GERNSBACK SPECIALTY SERIES 49604

1990 Radio Electronics

ELECTRONICS EXPERIMENTERS handbook™

Special High-Voltage Section Containing 10 Articles Guaranteed To Add Zap To Your Experiments.

TELEVISION
- Gated-Sync Descrambler
- Surround-Sound Processor
- Video Edit Controller

YOUR HOME
- Electronic Thermometer
- Line-Power Monitor
- Amplified Speaker

HOW TO
- VCR Servicing
- Coping With Coils

AUDIO
- Subwoofer Simulator
- Hi-Fi Amplifier

HIGH VOLTAGE
- Jacob's Ladder
- Tesla Coil
- Electronic Tornado

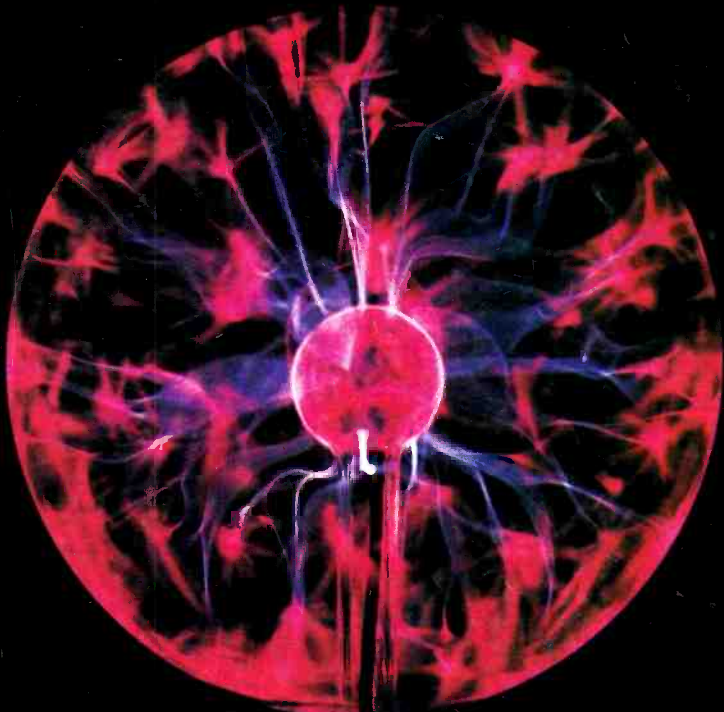
TECHNOLOGY
- High-Definition TV
- Thermoelectric Devices
- Nikola Tesla

COMPUTERS
- Speech Synthesizer
- RS-232 Control System
- Line-Carrier Modem

HIGH-TECH FUN
- Laser Listener
- Micro-Size Amplifier

BUILD IT
- Active Antenna
- FM Wireless Mike

MORE PROJECTS...
- Laser Power Supply
- Stun Gun
- Lightning Bulb



$3.50 U.S.
$3.95 CANADA

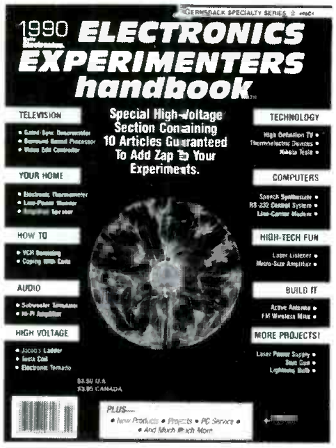
PLUS—
- New Products • Projects • PC Service • And Much Much More

A GERNSBACK PUBLICATION

CIRCLE 12 ON FREE INFORMATION CARD

1990 ELECTRONICS EXPERIMENTERS handbook

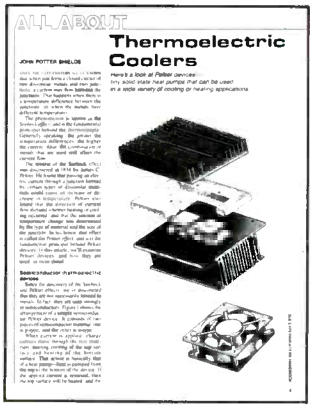
Radio-Electronics



HIGH-VOLTAGE PROJECTS

COMPUTERS

TECHNOLOGY



BUILD THIS

AND MUCH MORE

EDITORIAL

Why shouldn't electronics be fun?

Welcome to a new edition of the **Radio-Electronics Experimenters Handbook**! As in past editions, we've gone through the issues of *Radio-Electronics* from the last year or so. We've picked the stories that we thought would interest you most.

In a break from tradition, we've also gone back through the pages of our sister publication, *Popular Electronics*, to find even more feature articles to get you going. The result is 164 pages jam-packed with a wider variety of construction projects than you'll find anywhere else.

We have projects ranging from the simple (*Wireless FM Michrophone*) to the complex (*Hi-Power Hi-Fi Audio Amp*). We have projects for your home theater (*Surround Sound Processor*) and projects for high-tech fun (the *Laser Listener*).

For the computer buffs in our audience, we not only show how computers can speak (*Build This Speech Synthesizer*) but how they can control the world through their serial ports (with our *RS-232 Monitor/ Control System*)!

We also have articles on technology that you'll want to keep on top of, such as high-definition TV and thermoelectric devices. But the highlight of this year's handbook is our special section on High-Voltage Projects. We'll show you how to build a plasma display, a stun gun, a high-voltage pulse generator, a Jacob's ladder, and six other high-voltage projects.

Our job is done. We had a lot of fun putting this magazine together. Now it's your turn. It's time to build our projects and build your knowledge. And it's time to have fun, too!

—The Editors

1990 ***ELECTRONICS EXPERIMENTERS handbook***

Hugo Gernsback (1884-1967) founder
M. Harvey Gernsback, editor-in-chief, emeritus

Larry Steckler, EHF, CET, editor-in-chief and publisher

EDITORIAL DEPARTMENT
Brian C. Fenton, editor
Marc Spiwak, associate editor
Daniel Goodman, technical editor
Teri Scaduto, assistant editor
Jeffrey K. Holtzman computer editor
Robert A. Young, assistant editor
Jack Darr, CET, service editor
Robert Grossblatt, circuits editor
Larry Klein, audio editor
David Lachenbruch contributing editor
Don Lancaster contributing editor
Richard D. Fitch contributing editor
Kathy Campbell, editorial assistant
Andre Duzant, technical illustrator
Injae Lee, assistant illustrator

PRODUCTION DEPARTMENT
Ruby M. Yee, production director
Robert A. W. Lowndes editorial production
Karen Tucker, advertising production
Marcella Amoroso, production traffic

CIRCULATION DEPARTMENT
Jacqueline P. Cheeseboro, circulation director
Wendy Alanko, circulation analyst
Theresa Lombardo, circulation assistant

Typography by Mates Graphics
Cover photo by Herb Friedman

Advertising Sales Offices listed on page 166.

Gernsback Publications, Inc., 500-B Bi-County Blvd., Farmingdale, NY 11735. 516-293-3000

NEW PRODUCTS

CIRCLE 100 ON FREE INFORMATION CARD

DIGITAL WALKMAN. Digitally synthesized tuning precisely locks in AM- or FM-stereo signals for accurate reception on *Sony's WN-AF605 Super Walkman* personal stereo. For convenience, channel seek automatically scans up or down the tuning band, stopping at the next receivable station.

The personal stereo features 14 station presets and a stereo cassette player with auto-reverse, allowing both sides of a tape to be played without removing it. Auto-reverse provides a choice of continuous or single play of both sides, and a choice of tape direction. The unit uses Sony's "Mega Bass" system to provide stronger, fuller bass and an automatic shut-off feature to extend battery life. The portable audio package also includes lightweight headphones.

The *WM-AF605 Super Walkman* has a suggested retail price of $249.95.—**Sony Corporation of America**, Corporate Communications Department, 9 West 57th St., New York, NY 10019.

CAR SPEAKERS. *Sanyo's HD-622 TD* automotive speakers use a high-definition, twin drive system that reduces high-frequency harmonic distortion, delivers extended bass reproduction, and handles exceptionally high power. Each woofer is driven from both front and rear by twin magnets. An oscillator plate, placed between two facing drive units to create a "push-pull" motion, can efficiently convert even low-power signals to deliver extended bass reproduction. Because the total power is divided between two separate circuits, the heat produced by each side is cut in half, although the total dissipated heat is unchanged.

CIRCLE 99 ON FREE INFORMATION CARD

The system uses a 6½-inch, twin-drive, flat honeycomb-laminate woofer for stiffness; a 2½-inch hybrid tweeter for clean, extended highs; and an 8-ounce strontium magnet to improve overall frequency response. With a power capability of 200 watts with 75 watts RMS, a 30-Hz to 20,000-kHz frequency response, and an 88-dB sensitivity, the system delivers deep, clear sound while handling the kind of power levels that normally require much larger speakers.

The *HD-622 TD* speaker system has a suggested retail price of $199.99.—**Sanyo Fisher (USA) Corporation**, 21350 Lassen Street, Chatsworth, CA 91311-2329.

VIDEO SWEEP GENERATOR. *Leader Instruments'* model *430* is a video sweep and multiburst generator for the performance evaluation of VTR's, monitors, and video-processing equipment. The sweep and multiburst output can be continuously variable or preset, and the unit contains a built-in color-bar generator.

The sweep signal repeats at the field rate from 100 kHz to 10 MHz. Any one of five sets of drop-out markers can be

CIRCLE 98 ON FREE INFORMATION CARD

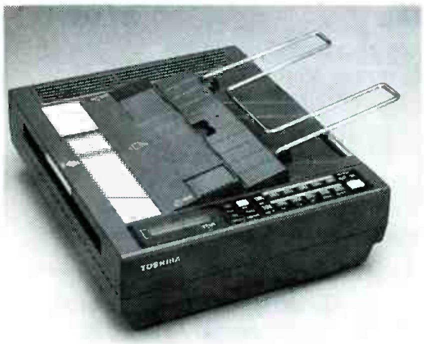
selected. Sweep start/stop is provided. For multiburst operation, the *430* provides a 100% white reference pulse at the beginning of each line, followed by equal amplitude bursts of 0.5, 1.25, 2, 3, 3.58, and 7 MHz.

The built-in color-bar generator produces full-field and SMPTE color bars. It also provides eight color rasters and selectable burst, chrominance, and luminance. For easy oscilloscope triggering, sync-trigger output is available. All of the patterns are in NTSC-composite and S-VHS (Y/C) formats. A sync and setup ON/OFF control allows non-composite output.

The model *430* video sweep/multiburst generator has a suggested list price of $1,756.00.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788.

FACSMILE MACHINE. The *3700* fax machine from *Toshiba* has a built-in automatic paper cutter, will transmit at 9600-BPS in as little as 15 seconds per page, and is compatible with all G2 and G3 fax machines.

Designed to meet the communication needs of small businesses and home offices, the *3700* offers a wide selection of user-friendly features. It has gray scale with 16 resolution settings for clear halftones and photos. An automatic document feeder lets



CIRCLE 97 ON FREE INFORMATION CARD

users send up to 15 pages while the machine is unattended. Several polling functions let the user dial other fax units, request messages, and retrieve documents. The *3700's* delay function makes forwarding messages easy. Users can preset the machine to send messages to another fax at a later time—often at lower phone rates. As many as 50 fax numbers can be stored for automatic speed dial, and an automatic redial function will try to call a busy number up to three times. Ten single-touch memory buttons provide easy access to frequently-dialed fax numbers. "Voice-confirmation request" lets the sender and receiver converse after a message is sent.

The *3700* facsimile machine has a suggested retail price of $1,995.00.—**Toshiba America Inc.**, Telecommunications Systems Division, 9740 Irvine Boulevard, Irvine, CA 92718.

PORTABLE AUDIO SYSTEM. The *PHD850*, with a full-logic double-cassette deck, a 25-selection programmable CD player, and a 19-function remote control, is *Fisher's* most sophisticated portable-audio system. It features built-in surround-sound circuitry; a 4-band graphic equalizer; detachable, 3-way bass-reflex speakers; and a quartz clock and timer with sleep-on/off, play, and recording functions. It has full logic controls and a rechargeable battery pack.

CIRCLE 96 ON FREE INFORMATION CARD

The CD player includes 3-way repeat for one selection, all selections, or only programmed selections. It can play 3-inch CD singles without an adaptor, and has dual-LED volume meters that graphically display audio output.

The double-cassette deck has double auto reverse for hours of uninterrupted, two-sided cassette play. It provides high-speed dubbing for duplicating tapes in half the normal time, and Dolby noise reduction.

The *PHD850* portable audio system has a suggested retail price of $699.99.—**Sanyo Fisher (USA) Corporation**, 21350 Lassen Street, Chatsworth, CA 91311-2329.

UNIVERSAL REMOTE CONTROLLER. *Bondwell's* sophisticated *BW-5000* remote controller can be programmed to reproduce the infrared remote-control commands of eight different devices. It consolidates the commands of an entire home-entertainment system into one hand-held device.

The *BW-5000* can learn and reproduce up to 126 commands, including commands for digital audio tapes, audio tape decks, laser-disc players, cable control boxes, color TV's, and surround-sound amplifiers. The controller features LED indicators for "use" and "learn" modes of operation. It has a 10-minute battery back-up when batteries are removed, a range of 20 feet from the remote sensor, and a master ON/OFF switch.

The *BW-5000* universal remote con-

CIRCLE 95 ON FREE INFORMATION CARD

troller has a suggested retail price of $89.99.—**Bondwell Industrial Company, Inc.**, 47485 Seabridge Drive, Fremont, CA 94538.

CIRCLE 94 ON FREE INFORMATION CARD

POWER SUPPLY. The *Elenco SP-620* is a fully regulated 3-output power supply that provides one fixed voltage (5 volts DC at 3 amps) and two variable supplies (1.5 to 15 volts DC and −1.5 to −15 volts DC at 1 amp). Regulation is better than 200 mV when going from no-load to full-load.

The unit shuts off if a short occurs, avoiding internal damage. The compact, 8¼- × 7- × 4-inch unit is available fully assembled or in kit form, with easy-to-follow instructions and circuit descriptions.

The *XP-620* power supply costs $89.95 assembled, or $59.95 in kit form.—**Elenco Electronics**, 150 West Carpenter Avenue, Wheeling, IL 60090.

MONITOR-STYLE TV RECEIVER. With a dark metallic finish for a contemporary look, *Samsung's* 27-inch *TC2750S* color TV offers 600-line resolution, an MTS decoder for stereo and SAP reception with dbx noise reduction, a Super-VHS input jack, and 181-channel cable compatibility.

The set's on-screen multi-mode display indicates channel; time; picture controls (color, tint, brightness, and contrast); audio controls (bass, treble, and balance); and a sleep timer. Other features include a quick-start picture tube, video input/output jacks, audio-input and variable audio-output jacks, a 36-key infrared remote control, programmable channel scan, dual RF-antenna inputs, and a comb filter for higher resolution.

CIRCLE 93 ON FREE INFORMATION CARD

The *TC2750S* color television has a suggested retail price of $899.95.—**Samsung Electronics America**, 301 Mayhill Street, Saddle Brook, NJ 07662.

SOLDERING-IRON SLEEVE. Technicians can save 5 to 10 minutes per field-service call with the innovative *Iron Sleeve* from *Electron Processing*. The device lets a technician place a hot soldering iron back in a toolkit without having to wait for the iron to cool off.

CIRCLE 92 ON FREE INFORMATION CARD

The *Iron Sleeve* is an 11-inch long, 1½-inch diameter tube that contains a proprietary heat-absorber. Besides absorbing the soldering iron's heat, the tube protects the iron from potential tip damage caused by other tools in the tool case. Most popular soldering irons of 50 watts or less will fit the sleeve. The iron is held in place by a Velcro fastener.

The *Iron Sleeve* has a suggested price of $19.95; quantity discounts are available.—**Electron Processing, Inc.**, Sales Department, P.O. Box 708, Medford, NY 11763.

GPIB INTERFACE CARD. The *Philips PM 2202* GPIB interface card from *John Fluke* turns an IBM PS/2 computer into a versatile GPIB/IEEE-488 instrumentation- and measurement-systems controller. The card is easily inserted into

CIRCLE 91 ON FREE INFORMATION CARD

one of the computer's Micro Channel plug-in slots. No hardware setup is required; initialization is automatic upon power-up.

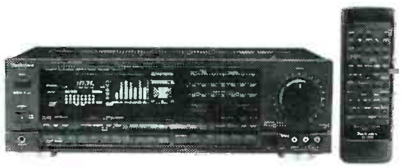
The *PM 2202* comes with a set of software routines and drivers that simplify GPIB programming, and can be included in applications written in BASICA/GWBASIC, Microsoft C, and Microsoft Pascal. The routines include commonly used functions such as bus commands, message sending and receiving, remote and local instrument setting, serial polling, error checking, and time-out setting. The interface card supports a number of Philips GPIB software packages, and includes comprehensive user manuals with complete installation, start-up, and programming instructions.

The *PM 2202* GPIB interface card has a list price of $695.00.—**John Fluke Mfg. Co., Inc.**, P.O. Box C-9090, Everett, WA 98206; Tel. 800-443-5853 ext. 77.

AUDIO RECEIVER. *Technics'* model *SA-R477* is a full audio/video and home-entertainment-center control system. Its 45-key full A/V remote lets the user control selected Technics cassette decks and Panasonic televisions and VCR's.

Delivering 100 watts per channel, the receiver drives two channels into 8 ohms from 20 Hz–20 kHz, with 0.008 THD. With the addition of a second set of speakers, the *SA-R477* delivers surround sound. The receiver also features a built-in, 7-band graphic equalizer with electronic level keys. Five personalized EQ curves, in addition to five popular factory-preset curves, can be stored in memory.

The unit's preset RAM lets the listener store any combination of 24 AM and FM stations. The stations can be "filed" by music type: rock, classical, jazz, easy listening, news, and other.



CIRCLE 90 ON FREE INFORMATION CARD

The station-file function can be operated remotely, or by pressing one front-panel button.

The *SA-R477* stereo receiver has a suggested retail price of $529.95.—**Technics**, One Panasonic Way, Secaucus, NJ 07094.

PHONE-ANSWERING SYSTEM. Combining a full-feature telephone with a remote-access answering machine, *AT&T's Answering System 1521* offers one-touch message playback, memory dialing, and an audible tone to alert users when messages have been received. By pressing one button, the message tape rewinds and plays all messages, and the machine automatically resets. The message-alert tone sounds once every 10 seconds.

The beeperless remote—which works from touch-tone phones using a pre-set 2-digit code—offers several advanced features, including options to play new messages only, skip messages, and change the outgoing announcement. Other remote features include fast forward, rewind, save, erase, reset, and access to all messages even when the tape is full.

CIRCLE 89 ON FREE INFORMATION CARD

The unit's dual-microcassette system uses separate tapes for the outgoing announcement and incoming messages, so that messages can be left immediately after the announcement ends. The user can give important callers a special code that is entered from a touch-tone phone and that sets off a special tone, alerting the user to a priority caller.

Other features include an LED display that indicates the number of messages received, message save, call monitor/screen, personal memos that the user can record for later retrieval, and an announce-only mode in which an outgoing announcement is played but no messages are recorded.

The *Answering System 1521* has a suggested retail price of $169.95.—**AT&T Consumer Products**, 5 Woodhollow Road, Parsippiny, NJ 07054.

Thermoelectric Coolers

Here's a look at Peltier devices—tiny solid-state heat pumps that can be used in a wide variety of cooling or heating applications.

JOHN POTTER SHIELDS

SINCE THE LAST CENTURY WE'VE KNOWN that when you form a closed circuit of two dissimilar metals and two junctions, a current may flow between the junctions. That happens when there is a temperature difference between the junctions, or when the metals have different temperatures.

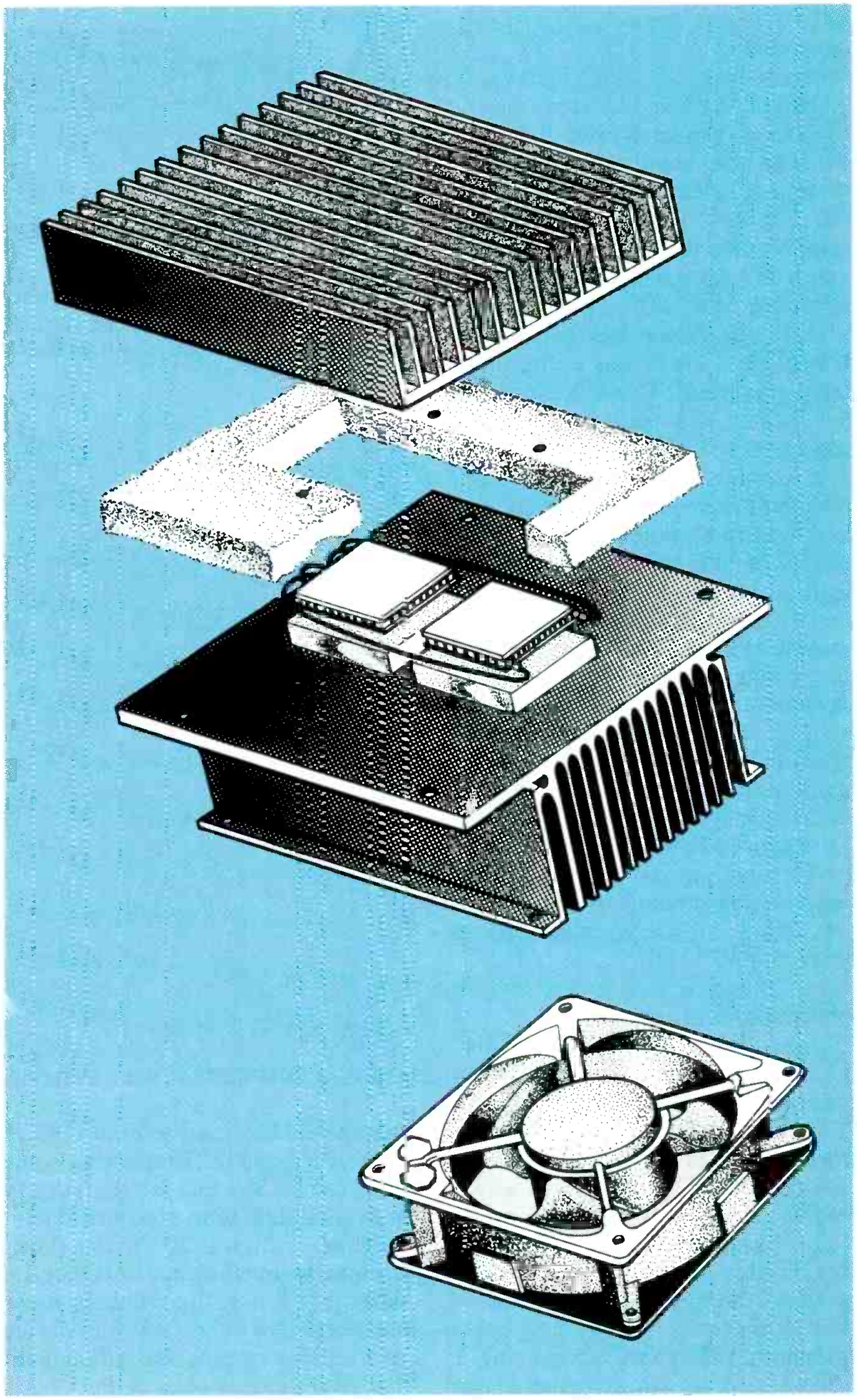
The phenomenon is known as the *Seebeck effect*, and is the fundamental principal behind the thermocouple. Generally speaking, the greater the temperature differences, the higher the current. Also, the combination of metals that are used will affect the current flow.

