lead photo are + and − light-emitting diodes *LED3* and *LED1*. These were added to the prototype after the photo was taken. Also not shown in the lead photo are the +5V POWER switch, LED POWER indicator and + and − 5V OUTPUT binding posts you might have incorporated into your Power Supply project. If you included this optional supply, label the panel accordingly.

When you are finished labeling the panel, mask off the controls, switch(es), binding posts and display window with masking tape. Then spray two or more light coats of clear acrylic over the legends to protect them from abrasion while the Power Supply is in use. Allow each coat to dry before spraying on the next.

Finally, when the acrylic coating has completely dried, remove the masking tape and return the knobs to the shafts of the controls.

Closing Comments

You now have a Dual-Polarity Power Supply that is tailor-made for operational-amplifier and other linear-circuit experiments. If you built into the project the optional 5-volt dc supply, you also have a power source that can be used with TTL digital circuits, as well as mixed analog/digital circuits. You will never again have to resort to an arrangement of battery cells or kludge up a power supply when you need it. **ME**

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Tide-Clock *(from page 37)*

you the sign of the difference, but this will be easy enough to figure out once the project is operating. Then you can mark the panel accordingly.

For a drive frequency of 57.987 Hz, adjust the setting of the potentiometer in the "slow" direction for a LED blink rate of about two times per second. For accuracy, you could use a stopwatch to time the beat frequency over intervals of about a minute. For a frequency of 60.1643 Hz, adjust so that the LED blinks once every 6.09 seconds. For frequencies close to 60 Hz, the beat-frequency LED can be a quite useful indicator.

Without a frequency counter or beat-frequency indicator, just set the potentiometer to about the middle of its range and hope for the best. Several corrections will probably be needed over a period of many days to accurately calibrate the Tide Clock. If this is your method of calibration, it helps to mark the potentiometer setting each time and write "S" or "F" next to the mark to indicate if the clock ran slow or fast at that setting. This will give you an idea of how much rotation is needed for a given change in speed. After a few resettings, you will notice the marks zeroing in on a point that has slow settings marked on one side and fast settings on another side.

Once the Tide Clock is calibrated, it can be set to the current tide by consulting a chart (check your daily newspaper). After making this initial setting, you can dispense with the need for the chart, unless the project should lose power for a prolonged period of time and where exact times are needed.

Even if you built this project to serve primarily as a Tide Clock, do not overlook its other uses. Away from home, it can be used as a low-power inverter for equipment that does not require a true sine wave as the drive signal. At home, the main application for this project will be its use as a means for changing the speed of synchronous motors. **ME**

Pocket Alarm *(from page 52)*

tances being used to get closer to the mark. In addition, if you wish to increase the timing intervals, you can increase the resistances of the timing resistors.

All timing tests should be made from a "cold" start. Let the timer rest for 5 minutes between checks of each range selected by the DIP switch.

To put the project into service, you simply select the desired snooze interval with the DIP switch, turn on power and press and release the START switch to start the project counting down. Bear in mind that it is possible to have more than one switch in the DIP switch assembly set to "on" at any given time. If more than one switch is set to "on," the snooze interval will be shorter than if a single switch is closed because two timing resistors will be connected in parallel with each other. So always make sure that only one DIP switch is closed for any desired countdown period. **ME**

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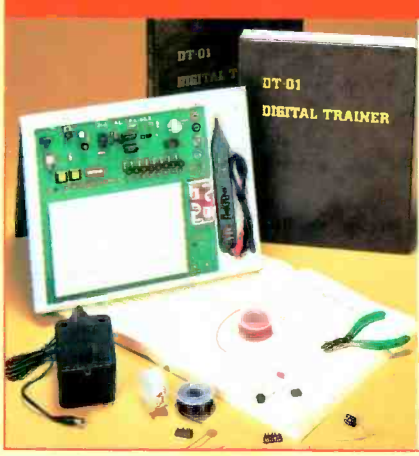

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