The reverse of the Seebeck effect was discovered in 1834 by James C. Peltier. He found that passing an electric current through a junction formed by certain types of dissimilar materials could cause an increase or decrease in temperature. Peltier also found that the direction of current flow dictated whether heating or cooling occurred, and that the amount of temperature change was determined by the type of material and the size of the junction. In his honor, that effect is called the *Peltier effect*, and it is the fundamental principal behind Peltier devices. In this article, we'll examine Peltier devices, and how they are used, in more detail.

Semiconductor thermoelectric devices

Since the discovery of the Seebeck and Peltier effects, we've discovered that they are not necessarily limited to metals. In fact, they are seen strongly in semiconductors. Figure 1 shows the arrangement of a simple semiconductor Peltier device. It consists of two pieces of semiconductor material; one is p-type, and the other is n-type.

When current is applied, charge carriers move through the two materials; causing cooling of the top surface and heating of the bottom surface. That action is basically that of a heat pump—heat is pumped from the top to the bottom of the device. If the applied current is reversed, then the top surface will be heated, and the



bottom surface cooled. The device is then a heater. Most practical thermoelectric devices, like the Marlow (10351 Vista Park Road, Dallas, TX 75238) MI 1069 shown in Fig. 2, consist of many such elements. In those, the elements are connected in series electrically, and in parallel thermally.

The tiny devices are capable of putting out great quantities of cold and heat, regardless of whether they are used as a cooler or heater. Therefore, a practical semiconductor cooler or heater absolutely requires a heat sink. Otherwise, the device would overheat and fail within seconds.

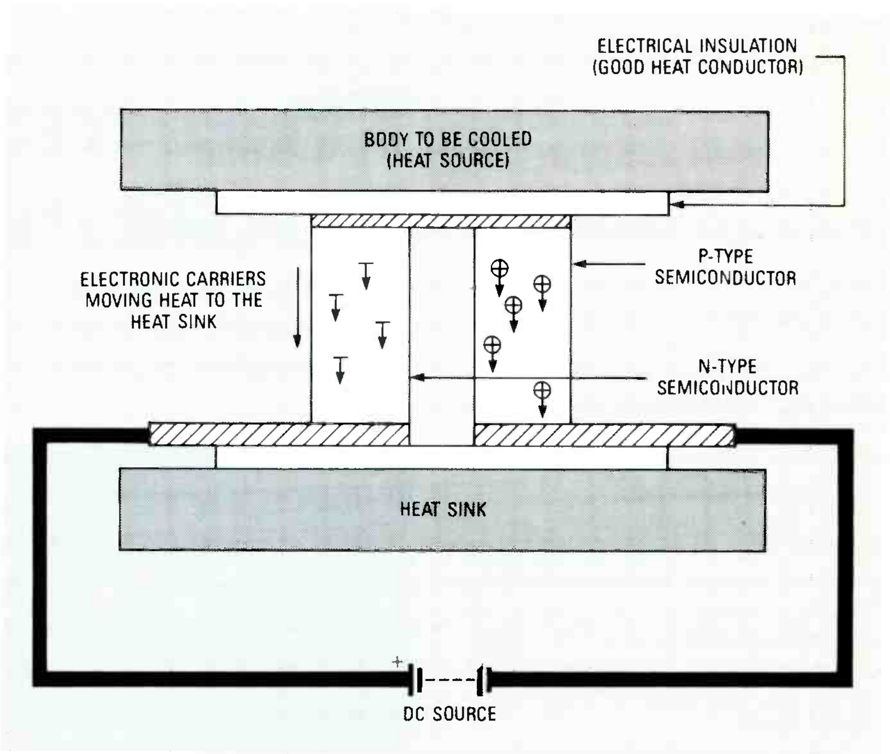


FIG. 1—A BASIC THERMOELECTRIC COOLER. The action is similar to that of a heat pump, conducting heat away from the cold side to the hot side.

Applications

One of the most interesting applications, especially for the electronics experimenter, is localized cooling of electronic components. For that, the cold side of the Peltier device is mounted directly to component using thermal epoxy, solder, or thermal grease. When power is applied to the Peltier device, heat is drawn away from the component being protected. Those components can include IC's, power transistors, laser diodes IR detectors, and solid-state imaging devices.

Peltier devices can also be used to cool moderate volumes of air or other gasses. In that application, a finned heat sink is attached to the cold side of the Peltier device. That heat sink thus becomes a *cold sink*. The Peltier device cools the cold sink; when air passes over the cold sink, a small air conditioner is created. The cold sink serves the same function as the evaporator coil in a conventional air-conditioner design.

Likewise, Peltier devices can be used to cool liquids. In that application, liquid is pumped through the cold sink and is cooled to the desired temperature.

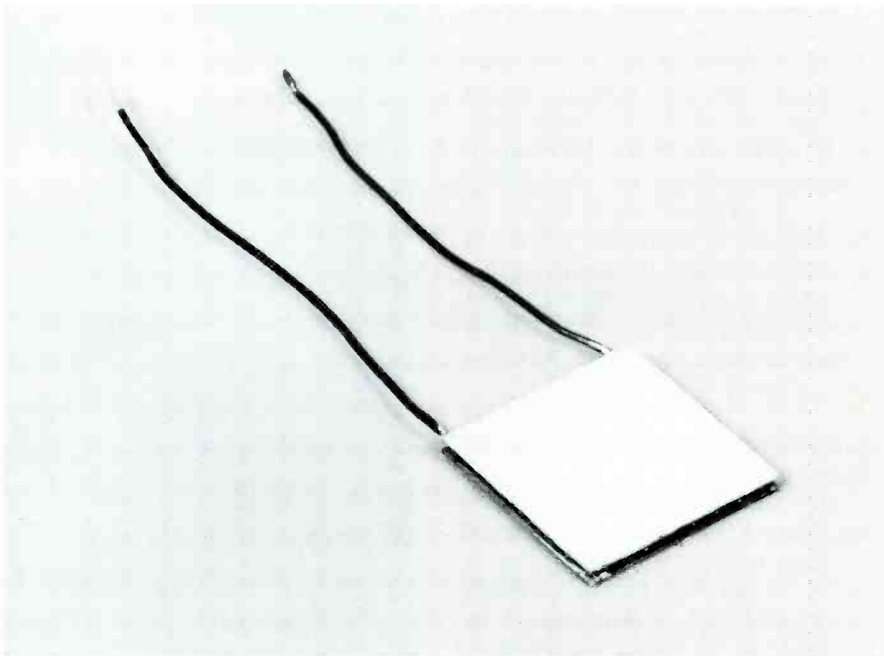


FIG. 2—A COMMERCIAL PELTIER DEVICE. This single-stage unit is the Marlow MI 1069.

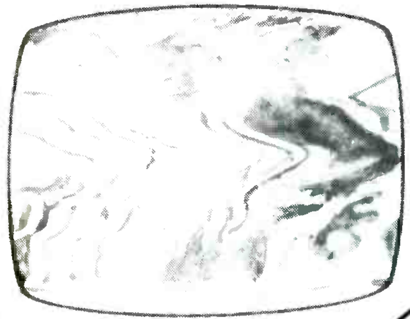
Power generators

One interesting, and little-discussed application of Peltier devices is as power generators.

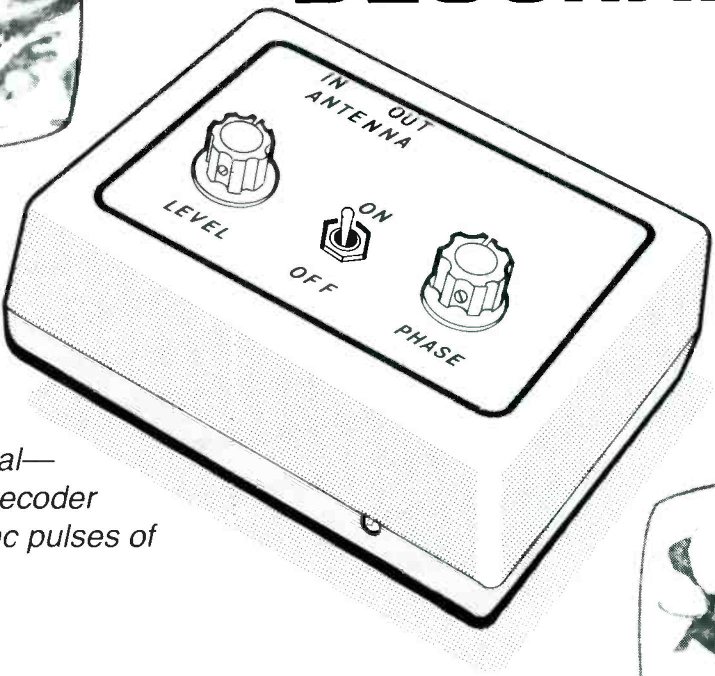
The circuit shown in Fig. 1 can be used as a power generator by simply replacing the DC power source with a load and applying heat to the top surface of the Peltier device. Note that the delivered power will have a polarity that's the opposite of the battery polarity shown.

One consideration when using a Peltier device as a power generator is that the solders used in most devices melt at about 138°C (although some units use solders that are designed to withstand short term exposure to temperatures as high as 200°). That limits the maximum efficiency of Peltier devices, but it is still possible to use a solar collector to heat a Peltier device and achieve outputs and efficiencies that rival those of solar cells.

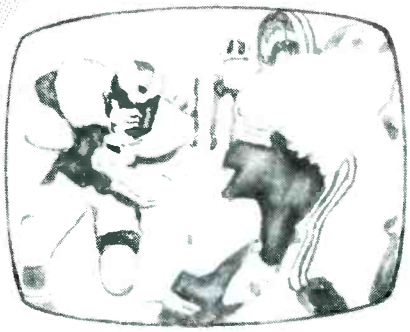
Thermoelectric coolers are available in single-stage configurations at prices that range from about $15 to $50. For applications where a high degree of cooling is required, single-stage units can be ganged; that is the hot side of one unit is attached to the cold side of the other. Commercial units with up to six stages are available. **R-E**



GATED-SYNC DESCRAMBLER



This somewhat unusual—but easily installed—decoder restores the gated sync pulses of scrambled TV signals.



STEVE PENCE

OF THE MANY METHODS USED TO SCRAMble a video signal for secure transmission, one of the more popular ones is called *Gated Pulse* or *Gated Sync*. The scrambling is accomplished by applying 6-dB suppression to the video signal's horizontal sync pulses thereby making it impossible for a television set to maintain a synchronized picture on the screen.

Figure 1 shows how gated sync works. Figure 1-*a* shows a conventional video signal with normal horizontal sync pulses. Notice the colorburst riding on the *back porch* of the horizontal blanking pulse. Figure 1-*b* shows the same signal with the horizontal sync pulse suppressed 6 dB. Notice that in Fig. 1-*b* the horizontal sync pulse and its blanking pulse, and the colorburst are all within the video-signal level.

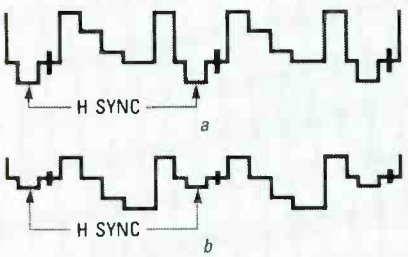


FIG. 1—A CONVENTIONAL TV signal is shown in *a*. With suppressed sync the signal resembles *b*.

YOU MUST PAY

Please note that the gated-pulse decoder is intended only for those who presently subscribe to a scrambled cable service and are dissatisfied with the picture quality attained from the supplied decoder, or who want to experiment with various decoding devices. If you are not presently a subscriber but want to view scrambled programs using our decoder, you must make subscriber arrangements with the originating program service.

The subscriber arrangement is necessary because the unauthorized reception of cable services is illegal under Federal and State laws. Federal law renders illegal both the interception and reception of any communications service offered over a cable system, unless those actions have been specifically authorized by the cable operator or by law. Federal law imposes both civil and criminal penalties for violation of the applicable statutes. In addition, states have enacted "theft of cable services" statutes that impose penalties for violations thereof.

The foregoing is not intended to constitute legal advice. Readers are advised to obtain independent advice based upon their individual circumstances and jurisdictions.

Although the gated-sync scrambling technique is basic and straightforward, its exact implementation can vary greatly from one equipment manufacturer to another; which means that each system needs its own particular kind of decoder to regain the original programming. As a general rule, the variations used to customize gated-sync scrambling usually involve a reference signal of some kind that is either multiplexed onto the audio carrier in some fashion, or onto some kind of outband carrier on an empty channel.

But if we can get around the "misplaced" reference signal, a simple gated-sync decoder is all that's necessary to decode nearly any single-level gated-pulse signal. And that's exactly what our decoder does. It eliminates the need for a reference signal, so it doesn't matter where the scrambling system hides the reference.

As you'll see, our decoder requires no special set-up equipment, although a scope does simplify setting up. Best of all, there's no intricate RF alignment because no RF tuned circuits are used in the decoder.

Pluses and minuses

As with any other decoder, ours has both advantages and disadvantages. Its advantages include: versatility—it will work on nearly any single-level sync-suppression system and does not need a reference signal to operate; no demodulation of any kind; a simplified circuit design that uses low-cost, readily available parts.

The disadvantages are that the device must be used with a television set—a VCR by itself will not do. The television set must be tuned to the channel that is being decoded, and phase-lock is not automatic—it must be done manually each time the decoder is turned on or when the channel is changed. Also, the decoder will not work on tri-mode systems or any other system that uses more than one level of sync suppression, or on any system that suppresses the vertical sync pulse. Also, the decoder will operate only in the low VHF band; hence it must be used with a cable downconverter that outputs on channels 2, 3, or 4.

How it works

As shown in Fig. 2—a functional block diagram of the decoder and some of a TV set's circuits—the basic principle used in the gated-sync decoder is that of a phase-locked loop. The loop, which is indicated by the bold lines, is formed by the TV set's sync separator, horizontal AFC circuit, horizontal oscillator and output, and the high-voltage *flyback* transformer. When all of that circuitry is being fed normal video (containing sync pulses), the loop is closed by taking a pulse from a winding on the flyback transformer and feeding it back to the AFC circuit, where the flyback's pulses and the sync pulses are compared. If they are not in phase, an error voltage is generated that forces the horizontal oscillator to change frequency until the two signals are finally in phase and the picture locks.

If the sync pulses are suppressed, as they are in a gated-sync system, the AFC loop has been opened because the pulses from the flyback transformer have nothing to be compared with; so the horizontal oscillator runs free (unsynchronized).

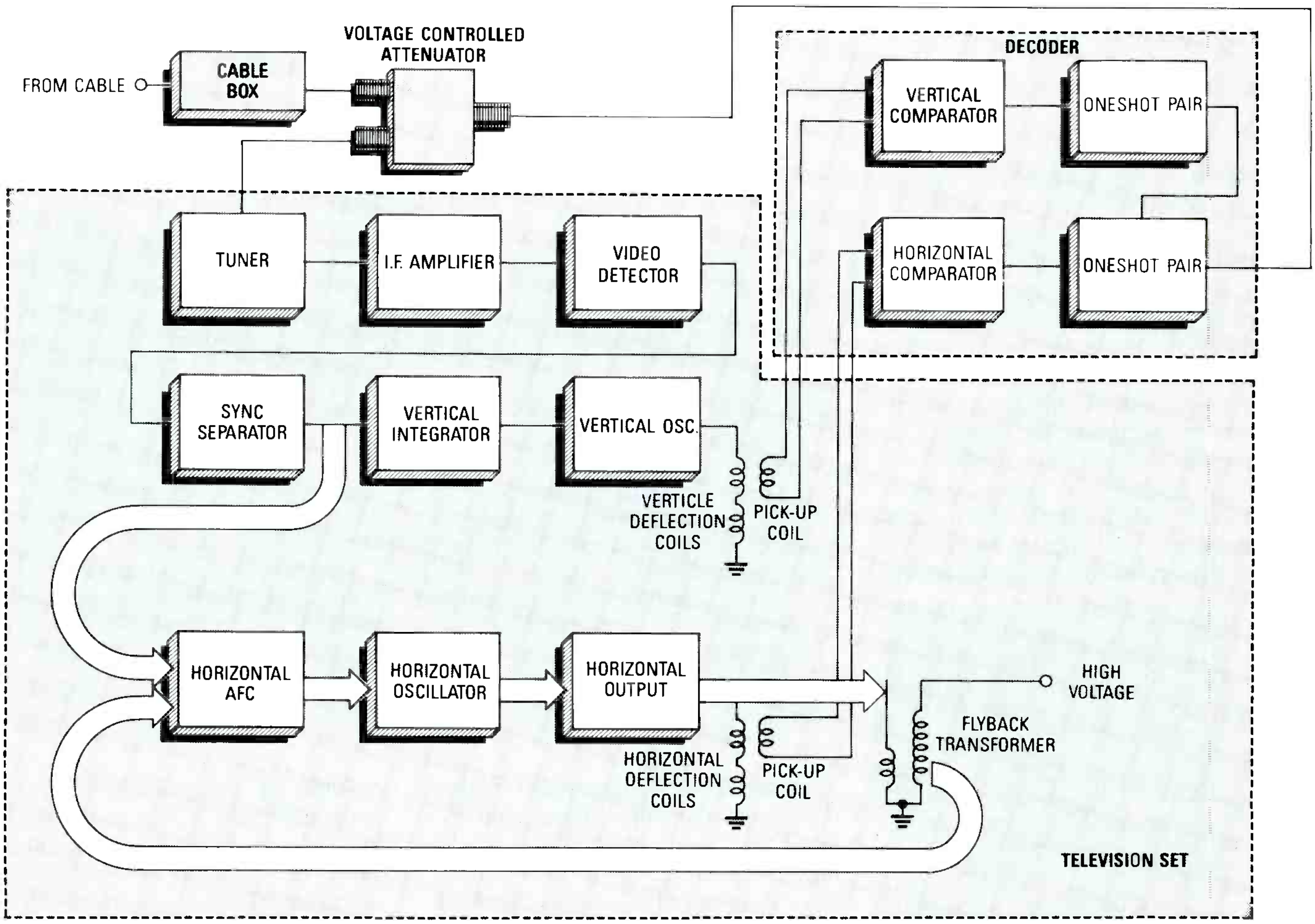


FIG. 2—THE DECODER WORKS by using sync samples from the TV's deflection yoke to control a signal attenuator.

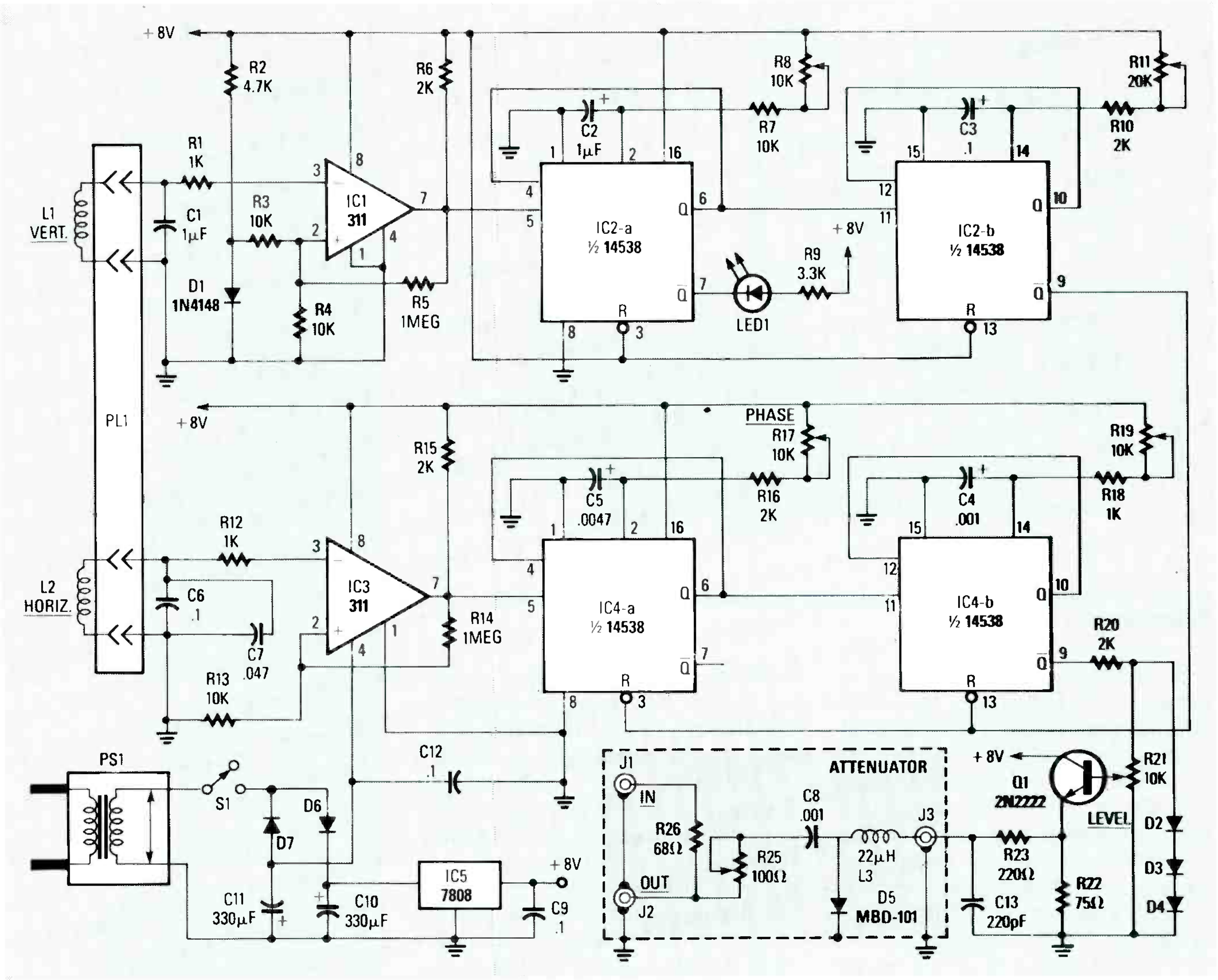


FIG. 3—THE DECODER'S CIRCUIT. The attenuator is built as a separate subassembly.

Closing the loop

Our decoder closes the loop by taking samples of the pulses produced by the horizontal oscillator and feeding them back around to the antenna input to increase the amplitude of the RF envelope during the signal's sync-pulse period. The samples of the TV set's vertical and horizontal sync pulses are obtained by induction from the TV's vertical and horizontal deflection coils.

The sync-pulse reinsertion is accomplished with a voltage-controlled attenuator. The attenuator reduces the amplitude of the RF signal feeding the TV set. Pulses from the decoder cause the attenuator to "unattenuate," thus increasing the signal level during the "unattenuate time"—which is effectively the same thing as re-inserting the sync pulse. Sync pulses are inserted pretty much randomly until the right combination of horizontal oscillator, decoder oneshot phase delay, and re-insertion level occur. When everything is correct, so that a few sync pulses are inserted at the proper time, the whole system locks up and stability is restored to the picture.

The circuit

The decoder, which is shown in Fig. 3, requires that no direct electrical connection, nor any modification, be made to the TV set. The TV signals are obtained by pickup coils L1 and L2 through inductive coupling; hence, there is no shock hazard during set up as long as the television set is unplugged from the powerline and you touch nothing but the deflection yoke during the installation of the coils. The purpose of the coils—which are taped to the deflection yoke—is to pick up the horizontal and vertical scanning pulses.

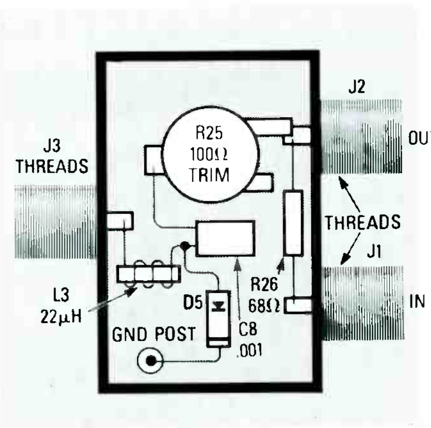


FIG. 4—THE ATTENUATOR is built in a gutted splitter. The assembly will be simplified if you follow this parts layout.

L1 and L2 are identical air-core coils. The vertical coil, L1, is taped to the *side* of the yoke (either right or left, it doesn't matter). Coil L2 is the horizontal coil, and it is taped to the *top* of the yoke.

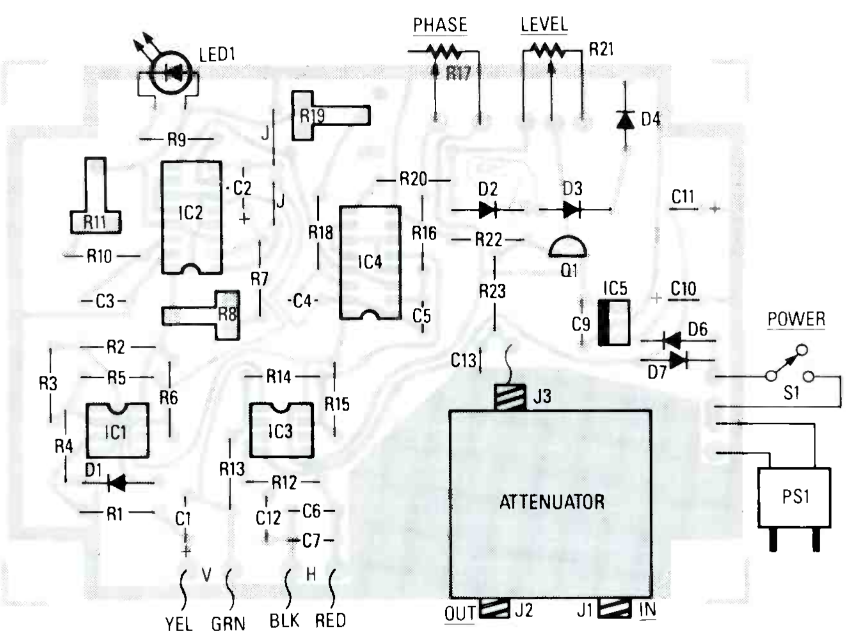


FIG. 5—THE PARTS LAYOUT. The attenuator subassembly is installed directly on the component side of the PC board.

A 15.734-kHz resonant circuit is formed by L2 and C6/C7. The waveform displayed on an oscilloscope that is connected across L2/C6/C7 will be a pure sine wave whose amplitude depends on the size of the picture tube. That's because as the screen gets larger, the yoke scanning current must become larger to deflect the beam.

IC3 is a zero-crossing detector that squares up the sine wave induced in L2 and converts it to single-ended drive for IC4—a CMOS oneshot—that follows. Because the input to IC3 is a sine wave that goes both above and below ground potential, IC3 must have both a positive and negative supply voltage. The positive voltage is supplied by voltage regulator IC5. IC3's negative voltage is provided by D7 and C11.

IC4-a is used as a phase delay and sync pulse restorer pair. *Phase Adjust* control, R17, can vary the period of IC4 over the range of 9–56 µs. R17 is installed on the front panel because it is used to phase-lock the decoder when the unit is first powered up, or when the user selects a different television channel.

IC4-b is used as a sync restorer that provides a pulse of 1–11 µs (set by trimmer-potentiometer R19). The output pulse at pin 9 is normally high; it goes low during the sync pulse. Transistor Q1 is a low-impedance driver for attenuator-diode D5. Diodes D2, D3, and D4 limit the amplitude of the pulse so that D5 (in the attenuator) cannot be overdriven.

A simple shunt attenuator is made up of R25, R26, and D5. The RF signal that is applied to J1 is attenuated at J2 when D5 is forward biased. When the voltage across D5 drops to zero, the RF signal is unattenuated.

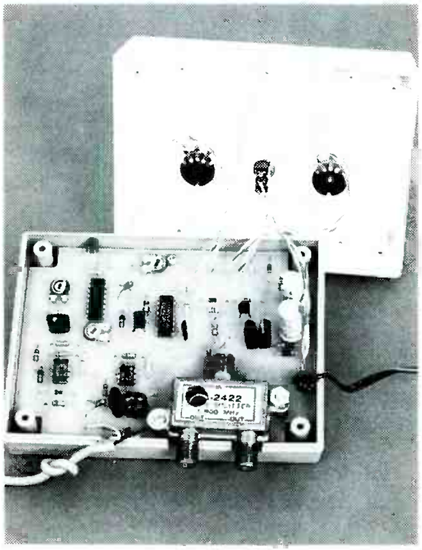


FIG. 6—THE COMPLETED DECODER. The three operating controls are mounted on the cabinet's cover.

Basic circuit

In many instances, only the previously described circuit that is associated with L2 is all that's needed. With some judicious knob twisting, the circuit can be aligned by simply observing the picture to see the effect

PARTS LIST

All resistors ¼ watt, 5%

R1, R12, R18—1000 ohms
R2—4700 ohms
R3, R4, R7, R13—10,000 ohms
R5, R14—1 megohm
R6, R10, R15, R16, R20—2000 ohms
R8, R19—10,000 ohms, trimmer
R9—3300 ohms
R11—20,000 ohms, trimmer
R17, R21—10,000 ohms, potentiometer
R22—75 ohms
R23—220 ohms
R24—not used
R25—100 ohms, trimmer
R26—68 ohms

All capacitors polyester, 25 volts, unless otherwise noted

C1, C2—1 µF, 25 volts, tantalum
C3, C6, C9, C12—0.1 µF
C4, C8—0.001 µF
C5—0.0047 µF
C7—0.047 µF
C10, C11—330 µF, 25 volts, electrolytic
C13—220 pF

Semiconductors

IC2, IC4—MC14538 dual monostable multivibrator, Motorola, National, or Toshiba only
IC5—7808, 8-volt regulator
D1, D2, D3, D4—1N4148 silicon rectifier
D5—MBD-101 silicon rectifier
D6, D7—IN4001 silicon rectifier
LED1—red light-emitting diode
Q1—2N2222, NPN transistor

Other components

L1, L2—see text
L3—22µH coil
Attenuator—see text
J1, J2, J3—part of attenuator
PS1—wall transformer, 12 VAC, 50mA
S1—SPST switch
PL1—Mating DIN connectors
Miscellaneous: Printed-circuit materials, wires, solder, etc.

Note: The following items are available from Cybernetworks, P.O. Box 41850, Phoenix, AZ 85080. The printed-circuit board: $15.00. A partial kit that includes the PC board, IC's, and coils: $25.00. The PC board for the April '85 Sync Separator project is available for $15.00 (the complete kit has been discontinued). Allow 4 to 6 weeks for delivery. We cannot accept orders from Arizona residents. Canadian orders please use postal money orders in U.S. funds and add $2.00 handling.

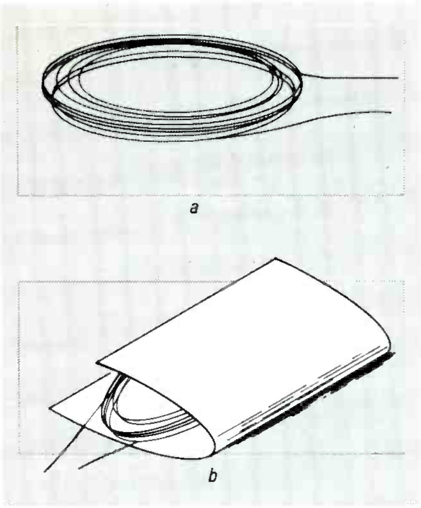


FIG. 7—STRETCH THE COIL into an oval, as shown in *a*. Then cover the coil with tape, as shown in *b*.

of each control. The decoder is connected between the output of a cable box and the antenna input of the television set. If desired, a VCR can be placed between the decoder and the television set, and the effect on the signal can then be observed with a scope by looking at the VCR's video output.

The vertical circuit, composed of L1, IC1, and IC2, locks out IC4 during the vertical interval. The pickup coil, L1, must be taped to the deflection yoke in order to pick up enough of a signal to drive IC1. Capacitor C1, which is connected across L1, serves only as a filter to remove the horizontal hash that is picked up along with the vertical pulse by L1.

The signal across L1 will be polarized, and must be of the correct polarity to drive IC1; hence it may be necessary to reverse the coil's connections. LED1 will light when L1's polarity is correct.

The two sections of IC2 operate the same as they do for IC4, except that they are used for the vertical, rather than the horizontal, sync pulses. IC2 is adjusted by R8 and R11 until the output pulses at pin 9 go low during the time you want the horizontal pulses locked out, which usually occurs during vertical blanking.

Construction

Except for the RF attenuator, construction is non-critical. The author's prototype was first built on a Radio Shack breadboard, and the circuit worked perfectly the first time. For those of you who prefer printed-circuit assembly, we provide a full-scale template in PC Service. Take note that space and a ground plane are provided on the PC board for the RF attenuator, which, as shown in Fig. 3, is a separate unit.

Figure 4 shows the assembly of the attenuator, which is built inside a gutted two-set coupler. Most couplers are made of aluminum and cannot be soldered to; and most, but not all, will have a solderable ground stud inside. If yours does not, you will have to drill a hole for a machine screw with which you can bolt down your own ground lug. Solder a bare bus wire to the ground lug in the attenuator (the cut-off lead of a resistor or capacitor will do). The wire should exit out the bottom of the attenuator and be snaked through a hole in the PC board that you must drill specifically for the ground wire. After the module is mounted to the board, solder the wire to the PC board's ground plane.

The reason for the ground wire is because the attenuator module's mounting screws often do not make a good ground connection to its case and the PC board. The ground wire is simply ensurance against possible grounding problems.

You should also drill a ⅜-inch hole in the top of the attenuator module directly over where trimmer-potentiometer R25 will be mounted. The hole will allow you to adjust the trimmer without dismounting the module.

Figure 5 shows the parts placement on the PC board. Secure the attenuator case to the PC board with two screws. If the case has a separate external grounding tab, simply cut it

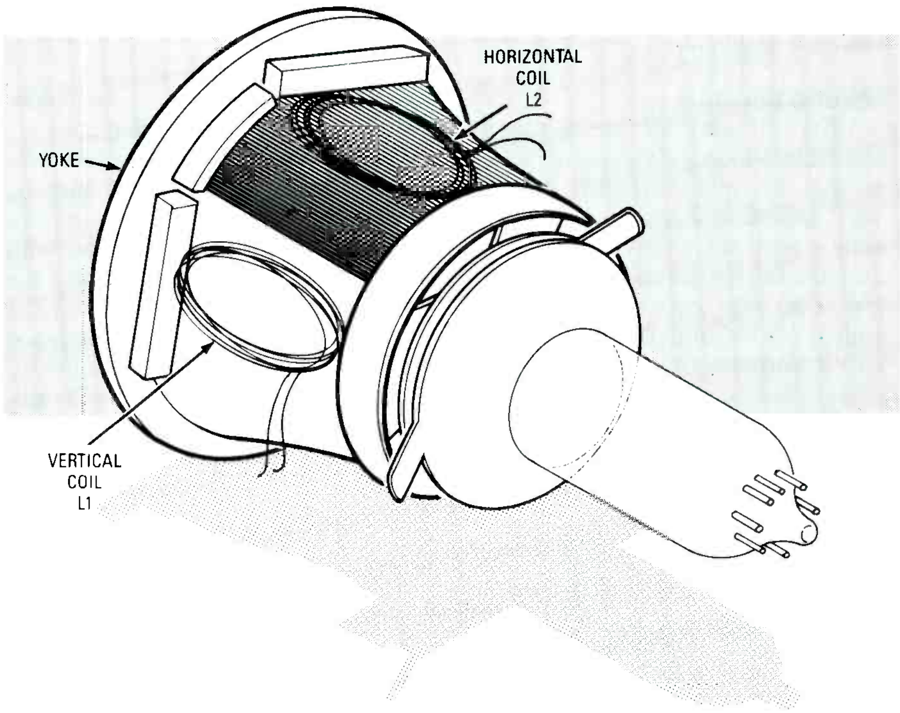


FIG. 8—TAPE THE COILS on the CRT's yoke as shown.

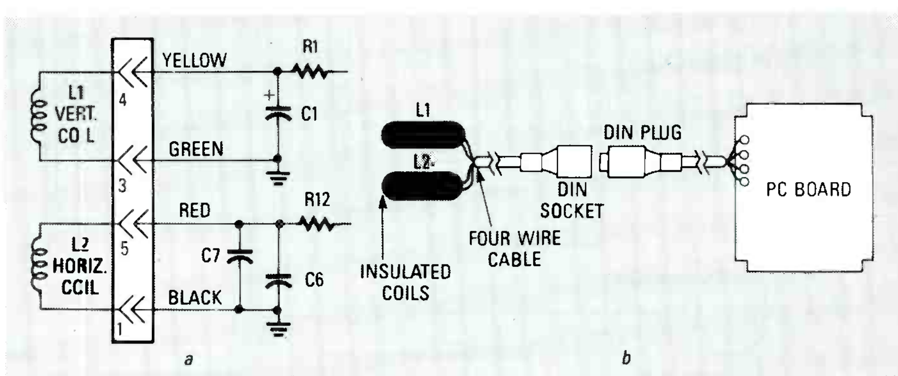


FIG. 9—THE ELECTRICAL COIL connections are shown in *a*. The way they are connected to printed-circuit board is shown in *b*.

off if it gets in the way of anything. Notice that IC1–IC4 are not mounted with the same orientation; that is, all No. 1 pins and/or notches do not face the same direction. Instead, all pin 1's and/or notches face the center of the PC board, as does IC5's metal tab.

Figure 5 also shows color-coding for the wires connected to the vertical and horizontal PC-board connections. The exact colors are unimportant—they will depend on the particular multi-conductor wire that's used. (The colors shown are those of conventional telephone quad.) We only show color-coding to help you integrate the parts placement with the wiring of L1 and L2, which we'll get to in a short while.

At this point the circuit board can be installed in a cabinet, as shown in Fig. 6. The phase (R17) and level (R21) controls, and the power switch (S1), are mounted on the cover.

Making the coils

Coils L1 and L2 are made by scramble-winding 100 turns of No. 28 or No. 30 solid, insulated, magnet wire around a 1¼-inch form. (The author used an empty 35-mm film canister for the form.) As shown in Fig. 7-*a*, after each coil is wound, slide it off the form and elongate the coil to form an oval. To prevent the coils from becoming unwound or deformed, dip them in hot candle wax or paraffin (available in most hardware stores.)

Make two coils, then attach leads to each coil that are long enough to reach from the inside of the TV set to the decoder. You can use either individual wires, pairs for each coil, or quad (four wires: two for each coil). Sandwich the coil assemblies in white adhesive tape for insulation, making certain that the tape covers the coils and the ends of the heavier hook-up wires. (The tape provides stress relief for the thinner coil wires).

Mount the coils to the yoke of the television set as shown in Fig. 8. The easiest way to do it is to simply hold the coils in place with a strip of adhesive or electrical tape. Snake the wires out of the TV set and connect them to a 5-pin DIN connector as shown in Fig 9. Figure 9-*a* shows the actual wiring and the DIN-connector numbers. Figure 9-*b* shows how the coils connect to the PC board.

Tweaking

Due to the differences in inductance that are possible when coils are wound by hand with whatever size wire is readily available, it may be necessary to select the value of C6/C7. The value needed to resonate with L2 will be near 0.15 µF. After the coils are taped to the yoke, turn on the TV set and use a high-impedance voltmeter or scope to measure the induced voltage across C6/C7. Try different values of capacitance until you attain the maximum peak-voltage reading.

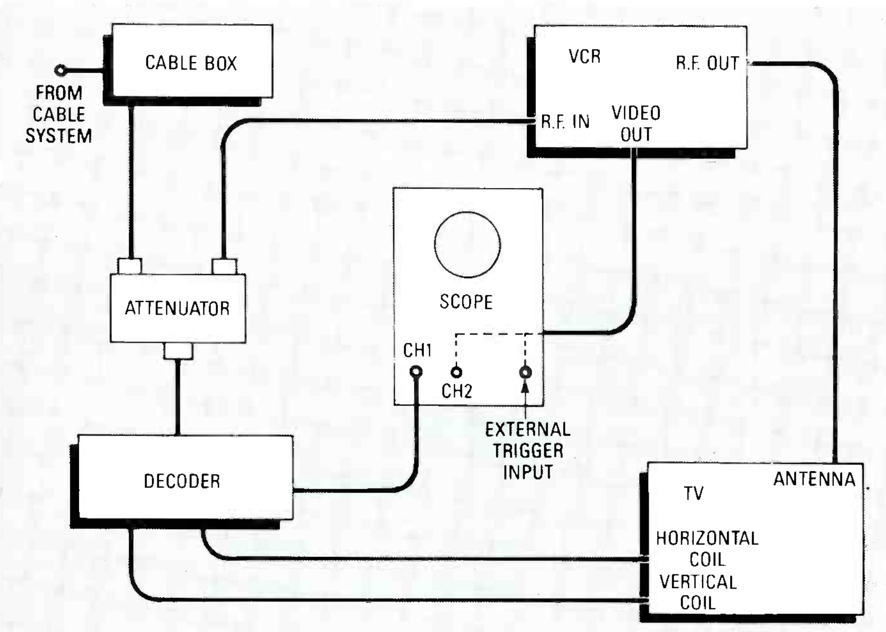


FIG. 10—THIS IS HOW TO CONNECT the equipment when making your checks and adjustments. The VCR is not necessarily required (see text).

USING A SCOPE

Whenever you work with video, and in particular when working with decoders, you must often correlate the video signal with another signal, such as a sync re-insertion pulse. That is impossible to do if the scope you are using is not set-up to be triggered properly.

The secret is in a setup that allows you to look at only one line of video at a time; each time the scope sweeps, it displays the same line. In other words, if you want to look at scanning line number 32 (that is, the 32nd line of video that occurs after the first field begins), you must make the scope sweep only during the time that line 32 is present.

Most scopes do not easily allow you to trigger that way. Those that can be triggered that way have an extra feature called "delayed sweep." Delayed sweep allows you to trigger on a relatively slow repetitive event like vertical sync, delay out to a specific line of video, then begin a very fast sweep that is set by a second timebase. The delayed sweep allows you zero in on any part of a waveform that occurs after the trigger, and then expand that portion.

A project that provides scope delay was described in the April 1985 issue of **Radio-Electronics.**

Alignment

Ideally, alignment should be done with a scope, using the equipment arrangement shown in Fig. 10. The best scope to use is a dual-trace model having delayed sweep. For those of you without access to such a scope, begin by interconnecting the decoder with your television as shown in Fig. 11 (the VCR is optional). Turn on the TV set and tune the cable box to a non-scrambled station. Adjust the set's vertical-hold control until you can see the vertical-blanking bar: Try to get it to sit still long enough so you can measure the vertical height *of the bar* with a ruler or a tape measure. Make a note of the height.

Set R8, R11, R17, R19, and R25 to the center of their rotation, and set R21 fully counterclockwise. When you apply power to the circuit the vertical-polarity LED should come on. If it does not, reverse the leads from L1 or physically flip the coil 180°.

Slowly adjust R21 clockwise—the picture becomes lighter as the control

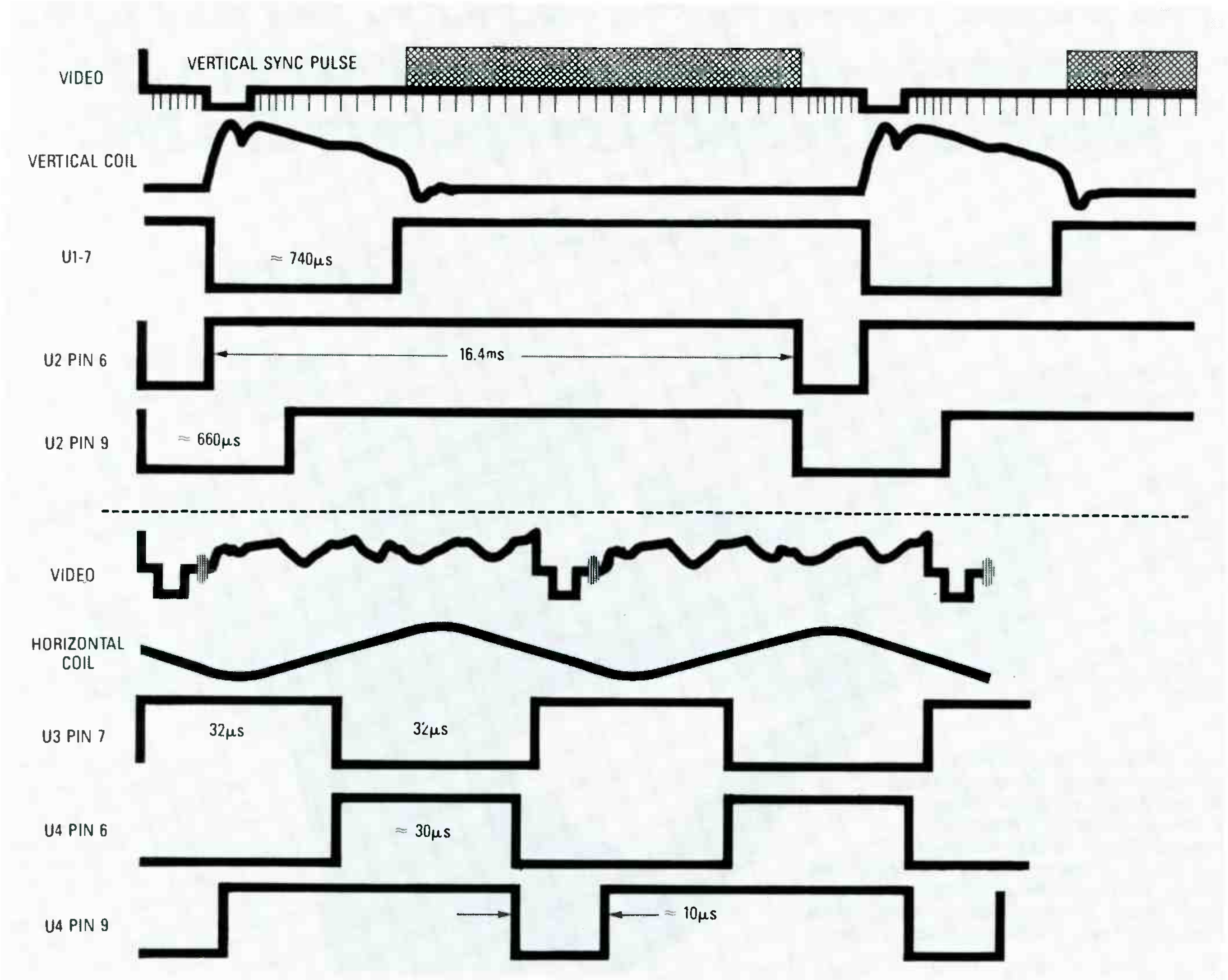


FIG. 11—IF YOU USE A SCOPE for checks and adjustments, this is how the important waveforms will be displayed.

is advanced. You may see a bar near the center of the picture that will be slightly darker than the picture itself. If you do not see the bar, adjust R17 to bring the bar in from either side of the screen. If you cannot make the bar appear from either side, reverse the connections to L2 or flip it over.

Adjust R17 until you can see the full width of the bar; then adjust R8 until you see a clear spot in the vertical bar. Then adjust R11 until the clear spot is just a little wider than the vertical blanking bar was that you measured previously. As R8 is adjusted through its full range, you should be able to make the clear spot appear from either the top or the bottom of the picture. Note where in R8's rotation the spot appears at the top, and where it appears at the bottom of the screen. Set R8 midway between those two points.

Set R17 midway between where the bar disappears on the left and right hand side of the screen. Tune in a scrambled channel and set R21 to about ¾ of its clockwise rotation. (That ensures that the attenuator diode is being driven hard.) Adjust R25 until the picture corrects; which will be easiest to do on a brightly lit picture, and nearly impossible to do on a dark picture. R25 should be set so that the picture is somewhat over-corrected and washed out; then adjust R21 for normal brightness and contrast. The three controls—R21 (phase), R19 (pulse width), and R21 (level)—all interact with one another and may require considerable experimentation and knob twisting to get them all correctly adjusted.

Keep in mind that D5 is being used as a switch and not as a diode. That means that it must be driven hard enough (controlled by R21) to keep it off the sharp knee of its forward-bias curve. If it is allowed to act as a diode, it will also rectify the incoming signals and produce a varying voltage that will also modulate its own forward-bias voltage. That action will produce an interference pattern in the picture.

Once everything is properly optimized, all you should have to do will be to adjust R17 and R21 whenever you turn the decoder on, or after you change channels. In most, but not all, instances, picture-lock will occur automatically when a scrambled channel is selected and a fairly bright scene is available.

If the signal level of your cable system is too low, the 6-dB signal loss caused by the attenuator module will often cause snow in the picture. One solution to the problem is to place a distribution amplifier in the signal chain prior to the decoder.

Scope set up

Begin by interconnecting everything as shown in Fig. 10. Set R8, R11, R17, and R19 to the center of their rotation. Set R21 for zero correction—full counter-clockwise. If the vertical-polarity LED does not come on, reverse the connections to pickup-coil L1 or flip it over and retape it to the yoke. Perform the set-up adjustments with an unscrambled signal.

Adjust R8 and R11 until the vertical-sync waveforms on your scope match those shown in Fig. 11-*a*. Both comparators of IC2 are triggered on the falling edge. The period of IC2-a is approximately 16.4 milliseconds. It should be adjusted to time out just before the beginning of the next vertical interval.

IC2-b is triggered by the falling edge from the first section. For most gated-pulse systems, its period will be approximately 660 μs. Again it should be set by comparing its pulse width to the video waveform. It should fire just before the vertical sync interval and time out just after the last equalizing pulse.

To set up IC4, compare the sine wave across L2 with the video waveform. The leading edge of the horizontal-sync pulses should correspond to the positive to negative transition of the sine wave through zero volts. If it does not, reverse the connections to L2 or flip the coil over.

Both sections of IC4, like IC2, are negative-edge triggered. Adjust R17 and R19 until they match the waveforms shown in Fig. 11. The output at pin 9 should be set for a starting pulse width of 8–10 μs.

Then, use the same alignment procedure as previously described, starting with the adjustment for R21.

Operating tips

If you can't locate an MBD-101 or a 1N5817 you can use a 1N4148; but if you do, another diode must be connected in series with D2, D3, and D4 to make certain that there will be enough drive voltage for D5.

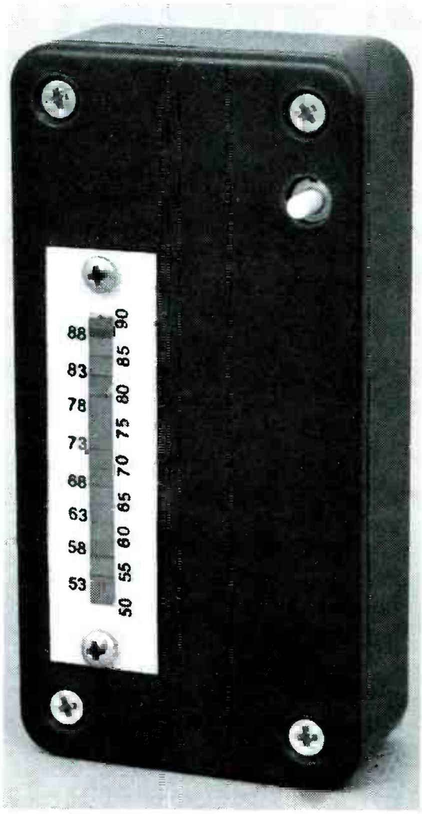
The 14538 used for IC4 must be manufactured by either Motorola or National. The reason for that is because most other manufacturers do not guarantee operation for pulse widths below 20 microseconds, which is not narrow enough. R-E

Electronic Thermometer

MARC SPIWAK, ASSOCIATE EDITOR

QUITE OFTEN, THE BEST KIND OF PROJECT to build is just a neat little gadget that you don't necessarily need, but one that will give you something to do without costing you an arm and a leg. That way, you don't have to rush the project in order to meet some deadline. And if you should run into any problems while trying to get your project to work, you won't be ready to kill your friends and family—and believe it or not, the fourth-most leading cause of death in this country is due to crazed electronics hobbyists who have wasted hundreds of dollars and hours on a dead-end project.

The project we are presenting, however, is one that you'll want to build. It is an electronic thermometer that displays a temperature range of 40 degrees Fahrenheit (or about 23 degrees Celsius) on a 16-LED bar-type display. It's easy to build, very inexpensive, and it is a great desktop-novelty item when it's finished. It's also so small that, with a little customizing, it can be made to fit, along with two small 6-volt batteries, inside a very small project case.



Here's something that you don't really need—but you'll probably want to build one, anyway!

Circuitry

As you can see from the schematic in Fig. 1, the heart of the electronic thermometer is IC1, a Siemens UAA170. That IC is really just a 16-LED driver. Depending on the level of the input voltage to pin 11, and how V_{REF}(min) and V_{REF}(max) (pins 12 and 13) are biased, one of the 16 LED's is illuminated.

The temperature-sensing ability of the circuit is made possible by R10, an NTC (*N*egative *T*emperature *C*o-efficient) thermistor. (A thermistor is a temperature-dependent resistor, and NTC means that as the temperature increases, the resistance decreases; PTC means that as the temperature increases, the resistance also increases.) As the ambient temperature increases, the thermistor's resistance, and consequently the input voltage to pin 11, decreases. The 16 LED's on the prototype display from about 50 to 90 degrees Fahrenheit, but you can calibrate the center temperature (the middle LED) via potentiometer R12.

The circuit also includes an LDR (*L*ight-*D*ependent *R*esistor), R11, that adjusts the display's brightness according to how much light is in the room. The LDR's resistance in bright light is about 350 ohms, and in total darkness its resistance approaches 200,000 ohms. When the prototype was tested, the photoresistor did its job too well. The display's brightness varied greatly between a very pleasant level and an excessively bright one. Thus, the light-dependent resistor was covered with a piece of tape so that the display will maintain the same low (pleasant) level of brightness and the batteries won't have to work so hard. However, because the LDR is in parallel with an 18K resistor (R1), the combined total resistance of those two components will never be more than 18K. Therefore, another alternative is to leave the LDR out of the circuit completely.

Components

The electronic thermometer can be built using parts that you gather individually, or purchased as a complete kit for $17.54 from the source listed in the Parts List. The kit includes the PC board and all components except a power supply, ON/OFF switch, and a case. While buying the kit is probably the easiest and cheapest way to build the project, you can also make your own PC board from the pattern in the PC-Service section of this magazine. You may even be able to get away with point-to-point wiring since it's such a simple circuit. Then, if you're lucky, your junkbox may contain all the parts you need except the IC.

The ON/OFF switch that was used in the prototype is a momentary push-button-type switch. A momentary switch was used because LED's are very power-hungry, and if the device were left on, the batteries wouldn't last very long. However, if you decide to build or buy a 12-volt DC power supply, or use a much larger battery pack, then it won't hurt a bit to leave the unit on all the time.

Construction

Begin building the project by installing all of the resistors on whatever PC board you're using, as shown in Fig. 2. Then, install the potentiometer R12, the thermistor R10, the light-dependent resistor R11, the IC socket, and lastly the LED's. Be sure to be very careful when spreading the leads of the LED's, because too much force will crack the LED in half. The kit includes 15 LED's of the same color, and one of a different color. You should install that single LED on the right-hand side of the board (above

R12 in the LED16 position) to indicate the maximum temperature on the display. (If you don't buy the kit, it's entirely up to you as far as the colors of the LED's are concerned.) Now just press IC1 into its socket.

After the board is completely assembled, you'll need some wire, an ON/OFF switch, and whatever you are using as a power supply. The prototype uses two 6-volt photo batteries (Eveready type A544 or equivalent) taped together, with the positive side of one connected to the negative side of the other. They are held in place inside the case with a piece of double-sided tape. Depending on what size case you're planning to install the board in, cut and solder appropriate lengths of wire to the + and – terminals on the PC board. Then install S1 in series with the positive supply line and connect the leads to the batteries. (Depending on what type of switch you use, and how it's supposed to mount to the project case, you may have to install it in the case first, and then solder it in the circuit.)

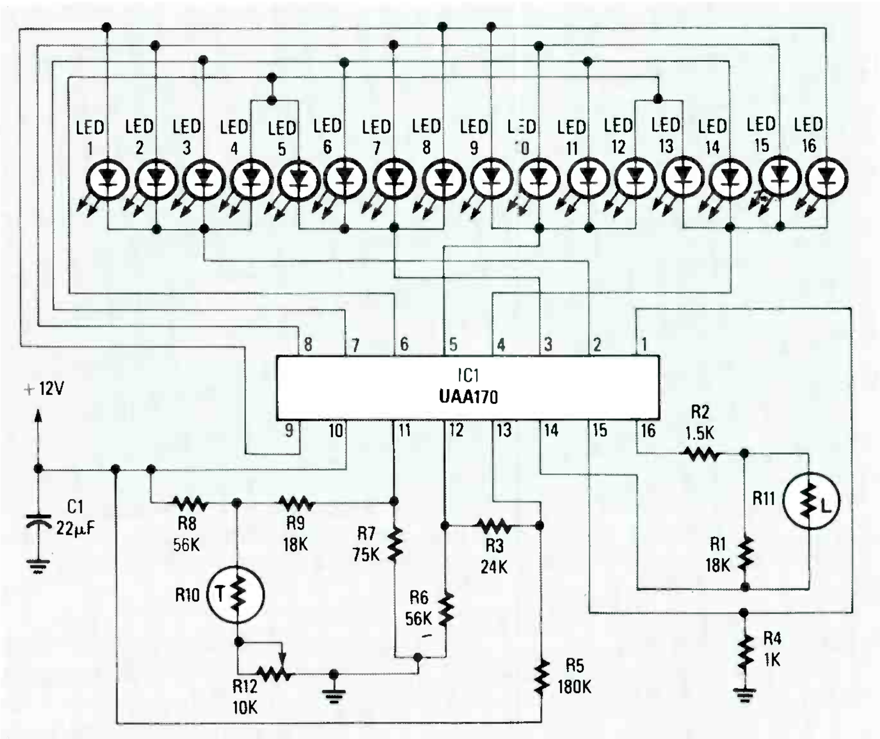


FIG. 1—THE SCHEMATIC FOR the electronic thermometer. It can be built from a kit or from separately purchased pieces on a PC board or perforated construction board.

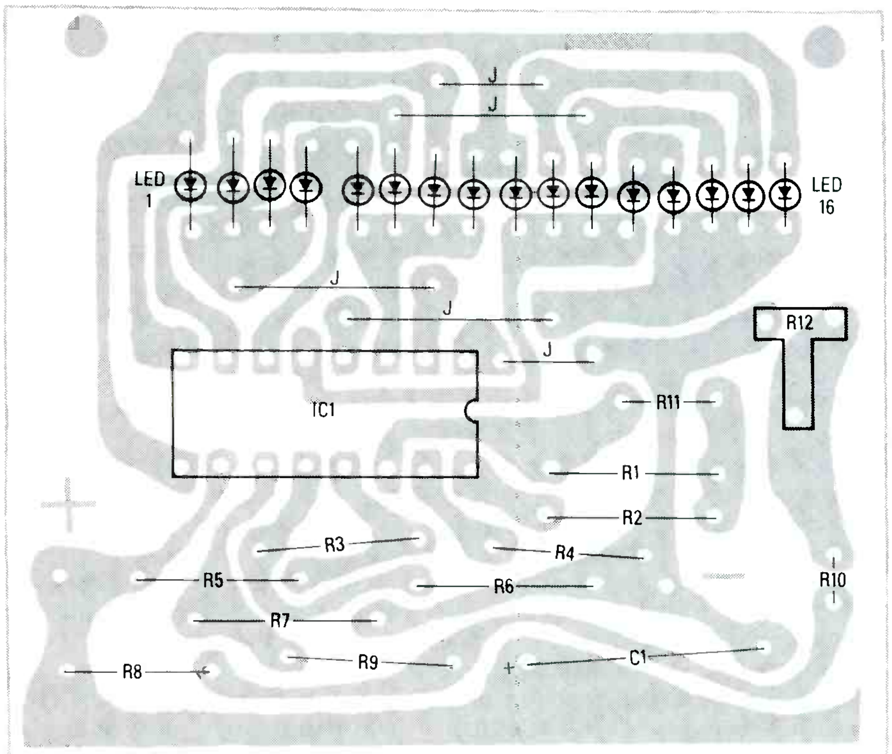


FIG. 2—PARTS-PLACEMENT DIAGRAM. Follow this when soldering the parts on the board supplied with the kit, or the one you can make from the pattern in PC Service.

Test and calibrate

By now you've probably already pressed the button to see if your thermometer is working—if not, do it now. At least one LED, or two right next to each other, should light up. (If nothing happens, check your soldering and the placement of the components—there can't be too much wrong with a circuit this simple!)

Once you are sure that your thermometer is working, you have to let it sit for about a half an hour. That's so the board can cool down to room temperature after all the soldering and handling. Try to let the board cool in a room that's at about 70 degrees—you'll have to get an ordinary thermometer, or look at your home thermostat's reading.

After the board's temperature has settled to about 70 degrees, adjust R12 so that the center LED (or one or two LED's higher or lower, depending on the exact room temperature) is illuminated. Now you should take a sheet of paper and draw 16 circles representing the 16 LED's on your display, and write a 70 next to the appropriate circle.

Place both the electronic thermometer and a regular thermometer inside a refrigerator for about ten minutes, and then remove them both. The temperature inside the refrigerator should be lower than 50 degrees, so the far-left LED should light up when the button is pressed. As soon as the next LED begins to light, check the temperature on the regular thermometer, and record it next to the appropriate circle on the sheet of paper. Then you can estimate what temperature the first LED should indicate. As the temperature continues to rise, keep on recording the readings until both thermometers once again level off at 70 degrees. (Try not to handle the board while you're doing that). If you are in doubt as to whether or not both thermometers are warming up at the same rate, you will have to do the calibrating by allowing both thermometers to level off in environments having different temperatures. Then you will have to approximate the temperatures in between.

Now you have to work near a warm lamp, or some other source of heat, and continue recording the readings until you reach the far-right LED. (It should be about 90 degrees when that LED lights.) Now you have a sheet of paper that represents the entire display on your thermometer. You should now check it out by placing both thermometers in different environments to make sure that they both display approximately the same temperature. At this time you can approximate the readings you've made in nice even increments, to allow for neat labeling later on.

All resistors are ¼-watt, 5%.
R1, R9—18,000 ohms
R2—1500 ohms
R3—24,000 ohms
R4—1000 ohms
R5—180,000 ohms
R6, R8—56,000 ohms
R7—75,000 ohms
R10—20,000 ohms, NTC thermistor
R11—350–200,000 ohms, light-dependent resistor
R12—10,000 ohms, PC-mounting type potentiometer
Capacitors
C1—22 µF, 15 volts, electrolytic
Semiconductors
IC1—UAA170 or equivalent
LED's 1–16—rectangular LED's
Miscellaneous
1 16-pin IC socket, plastic case, clear plastic, wire, solder, screws, tape, momentary switch, etc.
Note: A kit containing all parts except a power supply, a momentary pushbutton, and a project case, is available for $17.54 from all TSM distributers. You can contact the TSM headquarters, at 2065 Boston Post Road, Larchmont, NY 10538, for the TSM distributer nearest you.

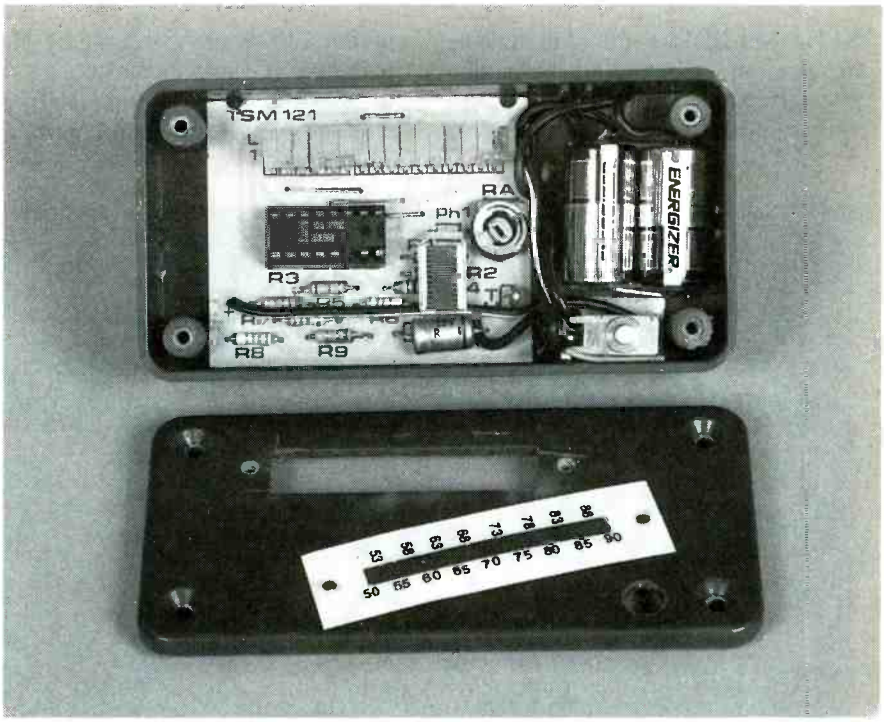


FIG. 3—THE BOARD FITS inside the case as shown. Holes are cut in the cover, and a lens is made using any kind of flexible clear plastic, which is then screwed in place.

Final assembly

Now you are ready to put the board in some kind of project case. In order to fit it inside Radio Shack's small project case (number 270220), the PC board's edges had to be filed down, as well as cutting away the plastic ribs inside the project case. (You can use a larger case if you like.) Then, the cover has to have a hole drilled in it for the switch, and a rectangular slot cut in it so that the faces of the LED's can come through (see Fig. 3). Make sure that the faces of the LED's are flush with the surface of the cover—you might have to put a piece of foam rubber of other kind of non-conductive material underneath the board in order to get them to the right height.

The lens for the display was made from two identical pieces of clear plastic cut from the box that the kit came in. However, any clear plastic, perhaps from bubble-type packaging, may be used. The plastic is cut large enough so that it can fully cover the slot in the case's cover, and also overlap enough to have room to screw it in place (see Fig. 3). Tape both pieces of plastic in place on the case cover, drill a small hole on each side, put a small screw in each hole, and then remove the screws and the tape.

Now take a piece of electrical tape, and cut a strip that is slightly narrower than the faces of the LED's, and the exact length of them (about 4 cm). Stick the tape down in the exact center of one piece of plastic, and make sure that the edges are firmly pressed down. At a distance of at least a foot, spray the plastic, tape-side up, with some spray paint (whatever color you like), until you can no longer see through it. Wait until the paint is completely dry, and then pull the tape off.

Now you have a lens that covers the rough edges of the slot in the cover of the case, yet still allows the LED's to be seen. Some rub-on lettering was used on the side *without* the paint to indicate the temperature scale on the display, as well as to add a professional appearance to the device. The temperature range on the prototype was divided into 5-degree increments, and the labeling was evenly spaced along the 4-cm display. The finishing touch is the second piece of plastic used to protect the lettering from being scratched off. The two pieces of plastic are then screwed back in place, and the case is then closed up.

The unit is now ready to be placed in the location of your choice. There it will silently wait, ready at all times, to give you an instant yet accurate temperture reading at the touch of a button. **R-E**

HIGH-VOLTAGE PROJECTS

Jacob's Ladder—The easy-to-build laboratory toy made famous in Frankenstein and other horror films.

Solid State Tesla Coil—Build an updated version of Nikola Tesla's famous electrical spark generator.

Lightning Bulb—Create a stunning electrical display within the confines of an ordinary light bulb.

Electronic Dazer—A budget project designed for the experimenter who needs experience with high-voltage circuits.

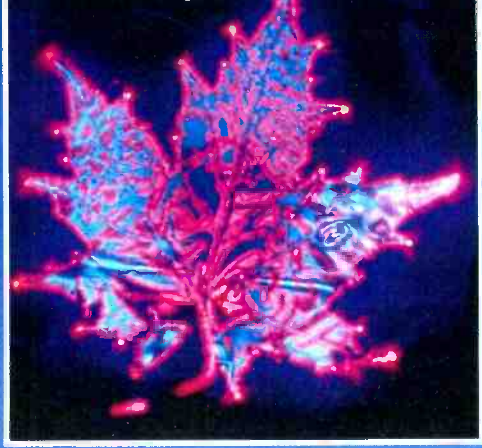
Universal Laser Power Supply—Power HeNe lasers for experimental work using a supply that can deliver about 2.5 amperes.

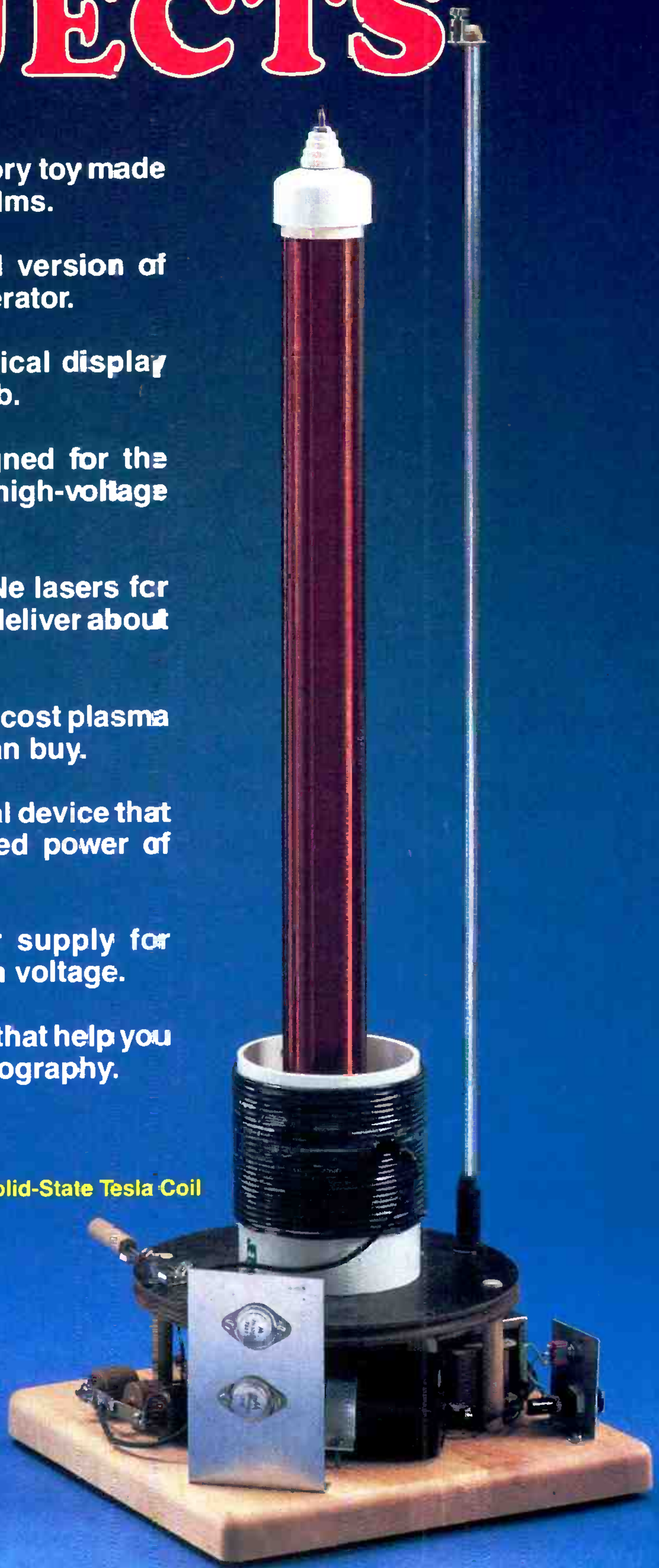
Electronic Tornado—Build a high-tech, low-cost plasma globe display that rivals the best money can buy.

Stun Gun—It's not a toy, but an experimental device that can produce 75,000 volts at a peak pulsed power of 25,000 watts.

HV Pulse Generator—A universal power supply for creating your own special effects with high voltage.

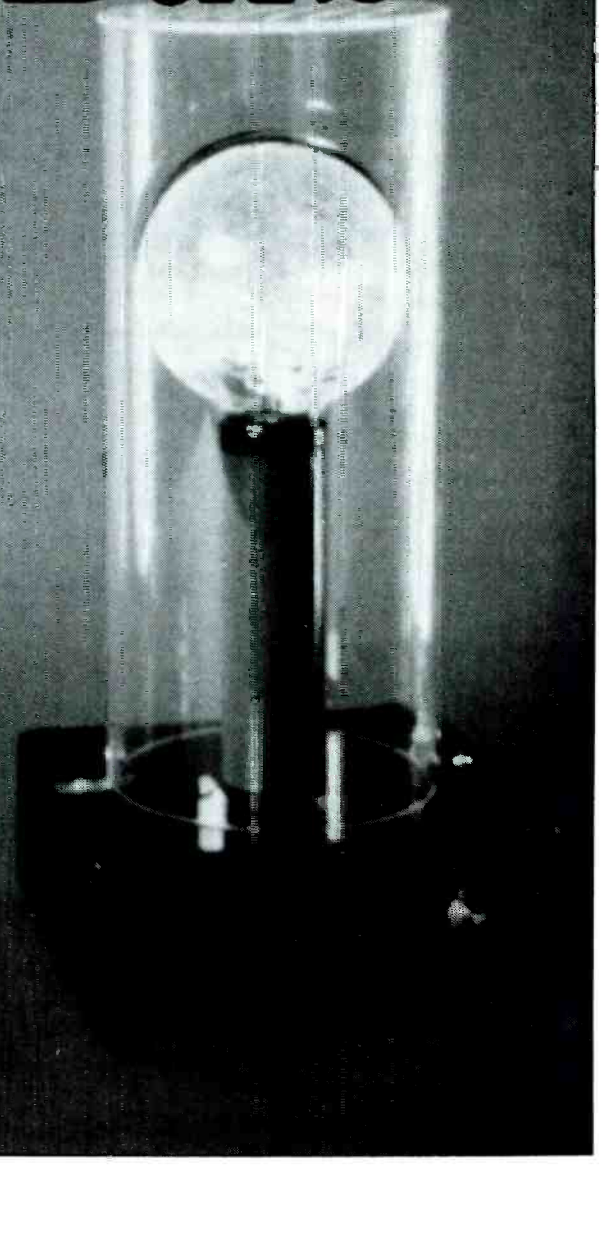
Kirlian Photographs—Tips and techniques that help you explore the mysteries of high-voltage photography.


Kirlian Photography


Solid-State Tesla Coil

Build the Lightning Bulb

Create an electrical storm in a light bulb with this easy-to-build project



BY VINNY VOLLONO

Since the dawn of civilization, mankind has been fascinated by lightning. And it was that fascination with lighting and electricity that has brought about many of the high-tech novelty items—like the Tesla Coil, *Eye of the Storm*, Jacob's Ladder, and the Van DeGraph Generator, for example—that are showing up in the market place.

Similar effects can be produced by the *Lightning Bulb*, which creates a stunning display, yet consists of little more than a modified clear incandescent lamp and a high-voltage power supply. The lamp is modified by taping a piece of aluminum

(continued on next page)

foil to the back half of its glass envelope, forming a sort of make-shift capacitor. The electrode inside the lamp forms one plate of the capacitor, the glass envelope of the lamp serves as the dielectric, and the aluminum foil is used as the second plate.

The aluminum foil, like the negative plate of a polarized electrolytic capacitor, is grounded. A high voltage is discharged into the lamp through its inner electrode, ionizing the thin gas that remains in the envelope, creating a visual effect similar to an electrical storm.

Circuit Description. The Lightning Bulb circuit uses a quadrac (see Fig. 1)—a device that combines a triac and a diac trigger in a single package—to control the supplied current. Figure 1A shows the schematic symbol for the quadrac, while Fig. 1B shows the pinout for the unit used in our circuit. Note that quadracs are becoming increasingly more difficult to come by; if one can not be located, a discrete diac/triac combination of equal or higher rating can be used in its place.

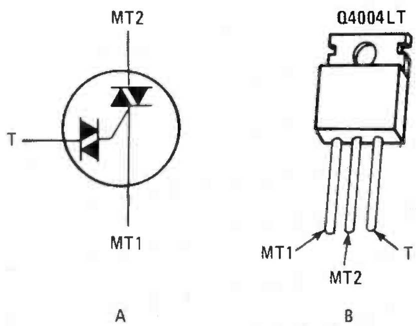


Fig. 1. The Lightning Bulb circuit uses a quadrac—a device that combines a triac and a diac trigger in a single pack- age—to control the input power source. Shown in A is its schematic symbol for the quadrac, while B is the pinout for the unit used in our circuit.

Figure 2 shows a schematic diagram of the Lightning Bulb circuit. The heart of the circuit is a 12-volt automotive ignition coil, T1, which is used to deliver a high-voltage charge of sufficient magnitude to ionize the gases within the glass envelope of lamp I1.

Power for the circuit is taken directly from the AC line and applied through a phase-shift network (consisting of capacitor C1 and resistor R1) to the trigger input (T) of quadrac TR1, causing it to conduct.

With TR1 conducting, a short burst of energy is applied via C2 to the primary winding of T1. (Recall that when power is first applied to a capacitor, the capacitor acts as a short, and then the capacitor begins to charge to the applied voltage.) That burst of energy creates a magnetic field around the primary winding of T1, causing a high voltage to be induced in its secondary.

When capacitor C2 begins to charge to its highest level, the AC signal begins to collapse. As the signal collapses, the current needed to maintain triac conduction dips below the holding level (I_H), the triac turns off, and the second half of the AC signal begins.

As the AC signal becomes more negative, a signal is again applied to the triac's trigger input, causing it to conduct. Triacs conduct during both the positive and negative half cycles of an AC waveform, and can be activated by either a positive or negative trigger source. (For a better understanding of the operation of triacs and other thyristor devices, see *All About Thyristors*, which appeared in the March and April 1988 issues of *Hands-on Electronics*.)

With TR1 now conducting in the opposite direction, the charge on C2 is bled off, via TR1, and a burst of energy (of opposite polarity) is applied to the primary winding of T1, causing a voltage to be induced in its secondary winding. The high-voltage output (about 20,000 volts) at the secondary of T1 is applied to the lamp, I1, creating an electrical storm-like effect.

The value of C2 must be limited to between 2–2.5 µF to prevent damage to ignition coil T1. On the other hand, if the value of C2 is too small, the display will be somewhat insufficiently pronounced. Inductors L1 and L2 were added to block any switching transients from entering the AC line.

Safety First. As shown in the schematic diagram (Fig. 2), you'll be dealing with a high-voltage transformerless power source. Because of the possible safety hazard associated with projects of this type, it is strongly recommended that you use an isolation transformer when testing and troubleshooting the circuit. For an extra margin of safety, always be sure to discharge the capacitors before performing any work on the circuit. A capacitor can store a charge large enough to melt a copper penny.

Caution: In assembling the Lightning Bulb, *do not* omit the protective plexiglass tube that covers the lamp. The clear ⅛-inch thick plexiglass tube helps to prevent an accidental shock. The high voltage can penetrate the glass and you could get a shock or worse. The safety cover is an absolute must.

Construction. Because of the simplicity of the circuit, the author's prototype was built on a piece of perfboard (measuring about 3 × 4 inches), and the connection between the components were made using point-to-point wiring. Note that for those who wish to use a printed-circuit board, one is offered by the supplier given in the Parts

PARTS LIST FOR THE LIGHTNING BULB

U1—Q4004 4-amp, 400-volt quadrac, or triac/diac combination (see text)
C1—0.02-µF metal-film capacitor
C2—2-µF, 400-WVDC metallized polyester or polycarbonate capacitor
F1—3-amp 3AG fuse
I1—G-40 clear incandescent lamp with 5-inch envelope
L1, L2—10-µH hash choke
R1—390,000-ohm ½-watt resistor
S1—single-pole, single-throw toggle switch
T1—12-volt automotive ignition coil
Perfboard materials or printed-circuit board, plastic enclosure, 6-inch OD plexiglass tube, 1½-inch OD plexiglass tube, high-voltage cable, fuse holder, aluminum foil, electrical tape, wire, solder, hardware, etc.

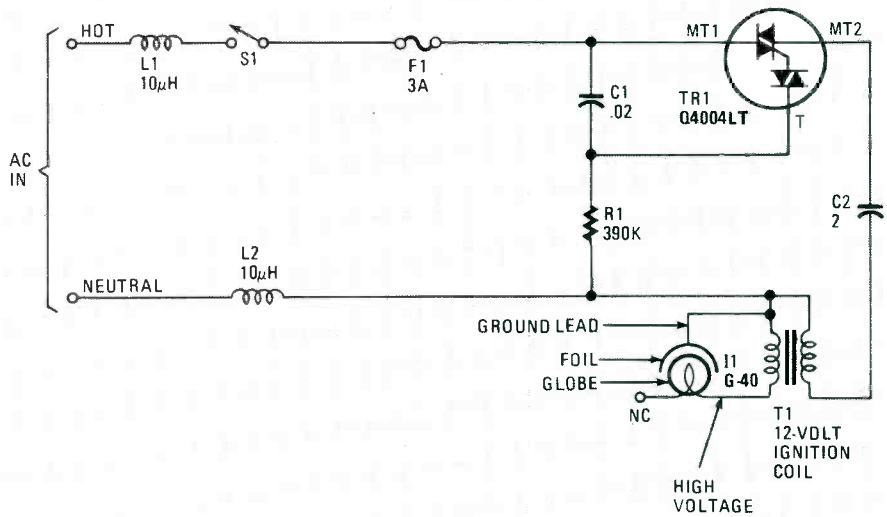


Fig. 2. Here's the schematic diagram of the LightningBulb circuit.

List. However, printed-circuit board construction will not be discussed in this article.

Assemble the circuit board using Fig. 2 as a wiring guide, making the interconnections between the components as the components are installed on the board. Just about any 12-volt automotive ignition coil should do for T1. The .02-μF capacitor specified for C1 can be replaced by two .01-μF units connected in parallel, which is what the author used in his prototype.

When the circuit-board assembly is complete, set it aside for a while and begin modifying the lamp. The lamp used in the author's prototype is a 25-watt designer's bulb with a 5-inch clear-glass envelope. Contrary to common belief, the area within the envelope—particularly where larger envelopes are concerned—is not a total vacuum. Some gas still remains within the envelope even after the evacuation process. Lamps having large envelopes produce a more impressive display because of the higher concentration of gas (in comparison to standard household lamps) within the envelope.

Start the modification process by placing black electrical tape on what will be the back half of the lamp. Place a layer of aluminum foil over the tape and then add a second layer of tape over the aluminum foil to hold it in place. Starting from the outer edges of the foil, apply the tape, working your way inward toward the center. Leave a small portion of the foil exposed so that a wire can be attached. The author used aluminum solder to the attach a lead to the aluminum foil, but gluing or taping should work. Once the wire is attached, it should be connected to the ground terminal of T1 as shown in Fig. 3. Then cover the exposed aluminum and the wire with tape.

The author used a regular plug-in lamp socket to connect the lamp to the high-voltage output of T1. A high-voltage cable is connected across the two contacts of the lamp socket. The type of lead wire used in TV sets to bridge the high-voltage output of

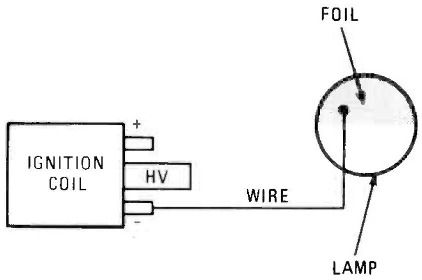


Fig. 3. A wire is connected from the ground lead of T1 to the aluminum foil that's been placed on the glass envelope of the lamp.

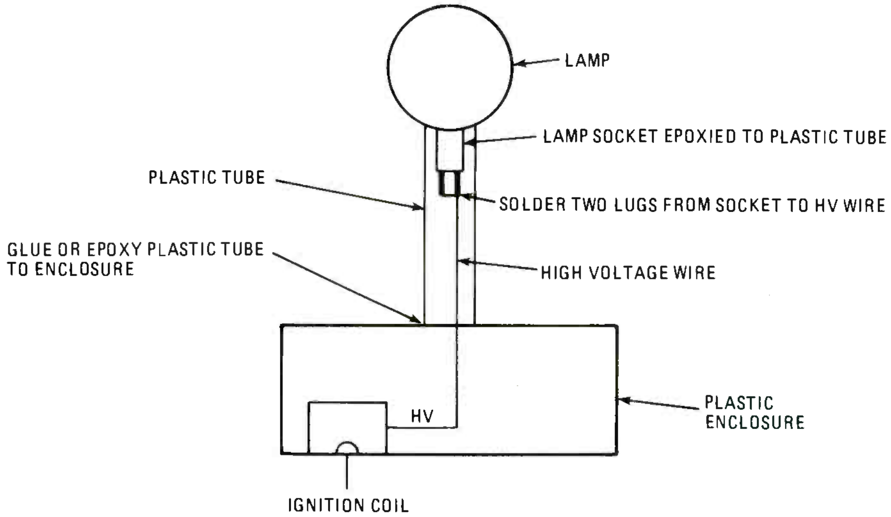


Fig. 4. Mount the lamp-and-socket assembly to its support column, and then mount the entire assembly on the project's plastic enclosure.

the flyback transformer to the anode of the CRT is ideal. Once the wires to the lamp are in place, mount the lamp and socket to their support column. It's a good idea to devise some sort of identification method for the leads; that will cut down on the confusion that may arise during the final electrical-assembly process.

The lamp-support column is a 5- to 6-inch length of plastic tubing with an outside diameter (OD) of 1½ inches. After threading the wires from the lamp-and-socket assembly through the tube, secure the lamp-and-socket assembly to the tube with glue or epoxy. (See Fig. 4.) Once the glue has dried, re-enforce the assembly where the lamp-and-socket assembly meets the support column with one or two wraps of tape .

The support-column assembly is then secured to the project box with glue, or is held in place with screws and "L" brackets. The two leads from the lamp are then connected to the circuit-board mounted components.

The "hot" side of T1's secondary is connected to the bridged lamp-socket terminals (as shown in Fig. 4), and the negative side is connected to the lead coming from the aluminum plate on the lamp. Feed a line cord through the enclosure wall to the circuit board. Connect one lead from the line cord directly to the circuit board. The other lead is then connected through S1 to the circuit board.

Once that is done, check your work. If everything looks okay, seal the board in its enclosure and place a 6-inch OD plexiglass tube over the lamp and column assembly. (The actual length of the protective tubing depends on the physical height of the lamp/support-column combination.) The tube provides the user with some measure of protection from high voltage that's present in the circuit.

The 6-inch tube can be secured in place with ½-inch wide angle brackets. (See photos.) A lid for the tube can be fashioned from a piece of clear plexiglass. Holes, about ¼ inch in diameter, should be drilled in the lid for ventilating. The lid can then be glued to the top of the protective tube.

You are now all set to give your Lightning Bulb a test run. As with all other projects of a similar nature, ambient light detracts from the visual effect of the display. The Lightning Bulb gives a much more impressive display in a darkened room. ■

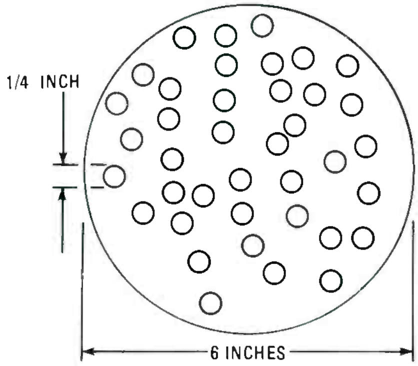
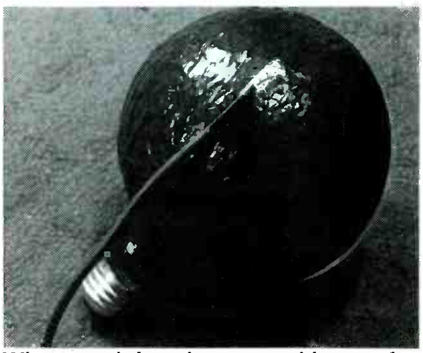


Fig. 5. A 6-inch diameter lid is fashioned from a piece of clear plexiglass. Quarter- inch holes are then drilled into the lid to help ventilate the lamp.



When applying the second layer of tape, leave a small area of aluminum exposed, and connect a wire to the foil.

HIGH-VOLTAGE ZAPPERS

It doesn't take much to generate enough high voltage to curl your hair

CHARLES D. RAKES

THE TWO CIRCUITS WE'VE GOT HERE ARE for the experimenter having a touch of Ben and Nikola's fascination for working with high voltage. But unlike those two brave pioneers who flirted with lightning and gigantic spark coils, our high-voltage circuits are mild in comparison, having outputs of less than 50 kilovolts (kV). Even so, don't ever become careless when working with high voltage. To do so could be dangerous to your health and your good nature. So please take care.

A circuit that generates a high voltage by discharging the energy stored in a large-value capacitor through the primary winding of a high-turns-ratio step-up transformer is known as a *C*apacitor-*D*ischarge (CD) system. It's the same concept used by many of the high-performance auto-ignition systems to produce a super-hot spark. It's also the same kind of system used by some of the top-of-the-line electric fence chargers. And let us not forget one of the most popular personal-defense devices now on the market, the electronic Stun Gun, which also generates its zap with a capacitor-discharge circuit.

How we make the zap

As shown in the circuit of Fig. 1, step-down transformer T1 drops the incoming line voltage to approximately 48 VAC and, in the process, adds a degree of safety through the transformer's primary-to-secondary isolation from the power line. T1's 48-volt secondary is rectified by diode D1; the resulting DC charges capacitor C1, through current-limiter R1, to a voltage level pre-set by R4. When the voltage on R4's wiper reaches about 8.6 volts, Q1 begins to turn on, drawing current through R7 and the base-emitter junction of Q2. Then Q2 turns on and supplies a positive voltage to the gate of silicon-controlled rectifier Q3. The positive gate voltage causes Q3 to conduct, thereby discharging C1 through the primary winding of step-up transformer T2; the end-result is a high-voltage arc at the output terminal (X).

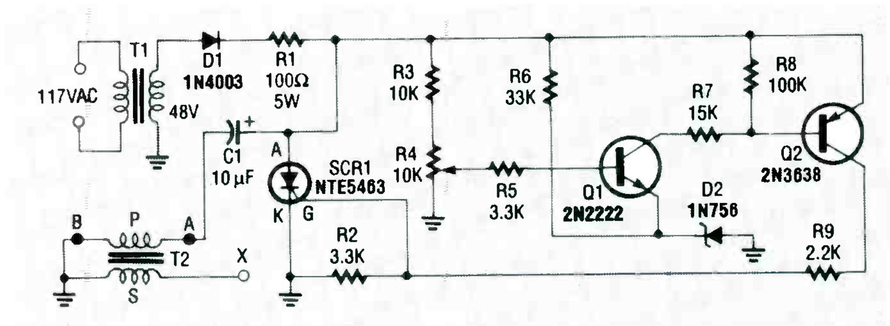


FIG. 1—BE SURE TO KEEP EVERYTHING, especially yourself, away from the high-voltage output at point "X."

The value of the high voltage developed at T2's output is determined by the value of C1, the voltage across C1, and the turns ratio of T2. The frequency or pulse rate of the high voltage is determined by the resistance of T1's primary and secondary windings, the value of R1, and the value of C1. The lower the value of each item, the higher the output pulse rate; the peak output voltage will remain unchanged only if C1's value remains unchanged.

PARTS LIST

FIG. 1

All resistors are ½-watt, 5%, unless otherwise noted.

R1—100 ohms, 5 watts
R2, R5—3300 ohms
R3—10,000 ohms
R4—10,000 ohms, potentiometer
R6—33,000 ohms
R7—15,000 ohms
R8—100,000 ohms
R9—2200 ohms

Capacitors

C1—220- or 440-µF, 75–100 volts, electrolytic, or 10-µF 220-VAC motor capacitor (see text)

Semiconductors

D1—1N4003 silicon rectifier
D2—1N756, 8-volt Zener
Q1—2N2222 NPN transistor
Q2—2N3638 PNP transistor
SCR1—NTE5463 10-amp, 200-volt silicon-controlled rectifier

Other components

T1—Step-down transformer, 48 VAC, 300 mA
T2—Auto ignition coil, or substitute (see text)

Building the CD system

The circuit shown in Fig. 1 is noncritical, so any parts layout and mounting can be used; perforated wiring board will probably make for the easiest assembly. But no matter what kind of construction is used, keep T2's output terminal (labeled X) at least three inches clear of all circuit components, yourself, and anything else that can conduct electricity.

The transformer used for T2 can be almost any 6- or 12-volt auto-ignition coil, but one designed with a high turns ratio for a capacitor-discharge ignition system will produce the greatest output voltage. The CD coil that we used produced a spark 1¼ inches in length from the output terminal to the coil's common terminal.

An old (but good) TV flyback transformer can also be used for T2. Simply wind about 10 turns of test-

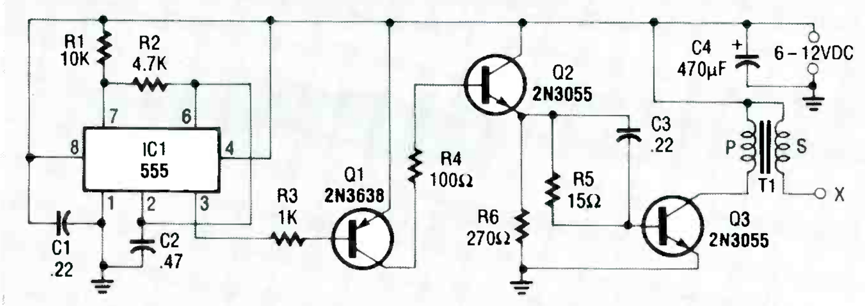


FIG. 2—THE SPARK DURATION is controlled by a 555 timer in this circuit.

lead wire around the transformer's ferrite core and connect the free ends of the wires to the points labeled "A" and "B" in Fig. 1. Some experimenting with the number of turns may be necessary to obtain good results with that type of transformer. Our experiments with the TV flyback produced a voltage that would jump a ¾-inch gap.

If a small-engine repair business is located in your area, see if the owner or mechanic will give you a few of the old ignition coils. If you obtain several old coils, one or more should be usable. To produce a high voltage with a small-engine ignition coil, connect the primary leads to terminals "A" and "B," and a ½ to ¾-inch spark should be possible.

To make a "magnetic charger," select one of the ignition coils that has a good primary winding and carefully remove the secondary winding from the coil's core. Connect the primary wires to terminals "A" and "B." Position any object that you want to magnetize on the exposed core laminations and apply power; you should hear a "Zap" sound as the magnetic pulses hit the metal object.

Maximum spark

If you want to achieve a maximum spark, select a CD ignition coil, and use a 440-µF, 75- to 100-WVDC electrolytic capacitor for C1. Using a DC voltmeter, monitor the voltage across C1. Adjust R4 so that the Q3 fires when the charging voltage across C1 reaches between 50–55 volts. That setting should produce a spark 1¼ to 1½ inches long every second or so.

To obtain a faster pulse rate, with some reduction in the output, change C1 to a 10-µF, 220-VAC motor capacitor (or any other lower value with a rating of 75 volts or more). Experiment with different component values to obtain the desired results.

An excellent electric fence charger can be made by building the CD circuit in a suitable case and selecting a 220-µF capacitor for C1. Adjust R4 for one to two pulses per second.

Battery-powered high voltage

A high-voltage generator circuit that can operate from a battery or other low-voltage DC source is shown in Fig. 2. Output voltage great enough to jump a 1-inch gap can be obtained from a 12-volt power source, and with a higher pulse rate than the circuit in Fig. 1.

A 555 timer IC is connected as an astable multivibrator that produces a narrow negative pulse at pin 3. The pulse turns Q1 on for the duration of the time period. The collector of Q1 is direct-coupled to the base of power-transistor Q2, turning it on during the same time period.

The emitter of Q2 is direct-coupled through current-limiter R5 to the base of power-transistor Q3. When Q3 turns on, there is a minimum resistance between its collector and emitter. That causes a high-current pulse through the primary of T1, which generates a very high pulse voltage at T1's secondary output terminal (labeled X). The pulse frequency is determined by the values of R1, R2, and C2. The values given in the Parts List were chosen to give the best possible performance when an auto ignition coil is used for T1. Here too, a CD-type ignition coil will produce the greatest output voltage.

Perforated wiring board construction is a good choice for this circuit, but remember to be careful when working near the output terminal of T1 while the power is on.

Getting parts

Radio Shack is a prime source for most of the components used in this article. Digi-Key Corp. (701 Brooks Ave. South, P.O. Box 677, Thief River Falls, MN 56701-0677) is another good source. A good selection of unusual components, such as photo-flash capacitors and telephone transformers, is available from All Electronics Corp. (905 S. Vermont Ave., PO Box 20406, Los Angeles, CA 90006). **R-E**

PARTS LIST

FIG. 2 All resistors are ½-watt, 5%, unless otherwise noted.

R1—10,000 ohms
R2—4700 ohms
R3—1000 ohms
R4—100 ohms
R5—15 ohms, 5 watts
R6—270 ohms

Capacitors

C1, C3—0.22 µF, 100 volts, Mylar
C2—0.47 µF, 100 volts, Mylar
C4—470 µF, 25 volts, electrolytic

Semiconductors

IC1—555 timer
Q1—2N3638 PNP transistor
Q2—2N3055 NPN power transistor
Q3—2N3055 NPN power transistor with heatsink

Other components

T1—Auto ignition coil (see text)

BUILD THIS

STUN GUN

ROBERT GROSSBLATT, and ROBERT IANNINI

This experimental high-voltage generator can produce 75,000 volts at a peak power of 25,000 watts.

Man's fascination with high voltages began with the first caveman who was terrified by a bolt of lightning. In more recent times, electronics experimenters and hobbyists have found the Tesla coil and the Van de Graaff generator equally fascinating. In this article we'll show you how to build a hand-held high-voltage generator that is capable of producing 75,000 volts at a power level as high as 25,000 watts. The stun gun can be used to demonstrate high-voltage discharge and as a weapon of self-defense. Before building one, however, you should read and pay very close attention to the warning in the accompanying text box, as well as to the description of physiological effects that follows.

WARNING

THIS DEVICE IS NOT A TOY. We present it for educational and experimental purposes only. The circuit develops about 75,000 volts at a maximum peak power of 25,000 watts. The output is pulsed, not continuous, but it can cause a great deal of pain should you become careless and get caught between its output terminals. And you should never, repeat, NEVER, use it on another person! It may not be against the law in your area to carry a stun gun in public, but, if you use it on another person, you may still be liable for civil action.

To help you build, test, and adjust the device safely, we have included a number of tests and checks that must be followed strictly. Do not deviate from our procedure.

Physiological effects

So that you may understand the danger inherent in the stun gun, let's discuss the physiological effects first. When a high voltage is discharged on the surface of the skin, the current produced travels through the nervous system by exciting single cells and the *myelin sheaths* that enclose them. When that current reaches a synapse connected to a muscle, it causes the muscle to contract violently and possibly to go into spasms.

The longer contact with the high voltage is maintained, the more muscles will be affected. If the high voltage maintains contact with the skin long enough to cause muscle spasms, it may take ten or fifteen minutes before the brain is able to re-establish control over the nerve and muscular systems.

How much power is required to cause such spasms? That's not an easy question to answer because, although it is relatively easy to make precise measurements of the power produced by a high-voltage device, it is difficult to rate the human body's susceptibility to shock accurately. Some obvious factors include age and diseases such as epilepsy. But the bottom line is simple: *The only one who fools around with a stun gun is a fool.*

The amount of energy a device delivers is actually the amount of power delivered in a given period of time. For our purposes, it makes sense to talk about energy in joules (watt-seconds). Using a fresh 9.8-volt Ni-Cd battery, the stun gun is capable of delivering peak power pulses of 25,000 watts. Actually, pulses start out at peak power and then decay exponentially. The length of the decay time depends on the components used in the circuit, the ambient temperature, the battery's capacity, and the positioning of the output contacts with respect to each other.

Assuming that the decay rate is purely exponential, the stun gun can produce about 0.5 joules of energy, provided that the battery is fully charged. Let's put that number in perspective.

Both the Underwriter's Laboratory (in Bulletin no. 14) and the U. S. Consumer Product Safety Commission state that ventricular fibrillation (heart attack) can be caused in humans by applying 10 joules of energy. Since the stun gun only generates about half a joule, you might think that a device that produces only one twentieth of the critical amount has a more-than-adequate margin of safety. *Don't bet on it.* A brief contact with the stun-gun's discharge hurts a great deal, but it takes only about five seconds of continuous discharge to immobilize someone completely.

Let's compare the stun gun's output with a similar device, called a Taser gun, which appeared on the market a few years ago. You may have seen a film demonstrating just how effective the Taser could

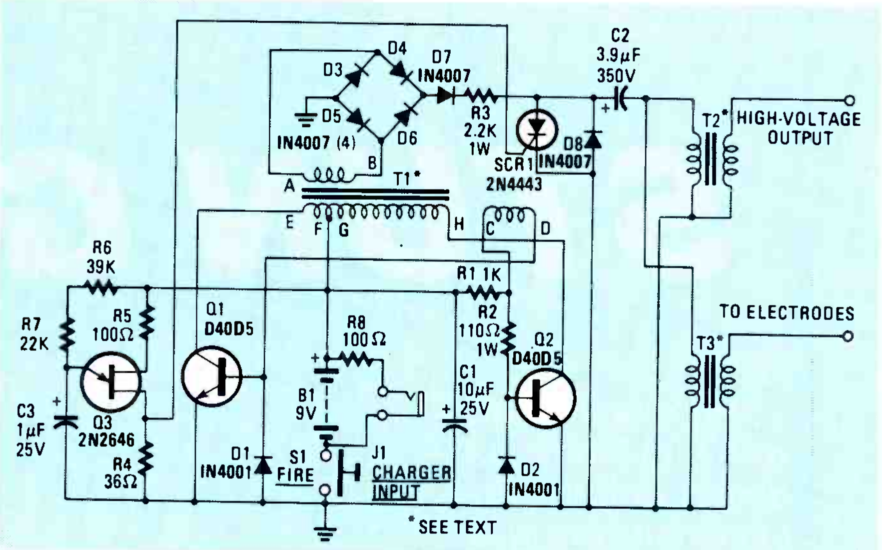


FIG. 1—THE STUN GUN'S CIRCUIT is a multi-stage voltage step-up circuit. The Q1/Q2 circuit produces a squarewave output of about 10 kHz, and Q3 produces 15-μs discharge pulses at a rate of about 20 ppm. Those pulses fire SCR1, which induces a voltage in the windings of step-up transformers T2 and T3.

be as a deterrent. A foolhardy volunteer was paid an enormous sum of money to have the Taser fired at him. No matter how big, strong, (and stupid) the person was, as soon as the Taser's "darts" hit him, he would collapse to the ground and go into uncontrollable convulsions.

The energy produced by the Taser is only 0.3 joules—about 60% of what our stun gun produces! Even so, the Taser has been officially classified as a firearm by the Bureau of Tobacco and Firearms because it shoots its electrode "darts" through the air. Even though our stun gun doesn't operate that way, the Taser puts out considerably less energy than the stun gun. Keep those facts and figures in mind as you assemble and use the device.

How it works

The schematic diagram of the stun gun is shown in Fig. 1. Basically, it's a multi-stage power supply arranged so that each succeeding stage multiplies the voltage produced by the preceding stage. The final stage of the circuit feeds two oppositely-phased transformers that produce extremely high voltage pulses. If that description sounds familiar, you've probably studied capacitive-discharge ignition systems—the stun gun works on the same principles.

The first section of the power supply is a switcher composed of Q1, Q2, and the primary windings (connected to leads E, F, G, and H) of T1. When FIRE switch S1 is closed, R1 unbalances the circuit and that causes it to start oscillating. Since base current is provided by a separate winding of T1 (connected to leads C and D), the two transistors are driven out of phase with each other, and that keeps the circuit oscillating. Resistor R2 limits base drive to a safe value, and diodes D1 and D2 are steering diodes that switch base current from one transistor to the other. Oscillation occurs at a frequency of about 10 kHz.

The switching action of the first stage generates an AC voltage in T1's high-voltage secondary (leads A and B). The amount of voltage depends on the battery used, but a battery of seven to nine volts should produce 250 to 300 volts across T1's secondary.

That voltage is rectified by the full-wave bridge composed of diodes D3–D6. Capacitor C2 charges through D7 at a rate that is controlled by R3.

The value of capacitor C2 affects the output of the stun gun. The greater the capacitance, the more energy that can be stored, so the more powerful the discharge will be. A larger capacitor gives bigger sparks, but requires more charging time, and that gives a lower discharge rate. On the other hand, a smaller capacitor gives smaller sparks, but a faster discharge rate. If you wish to experiment with different values for C2, try 3.9 μF (as shown in Fig. 1), 7.8 μF, and 1.95 μF. Those values were arrived at by using one 3.9 μF capacitor alone, two of the same capacitors in series, and two in parallel.

Meanwhile, UJT Q3 produces 15-μs pulses at a rate of about 20 ppm. That rate is controlled by C3 and the series combination of R6 and R7. When a pulse arrives at the gate of SCR1, it fires and discharges C2. That induces a high-voltage pulse in the primary windings of T2 and T3, whose primaries must be wired out of phase with each other. The result is a ringing wave of AC whose negative component then reaches around and forces the SCR to turn off. When the next pulse from Q3 arrives, the cycle repeats.

The outputs of the stun gun appear across the secondaries of T2 and T3. The hot leads of those transformers connect to

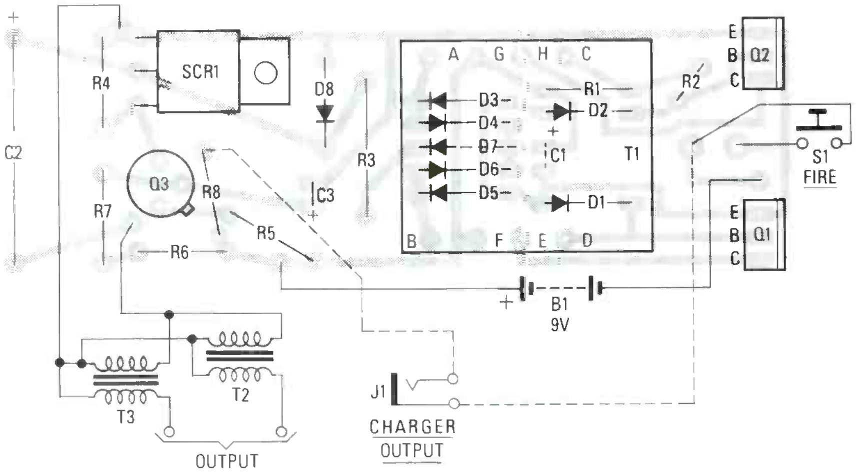


FIG. 2—MOUNT ALL COMPONENTS ON THE PC BOARD as shown here. Note that T2 and T3 are mounted off board, and that J1, C1, and D7 mount on the foil side of the board. In addition, a number of components mount beneath T1: D1–D6, R1, and R3. Those diodes and resistors must be installed before T1.

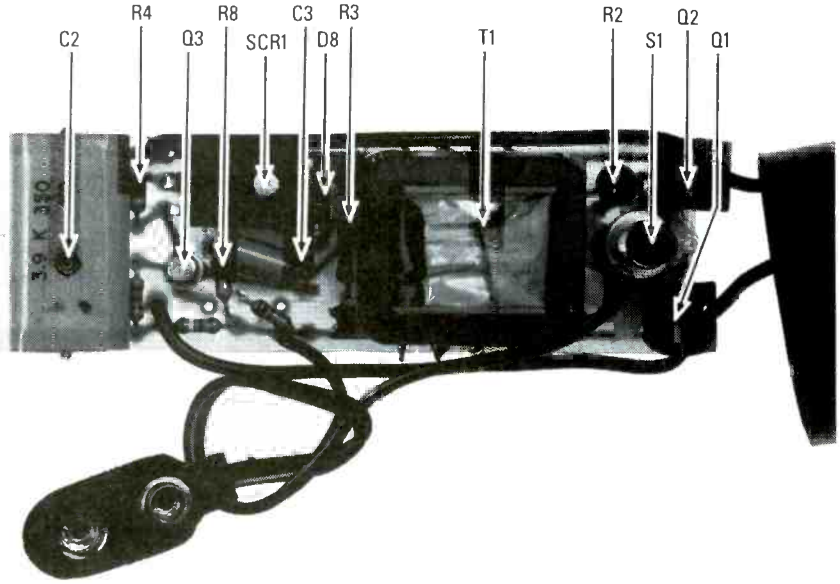


FIG. 3—BEND SCR1'S LEADS 90° so that the nomenclature faces up and then solder the SCR to the board. Also note that C3 must be bent over at a 90° angle, and that R2 is mounted vertically.

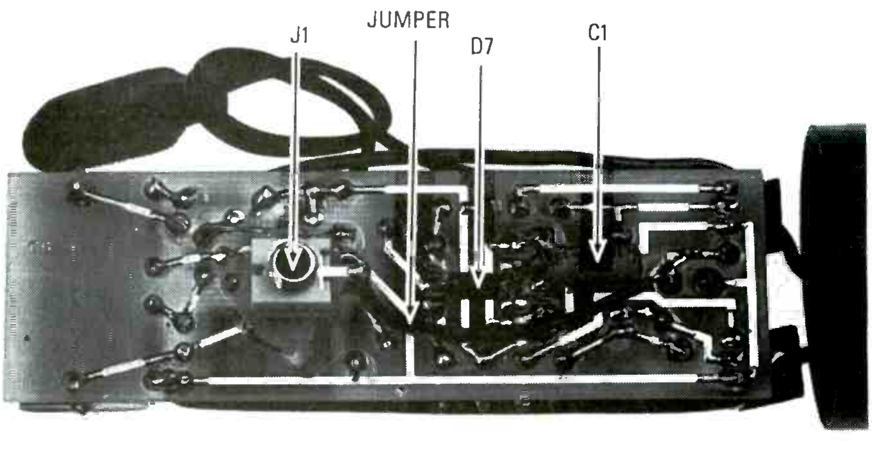


FIG. 4—JACK J1, DIODE D7, AND CAPACITOR C1 mount on the foil side of the PC board. One terminal of J1 mounts to the same pad as R8, and the jack should be glued to the board with RTV (or other high-voltage compound) after you verify that the circuit works properly.

PARTS LIST

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

R1—1000 ohms
R2—110 ohms, 1 watt
R3—2200 ohms, 1 watt
R4—36 ohms
R5, R8—100 ohms
R6—39,000 ohms
R7—22,000 ohms

Capacitors

C1—10 µF, 25 volts, electrolytic
C2—3.9 µF, 350 volts, electrolytic
C3—1 µF, 25 volts, electrolytic

Semiconductors

D1, D2—1N4001, 50-volt rectifier
D3–D8—1N4007, 1000-volt rectifier
Q1, Q2—D40D5, power transistor
Q3—2N2646, UJT
SCRI—2N4443

Other components

B1—9-volt Ni-Cd battery
S1—SPST momentary pushbutton switch
T1—12 to 400 volts saturable-core transformer. See text
T2, T3—50 kilovolt pulse transformer, 0.32 joules. 400-volt primary. See text

Note: The following components are available from Information Unlimited, P. O. Box 716, Amherst, NH 03031: T1, $12.50; both T2 and T3, $12.50; C2, $1.50; PC board, $4.50; case, $3.50; case with T2 and T3 potted, $17.50; charger, $6.50; 9.8-volt battery, $16.50; complete kit of all parts including all components, PC board, case, and charger, but no battery, $39.50.

the output electrodes, which should be held securely in position about two inches apart, and which should be insulated from each other and from the environment with high-voltage potting compound.

Batteries

The stun gun can be powered with almost any battery that can supply at least seven volts at one amp. A Ni-Cd battery would be a good choice; R8 and J1 will allow the battery to be recharged without removing it from the case.

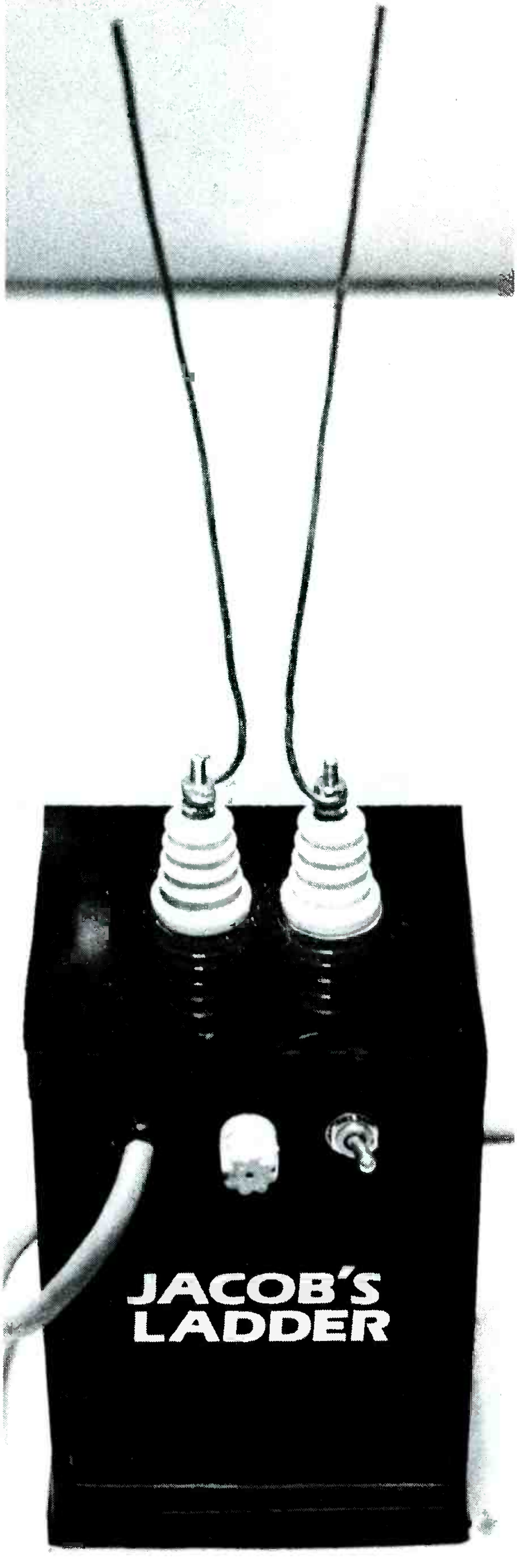
The higher the battery's voltage, the higher the stun-gun's output voltage. Most nine-volt Ni-Cd's actually have a maximum fully-charged output of only 7.2 volts. However, batteries that deliver 9.8 volts when fully charged are available from several sources.

Construction

Keep in mind the fact that the stun gun produces dangerously high voltages, and don't approach the construction of the stun gun with the same nonchalance with which you might build a light dimmer.

The circuit can be built on a PC board or on perfboard. The foil pattern for a PC

continued on page 67



BUILD JACOB'S LADDER

A climbing electric arc has held the imagination of science-fiction fans as the symbol for an eerie laboratory!

JAMES, NICOLE, and DWIGHT PATRICK, Jr.

IN MANY SCI-FI AND HORROR FLICKS, ESPECIALLY THE STOCK "FRANkenstein" variety, along with weird sound effects and the like, movie producers always feature the fantastic visual effects produced by Tesla coils, van de Graaff generators, and Jacob's Ladders. Of those three devices, the Jacob's Ladder is the easiest to build. With a low-current neon-sign transformer, a converted flyback transformer, converted auto spark coil, or other similar transformer, you can whip together your own Jacob's Ladder in less than an hour. Because the ladder is so simple, there's no need for a detailed parts list or a schematic. We tell you how to build one as we reveal the theory of operation.

Getting started

As we can see in Fig. 1, a Jacob's Ladder provides a fantastic visual effect. A beautiful electric arc hisses its way up two diverging wires, providing a fascinating and downright scary effect. The arc starts at the smallest distance between the vee electrodes (Fig. 1-*a*), and "walks" up the widening gap toward the top of the electrodes (Fig. 1-*b*).

Why does the arc walk up the vee electrodes? You would expect that when the arc starts to jump across the narrow gap at the bottom of the electrodes, that it would stay there where the electrical resistance between the electrodes is lowest. What actually happens is that the arc heats the air it passes through, causing it to rise. Because the heated air is ionized by the high-voltage arc, it provides a very low-resistance path, so the current path (the arc) rises with the warm air.

Eventually the arc reaches the top of the ladder (the electrodes) and bows upward creating an electrical path that gets longer and longer. At the point where the resistance at the bottom of the electrodes is less than that of the arc-path, the upper arc stops, and a new arc begins at the bottom of the ladder. Thus, what is seen is a continuous climbing arc that disappears at the top of the ladder and reappears at the bottom. It's all a lot of fun to watch, providing that you don't poke your finger between the electrodes or get your nose too close.

To build a Jacob's Ladder, you need a high-voltage source that

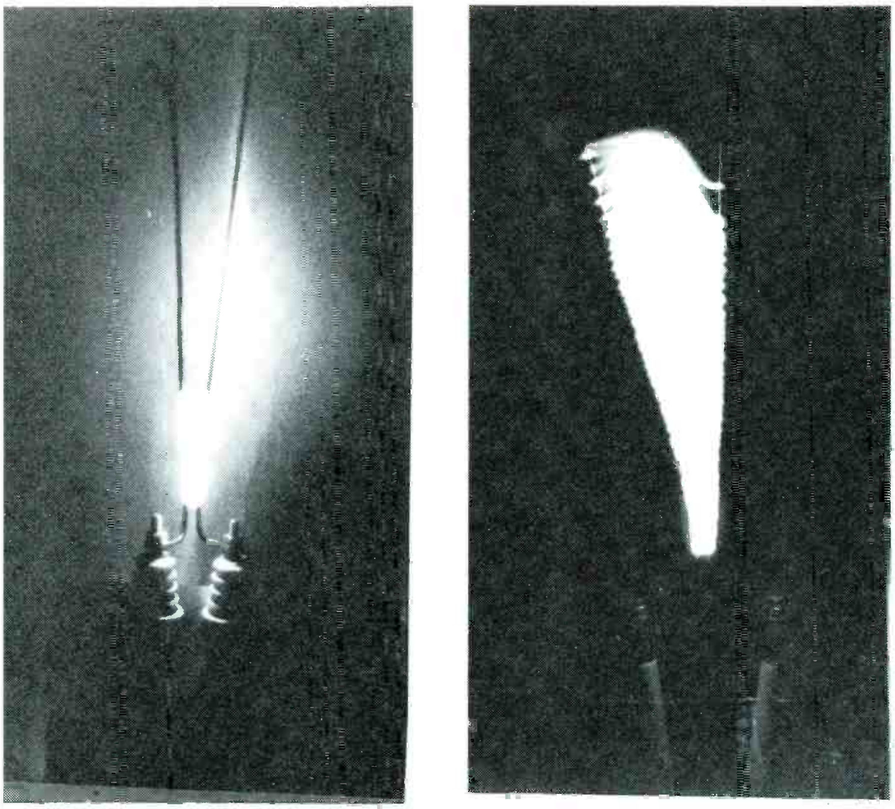


FIG. 1—HERE ARE TWO TIME-EXPOSED PHOTOGRAPHS showing the development of an arc at the bottom of the ladder (*a*) and its climb to the top (*b*). You should display Jacob's Ladder in a darkened room for maximum viewing effect.

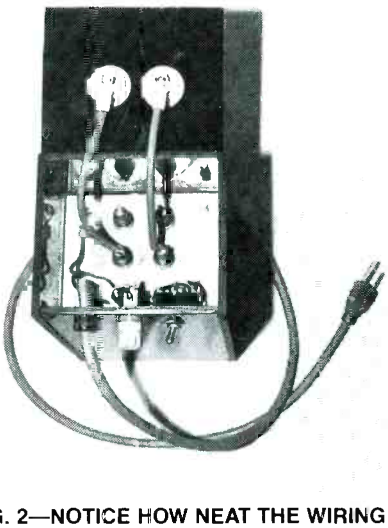


FIG. 2—NOTICE HOW NEAT THE WIRING IS. RTV cement is used around the high-voltage connection points. The line cord's third lead is used to ground the case.

can deliver around 10 kilovolts at 30 milliamperes or more—such as neon-sign transformer or high-voltage power-supply transformer. The lower the current output, the less chance there is for building a fatal shock hazard. The higher the voltage, the larger the separation you'll be able to make at the top of the ladder's electrodes.

The high-voltage source should be placed in a well-insulated case or cabinet. If the case is metal, it should be adequately grounded. In the photograph in the opening of this article, a 7-kilovolt transformer was placed in a ¼-inch Plexiglas case with the primary winding connected via fuse and switch to the 117-volt AC input. The output of the transformer was connected via high-voltage TV anode hook-up wire to two pieces of no. 12 copper wire used for the vee-shaped electrodes that protrude from porcelain insulators. When removing the insulation, be sure not to nick the wire. The connections between the transformer's secondary and the bottom of the insulators must be kept as short as possible and void of sharp bends (see Fig. 2). Exposed high-voltage points were given a coat of RTV silicon rubber to prevent any arcing inside the enclosure.

In Fig. 3, a 10-kilovolt neon-sign transformer in a grounded metal enclosure is used with a small auto transformer (a Variac type) to control the primary winding voltage input. Thus, the output voltage is adjustable. A different type of porcelain insulator is used, with the high voltage brought to the top of a stand-off type insulator.

Adjustment and operation

The last step in getting your Jacob's Ladder to work is the adjustment of the vee electrodes. DO NOT MAKE ANY ADJUSTMENTS WHEN THE UNIT IS TURNED ON. The unit should be turned off and unplugged when making adjustments, to prevent accidental electrical shocks.

The electrodes must be close enough at the bottom to establish the spark or arc-over, with the wires gently angling away from one another to form the "V." The initial distance at the base to start the spark will vary with the voltage applied, humidity, altitude, etc.; so, it's pretty much done by trial and error. Start with the wires at the base about an inch apart when using 10 kilovolts or more, and move them closer in small increments until an arc is established. But remember to kill the power before each adjustment.

When the distance is correct, the arc should start. On the other hand, if the ladder arcs at the initial setting, move the wires apart until an arc is just sustained. Placing the wires too close together will ruin the transformer over time. When you have established the arc, if it does not move up between the two diverging wires, they must be adjusted in or out.

Better safe than sorry

Once your Jacob's Ladder is up and running, a clear Plexiglas or acrylic

FIG. 3—ANOTHER JACOB'S LADDER. The transformer used in this model permitted the use of a low-profile baking-pan chassis.

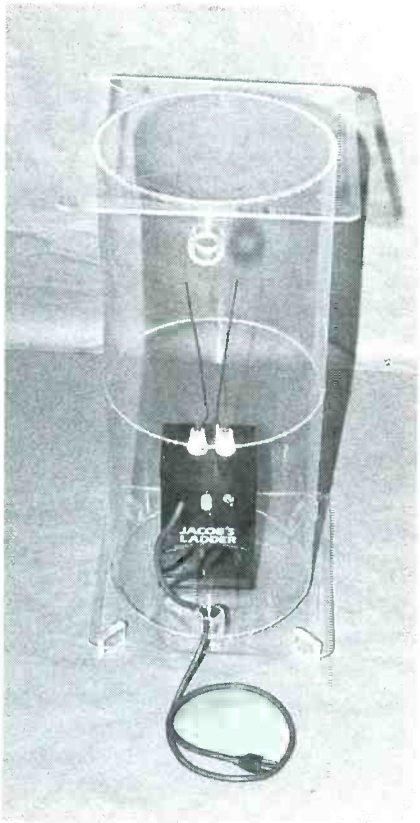


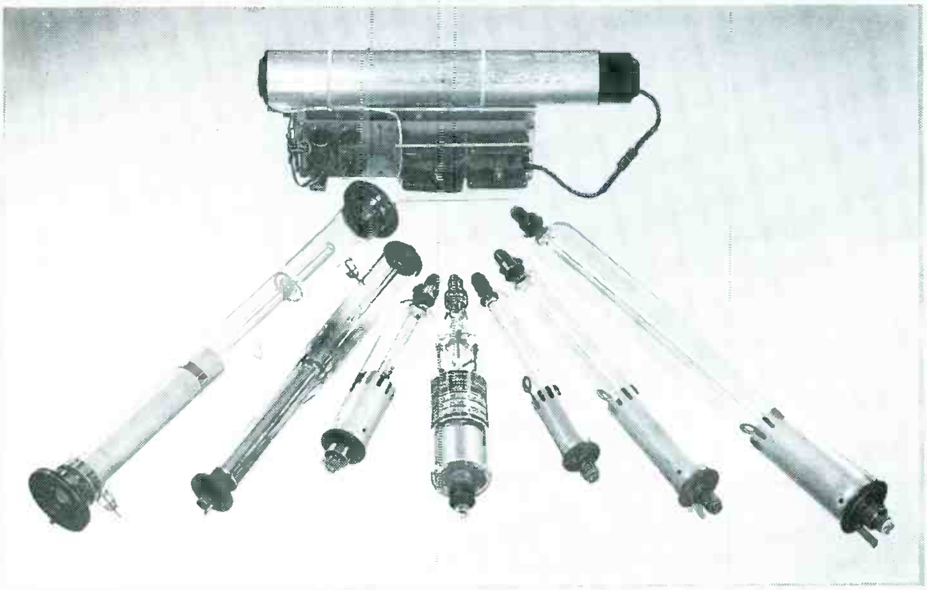
FIG. 4—A PLASTIC SHIELD SHOULD BE USED to prevent inquisitive people from accidentally touching the arc or the electrodes. Be sure to include a vent hole at the top and bottom of the shield so that gasses produced by the arc are allowed to escape.

cylinder around the entire unit will prevent the unthinkable from happening (see Fig. 4). The clear plastic housing should have vent holes at the top and bottom to allow heated gasses to escape, but not so large that the smallest child in the family can get his or her mitts or anything else inside. Generally, such cylinders can be purchased from most plastic-supply houses rather cheaply, and are well worth the added protection.

You do have to keep in mind that such high voltages are extremely dangerous, and you certainly don't want to come in contact with them. Anything that you can do to play it safe is worth your while, and be sure that you don't ever allow a child to get hold of a high-voltage device.

Come next Halloween, place your Jacob's Ladder in your front window, and turn it on every time the doorbell rings. Answer the door with a rubber monster mask on, and the chances are that the wee visitors may scoot down the front walk and never be seen again. Cruel? Not on Halloween! **R-E**

UNIVERSAL POWER SUPPLY



Here's a power supply that can easily be adapted for use with various kinds of hobbyist and experimenter laser tubes.

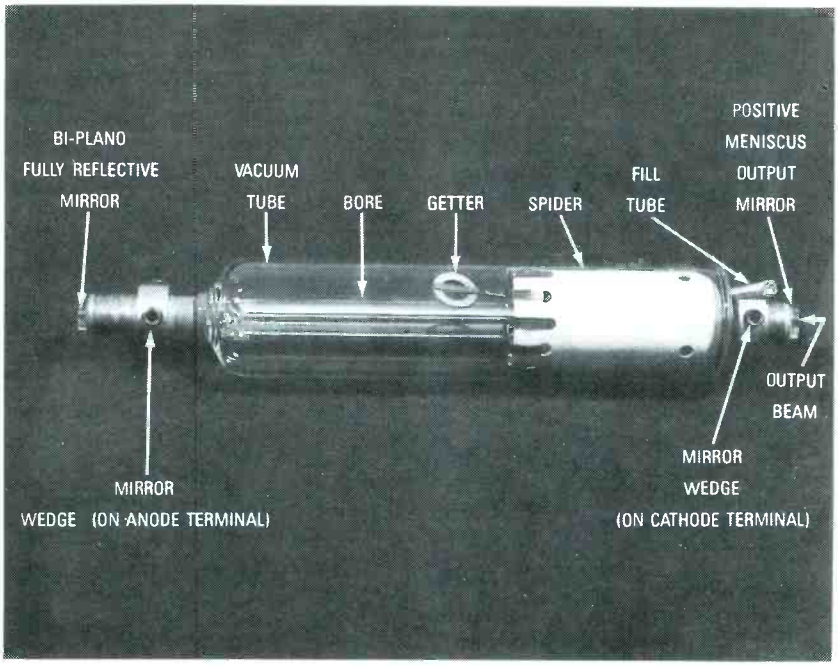
GORDON McCOMB

IT'S EASY TO GET STARTED EXPERIMENTING WITH LASERS. ALL YOU NEED IS A LASER TUBE, A power supply, and a protective enclosure of some kind. Getting a tube is usually no problem, because "surplus" and even used helium-neon (He-Ne) tubes are commonly available. But since the characteristics of He-Ne lasers vary considerably from model to model, a hobbyist's laser power supply should be able to work with all of them, which is exactly the case with our pulse-modulated He-Ne power supply.

Caution!

Before building the power supply, let's take time out for a few words of caution. All gas lasers—including the popular helium-neon variety—require a high-voltage power supply that boosts the main voltage, from 12-volts DC or 117-volts AC, up to 1200–3000 volts. Although the supply's output voltage is relatively high, the circuit-current, or the *laser current* is low.

Because of the low laser current, some laser experimenters tend to disregard the high voltage, possibly because they believe that as long as the current is low, a high voltage can't do more than give a nasty shock. Not so! The byproduct of a nasty shock can result in severe injury, so take extra care to prevent your coming in contact with any "live" power-supply circuits or connections. To that end, all components and wires of a laser



ANATOMY OF A LASER TUBE

The helium-neon tube is the staple of the laser experimenter. He-Ne tubes are in plentiful supply, especially in the surplus market. They emit a bright, deep-red glow that can be seen for miles around. Although the power output of He-Ne tubes is relatively small compared to other laser systems, it is perfectly suited for many homebrew and school experiments in diffraction, reflection, etc.

The helium-neon laser is a glass vessel filled with 10 parts helium and one part neon, pressurized to about 1 mm Hg. (The exact gas pressure and ratios vary between laser manufacturers.) Electrodes placed at the ends of the tube provide a means to ionize the gas, thereby exciting the helium and neon atoms. Mirrors mounted at either end form an optical resonator, or *Fabry-Perot* resonator. In most He-Ne tubes, one mirror is totally reflective and the other is partially reflective. The partially reflective mirror is the output of the tube.

Modern He-Ne lasers are composed of few parts, all fused together during manufacturing. Only the very old He-Ne tubes, or those used for special laboratory experiments, use external mirrors. The all-in-one design costs less and the mirrors are not as prone to mis-alignment.

Helium-neon lasers are actually composed of two tubes: an outer plasma tube that contains the gas and a shorter and smaller inner bore or capillary, where the lasing action takes place. The bore is attached to only one end of the tube. The loose end is the output and faces the partially reflective output mirror. The bore is held concentric by a metal element called the spider. The inner diameter of the bore largely determines the diameter of the laser beam.

The ends, where the mirrors are mounted, typically serve as the anode (positive) and cathode (negative) terminals. On some lasers, the terminals are mounted on the same end. A strip of metal or wire extends to the cathode on the other end. The output mirror can be on either the anode or cathode end, but on most tubes, it is the cathode. Many manufacturers prefer that arrangement, claiming it is safer and more flexible.

Metal rings with hex screws are often placed on the mirror mounts as a means to tweak the alignment of the mirrors. Unless you suspect that the mirrors are out of alignment, you should NOT attempt to adjust the rings. They have been adjusted at the factory for maximum beam output. Tweaking them may degrade the performance of the laser.

He-Ne lasers are available in two general forms: bare and cylindrical head. Bare tubes are just that—the tube is not shielded by any type of housing and should be placed inside a tube or box during operation for protection. Cylindrical-head lasers (or just "laser heads") are housed inside an aluminum sheath. Leads for power come out of the back end of the laser. The opposite end may have a hole for the output beam, or may be equipped with a safety shutter. The shutter prevents accidental exposure to the beam.

power supply must be properly insulated and covered. In particular, you must avoid operating a laser's power supply in the open. Play it safe, and you won't be sorry.

Most laser power supplies use high-voltage capacitors at the output stage. Like all capacitors, they can retain a charge even after the power supply has been turned off. So when working with a laser, make sure the power supply is off and disconnected from its power source, then temporarily short the output leads of the power supply together, or simply touch the supply's positive output connection to ground. Like the capacitors, the laser tube itself can retain an electric charge after power has been removed. That current should be drained by shorting the tube's terminals or leads together, or to ground.

How it works

Regardless of their size or output power, the operating conditions of helium-neon laser tubes vary widely. A new tube starts easily and runs very efficiently; an older or used tube is harder to start and needs more current to lase continuously.

The pulse-modulated laser power supply shown in Fig. 1 was designed to accommodate a wide variety of helium neon tubes—both old and new—up to a maximum laser power output of about five milliwatts. Using pulse-width modulation (that is, varying the duty cycle of the square wave), the power supply individually controls the laser's start and run currents.

Potentiometers R12 and R13 determine the pulse width of the square wave applied to the inverting transformer, T1. In the start mode, R12 varies the pulse width until there is sufficient voltage to start the laser tube—typically 3–4 kV. Potentiometer R13 is switched into the circuit by relay RY1's contacts as current starts to flow through the laser. R13 is adjusted for the minimum current possible while still allowing the tube to lase.

The power supply operates from a 12-volt, 750-mA source; either a battery or an AC-to-DC converter. Timer IC1 operates as a 16- kHz astable multivibrator. Relay RY1 is initially not energized, so R13 and R8 are disconnected from the circuit. The setting of R12 determines the duty cycle, and thus the pulse width of the square wave at pin 3 of IC1. That signal driv-

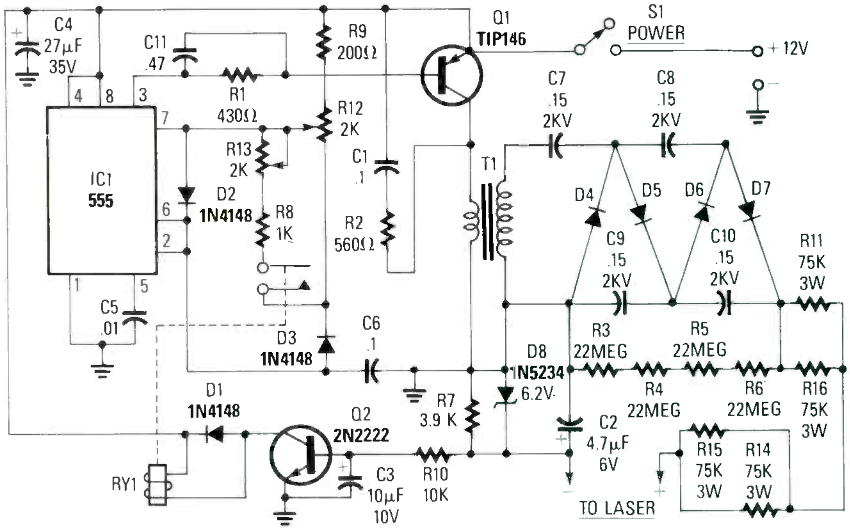


FIG. 1—THE COMPLETE POWER SUPPLY. Resistors R14–R16 are used only for laser tubes rated more than 1 mW.

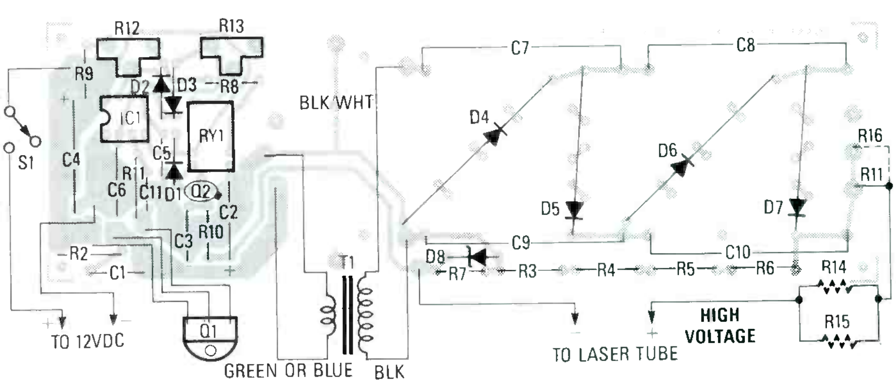


FIG. 2—THE PARTS LAYOUT. Although R16 mounts on the PC board, R15 and R16 are spliced into the laser tube's anode wire.

es the base of power transistor Q1 through current-limiting resistor R1.

Transistor Q1, which operates as a high-current/low-voltage chopper, delivers a series of square waves to the primary winding of step-up transformer T1.

With a 12-volt square wave at T1's primary, the output voltage at the secondary is between 800 and 2000 volts AC, the precise value depending on the setting of R12. Capacitors C7–C10, along with diodes D4–D7, form a standard voltage doubler ladder. The unloaded DC output of the voltage doubler is about 3–5 kV.

As the laser tube begins to conduct, current flows through R7, which causes a voltage to appear at the junction of R7 and R10. That voltage turns on Q2, which activates relay RY1, thereby switching resistors R8 and R13 into IC1's timing circuit, changing the square wave's duty cycle.

Potentiometer R13 must be readjusted to control the laser tube's current. The best position is determined by adjusting R13 clockwise until the relay chatters, then turning it counter clockwise until the relay remains latched in the energized position.

Resistors R3–R6 provide safety when handling the supply (with the power source disconnected) by draining the charge from the voltage doubler's capacitors, as well as the electrostatic charge from the laser tube. Note that the very high resistance of R3 through R6 prohibit them from quickly draining the excess charge, so you should still manually short the power supply's output terminals together before handling the laser or its power supply.

Resistors R11 and R14–R16 depend on the laser tube. For 1-mW tubes, only R11 is used. R16 is eliminated, while R15 and R15 are replaced by a wire.

Construction

The laser power supply is assembled on a printed-circuit board for which a template is provided in PC Service. Alternatively, an etched and drilled PC-board can be ordered from the source given in the Parts List.

Install the parts on the PC board as shown in Fig. 2. First mount R1 through R11. If you intend to use a laser tube rated for more than 1 mW, install R16 in the extra hole that is adjacent to R11. All resistors are installed flush on the board except for R11 and R16, which are mounted on end—and only one lead of each re-

LASERS AND SAFETY

Lasers emit electromagnetic radiation, usually either visible light or infrared. The level of "radiation" is generally quite small in hobby lasers, having about the same effect on external body tissues as sunning yourself with the livingroom lamp.

Skin is fairly resilient, even to exposure up to several tens or hundreds of watts of laser energy. But the eye is much more susceptible to damage, and it is the effects of laser light on the retina that is of the greatest concern. Even as little as 20–50 milliwatts of focused visible or infrared radiation can cause immediate eye damage.

The longer the eye is exposed to radiation, and the more focused the beam, the greater the chance that the laser will cause a lesion on the surface of the retina. Retinal lesions can heal, but many leave blind spots. Retinal damage when using hobby lasers—those having outputs of less than five or ten milliwatts—is rare, but can occur if you stare directly at the beam for extended periods of time. Therefore, NEVER look directly at the beam, or its reflection from a mirror or a metallic surface.

Keep these points in mind when working with laser:

- Any laser power supply delivers high voltages that, under certain circumstances, can injure or kill you. Use extreme caution when building, testing, and using lasers and high-voltage power supplies.
- Do not attempt to build your own power supply unless you have at least some knowledge of electronics and electronics construction.
- Although the power-supply project is not difficult, it should be considered suitable only for intermediate to advanced hobbyists.
- Power supplies and laser tubes retain a charge even after electricity has been removed. Be sure to short out the output of the power supply as well as the terminals of the laser tube before touching the laser or high-voltage leads.

BUYING AND TESTING HE-NE TUBES

Apart from size and output power, tubes vary by their construction, reliability, and beam quality. After buying a He-Ne tube, you should always test it; return the tube if it doesn't work or if its quality is inferior.

Should you need a laser for a specific application that requires precision or a great deal or reliability, you may be better off buying a new and certified tube rather than one from surplus; it will come with a warranty and certification of power output.

He-Ne's emit a deep red beam at 632.8 nanometers because it is the strongest wavelength produced within the tube. Although other colors are produced, they are weak or may not be sufficiently coherent or monochromatic. Yet there are some special helium-neon lasers that are made to operate at different wavelengths, namely 1.523 micrometers (infrared) and 543.5 nanometers (green). Green and infrared He-Ne lasers are exceptionally expensive and rare in the surplus market.

The first step in establishing the quality of the tube is to inspect it visually. If the tube is used, be on the lookout for scratched, broken, or marred mirrors. After inspection, connect the tube to a suitable power supply, point the laser toward a wall, and apply power. If the laser is working properly, the beam will come out of one end only and the beam spot will be solid and well-defined.

Occasionally, the totally reflective mirror allows a small amount of light to pass through and you see a weak beam coming out the back end (that is especially true if the mirror is not precisely aligned). Usually, that poses no serious problem unless the coating on the mirror is excessively weak or damaged, or if the mirrors are seriously out of alignment.

All lasers exhibit satellite beams—small, low-powered spots caused by internal reflections that appear off to the side of the main spot. In most cases, the main beam and satellites are centered within one another, so you see just one spot. But slight variations and adjustment of the mirrors can cause the satellites to wander off axis. That can be unsightly and if it matters to you, choose a tube that has a solid beam.

Should the tube start but no beam comes out, check to be sure that nothing is blocking the exit mirror. If the beam still isn't visible, the mirrors may be out of alignment and the laser should be returned for a replacement.

If the tube doesn't ignite at all, check the power supply and connections. Try a known good tube if you have one. The tube still doesn't light? The problem may be caused by:

- Bad tube. The tube is "gassed out," has a hairline crack, or is just plain busted.
- Power supply too weak. The tube may require more current or voltage than the levels produced by the power supply.
- Insulating coating or broken connection. New and stored tubes may have an insulating coating on the terminals. Be sure to clean the terminals thoroughly. A broken lead can be mended by soldering on a new wire.

Some "problems" with laser tubes are really caused by the power supply. In fact, if your laser doesn't work, expect the power supply first. One common problem is that the tube sputters when you turn it on. That fault is most often caused by a tube that isn't receiving enough current, either because the connections from the power supply are loose or broken, the power supply is not producing enough current for the tube, or the ballast resistor is too high or too low.

Hard-to-start tubes flick on but quickly go out. If the power supply incorporates a trigger transformer, the tube may "click" on and off once every 2–3 seconds (correlating to the time delay between each high-voltage trigger pulse). Tubes that haven't been used in a while can be hard to start, so once you get it going, keep it on for a day or two. In most cases, the tube will start normally. Hard starting may also be caused by age and degassing, two factors you can't fix.

sistor is connected; the other leads remain free for now. Then mount D1 through D8; C1 through C11; finally, IC1 and Q2. Q1 will be mounted on a heat sink, but its connections to the PC board should be made now. Simply solder insulated wires about 2½-inches long to Q1's terminals, and connect the free ends to the printed-circuit board.

One support

As shown in Fig. 3, the PC board is mounted on a metal plate—along with Q1, S1, and T1. The plate is 2⅜-inches wide × 5⅝-inches long. S1 and Q1 are mounted at one end on a ⅞-inch fold. You can't see it in Fig. 3, but there is a ¼-inch fold along the entire length of the bracket that provides overall rigidity. If you decide to attach the laser to the power supply as shown in Fig. 3, use the ¼-inch fold as the support, and secure the laser to the bracket with plastic tie-wraps that pass through two holes drilled along the long folded edge. Note that the laser tube shown in Fig. 3 is enclosed in a metal tube. It was manufactured that way, but it works the same as any other He-Ne laser tube.

Using a suitable insulating washer,

PARTS LIST

All resistors are ¼-watt, 5%, unless noted otherwise.
R1—430 ohms
R2—560 ohms
R3–R6—22 megohms
R7—3900 ohms
R8—1000 ohms
R9—200 ohms
R10—10,000 ohms
R11, R14–R16—75,000 ohms, 3 watts
R12, R13—2000 ohms, miniature potentiometer
All capacitors rated at least 12-volts DC unless noted otherwise
C1—0.1 µF
C2—4.7 µF
C3—10 µF, 10 volts, radial tantalum
C4—27 µF, 35 volts, axial electrolytic
C5—0.01 µF, ceramic disc
C6—0.1 µF, polystyrene
C7–C10—0.15 µF, 2–3 kV, ceramic or Mylar
C11—0.47 µF, polystyrene
Semiconductors
IC1—555 timer
Q1—TIP146 NPN power transistor
Q2—2N2222 NPN transistor
D1–D3—1N4148 diode
D4–D7—High voltage (8–10 kV, 20-mA) diode
D8—1N5234, 6.2-volt Zener diode
Other Components
RY1—6-volt SPST printed-circuit relay
T1—High-voltage step-up/step-down transformer, 12 to approximately 280 volts.
Miscellaneous: wire, tubing, metal bracket, insulator, spacers, cabinet, etc.
Note: The following items are available from General Science and Engineering, PO Box 447, Rochester, NY 14603 (716) 338-7001: Etched and drilled PC board, $9; transformer T1, $15; complete kit of parts, including PCB and T1 (excluding project box), $39. For each order add $3 for shipping and handling. COD's accepted. New York residents must include applicable sales tax.

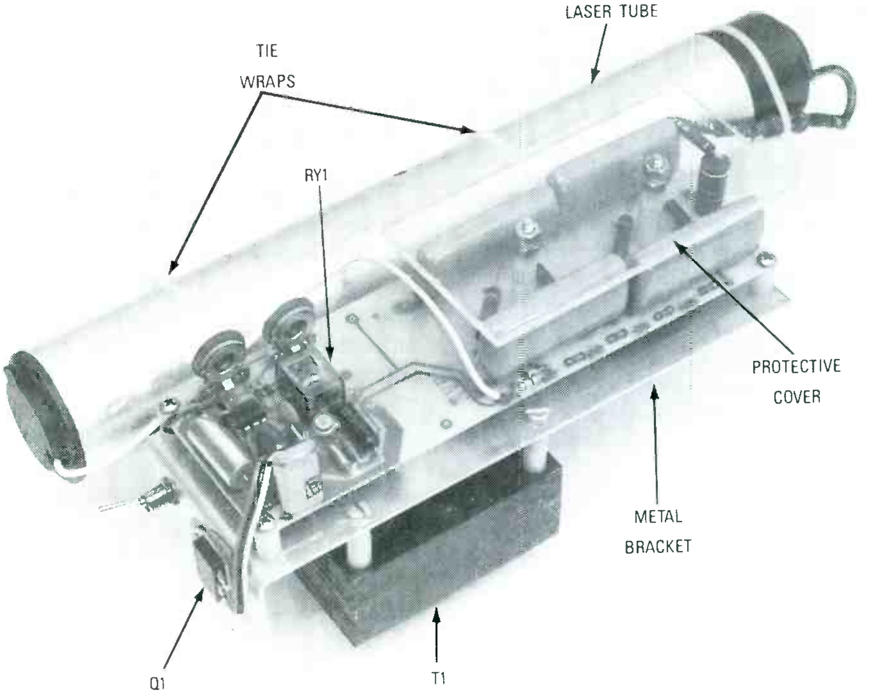


FIG. 3—FULLY ASSEMBLED, the tube is held to the bracket with plastic straps.

an insulator, and heat-transfer paste, mount Q1 on the folded end of the metal bracket. Use an ohmmeter to check for a short between the metal tab of Q1 (which serves as an alternate connection to Q1's collector) and the metal bracket. Remount Q1 if your meter indicates a short.

Transformer T1 is mounted on the bottom of the metal bracket. A ⅜-inch hole drilled in the bracket opposite T1 is used to pass the wires through to the underside of the PC board. The wires from T1's secondary are soldered to the pads labeled A and B on the foil side of the PC board. (The leads will protrude through the board to the component side.) In a similar way, the wires from T1's primary are soldered to the pads labeled C and D.

Connections

Make two 8-inch high-voltage leads from high-dielectric wire. Strip and tin ½-inch of each end and slip a 6-inch length of clear neoprene (aquarium) tubing over both wires. Solder one wire into the NEGATIVE OUTPUT hole near R7. Solder the remaining wire to the top of R11. If you use R14 and R15, cut the wire connected to R11/R16—and its tubing—in half and splice in R14 and R15; then cover the resistors with plastic or heat-shrinkable tubing.

If your laser tube has flying leads (wire leads already installed), then just connect them to the power-supply output leads later on. If your tube has its power terminals on its ends, then an electrical contact can be made by wrapping a length of wire around them.

Before using the power supply, inspect it carefully for solder bridges, loose connections, and improperly installed components.

Using the supply

Operating the power supply is straightforward. Secure the power leads to the tube and, if necessary, wrap high-voltage putty or electrical tape around the leads to hold them in place, but be sure that you don't block the laser's output mirror. Position the power supply so that you are facing R12's and R13's adjustment "dial" and set each potentiometer to its center position.

Apply power and observe the laser tube. Slowly adjust R12 clockwise until the tube triggers: You will hear the relay click in, and possibly a high-pitched whine. Both effects are normal. If the relay chatters and the tube sputters, keep turning R12 until the relay locks in and the tube stays on. If even a full clockwise adjustment fails to get the tube to ignite, adjust R13 slightly counter-clockwise.

THE PROPERTIES OF LASER LIGHT

- Laser light is monochromatic. Laser light coming from the output mirror consists of one wavelength or, in some instances, two or more specific wavelengths. The individual wavelengths can be separated.
- Laser light is spatially coherent. The term spatial coherence means that all the waves are in tandem. That is, the crests and the troughs of the waves that make up the beam are in lock-step.
- Laser light is temporally coherent. Temporal coherency is when the waves from the laser (which can be considered as one large wave, thanks to spatial coherency) are emitted in even, accurately-spaced intervals. Temporal coherence is similar to the precise clicks of the metronome, timing the beat of music.
- Laser light is collimated. Because of monochromaticity and coherence, laser light does not spread (diverge) as much as ordinary light. The design of the laser itself, or simple optics, can collimate the laser light into a parallel beam.

The four main properties of laser light combine to produce a shaft of illumination that is many times more brilliant than the light of equal area from the sun. Because of their coherency, monochromaticity, and low beam divergence, lasers are ideally suited for a number of important applications. For example, the monochromatic and coherent light from a laser is necessary to form the intricate swirling patterns of a hologram. Without the laser, optical holograms would be more difficult to produce.

Coherence plays a leading role in the minimum size of a focused spot. With the right optics, it's possible to focus a laser beam to an area equal to the wavelength of the light. With the typical infrared-emitting laser diode, for instance, the beam can be focused to a tiny spot measuring just 0.8 micrometers wide. Such intricate focusing is the backbone of compact audio discs and laser discs.

Minimum divergence (owing to the coherent nature of laser light) means that the beam can travel a longer distance before spreading out. The average helium-neon laser, without optics, can form a beam spot measuring only a few inches in diameter from a distance several hundred feet away. With additional optics, beam divergence can be reduced, making it possible to transmit sound, pictures, and computer code many miles on a shaft of light. The signal is intercepted by a receiving station in the light path.

LASER OPERATION

Some basics first. Albert Einstein was responsible for first proposing the idea of the laser in about 1916. Einstein knew that light was a series of particles, called photons, traveling in a continuous wave. These photons could be collected, using an apparatus not yet developed, and focused into a narrow beam. To be useful, all the photons would be emitted from the apparatus at specific intervals. Much of the light energy would be concentrated in a specific wavelength, or color, making the light even more intense and powerful.

Photons can be created by a variety of means, including the ionization of gas within a sealed tube, the burning of some organic material, or the heating of a filament in a light bulb. In all cases, the atoms that make up the light source change from their usual stable or ground state to a higher excited state by the introduction of some form of energy, typically electricity. The atom can't stay at the excited state for long, and when it drops back to the ground state, it gives off a photon of light.

The release of photons by natural methods results in spontaneous emission. The photons leave the source in a random and unpredictable manner, and once a photon is emitted, it marks the end of the energy-transfer cycle. The number of excited atoms is low, so the majority of photons leave the source without meeting another excited atom.

Einstein was most interested in what would happen if a photon hit an atom that happened to be at the excited, high-energy state. He reasoned that the atom would release a photon of light that would be an identical twin to the first. If enough atoms could be excited, the chance of photons hitting them would be increased. That would lead to a chain reaction where photons would hit excited atoms and make new photons—the process continuing until the energy source was removed. Einstein had a name for that phenomenon and called it the stimulated emission of radiation.

Raising atoms to a high-energy state is referred to as pumping. In common neon light, for example, the neon atoms are pumped to their high-energy state by means of a high-voltage charge applied to a pair of electrodes. The gas within the tube ionizes, emitting photons. If the electrical charge is high enough, a majority of the neon atoms will be pumped to the high-energy state. A so-called population inversion occurs when there are more high-energy atoms than low-energy ones. A laser cannot work unless that population inversion is present.

Protons scatter all over the place and, on their own, they simply escape the tube and don't strike many excited atoms. But assume that a pair of mirrors are mounted on either end of the tube, and that some photons may bounce back and forth between the two mirrors.

At each bounce, the photons collide with more atoms. If many of those atoms are in their excited state, they too release photons. Remember: The new photons are twins of the original, and share many of their characteristics, including wavelength, frequency, polarity, and phase. The process of photons bouncing from one mirror to the next, each time striking atoms in the path, constitutes light amplification.

In theory, if both mirrors are completely reflective, the photons would bounce back and forth indefinitely. Rub a little of the reflective coating off one mirror, however, and it passes some light. Now, a beam of photons passes through the partially reflective mirror after the light has been sufficiently amplified. In addition, because the mirror is partially reflective, it holds back some of the light energy. That reserve continues the chain reaction inside the tube.

The combination of light amplification and stimulated emission of radiation makes the laser operate. As you probably already know, the the word "LASER" is an acronym for its theory of operation—*L*ight *A*mplification by *S*timulated *E*mission of *R*adiation.

Once the tube lights, adjust R13 clockwise until the tube begins to stutter and the relay chatters. That marks the tube's *threshold*. Turn R13 just a *smidgen* counter-clockwise until the tube turns back on and remains steady. Every tube, even those of the same size and having the same output, has slightly different current requirements. You might have to readjust R12 and R13 for every tube you own.

Resistors R11 and R14–R16 form the ballast for the laser tube. With the components shown in Fig. 1, the total resistance is about 75,000 ohms. You can safely use ballast values from 60K to 120K; use R13 to adjust for tube-current variations. If the laser doesn't trigger or run after adjusting R12 and R13, try reducing the value of the ballast resistance, but avoid going below 60K. If the tube begins to flicker after warming up, readjust R13.

Most 1-mW tubes draw between 750-mA to 1-amp from the 12-volt DC source. You will find that you need higher current when operating a laser with greater power output. For example, a typical 5-mW laser draws 2.5–3 amperes from the 12-volt DC power source. However, take note that the power source *must* be able to deliver an initial surge of 3–5 amps. If your 12-volt power supply cannot handle that requirement, try powering the laser supply with a 12-volt alkaline lantern battery. Also, two 6-volt lead-acid, or gel-cell batteries in series make a good 12-volt source.

The enclosure

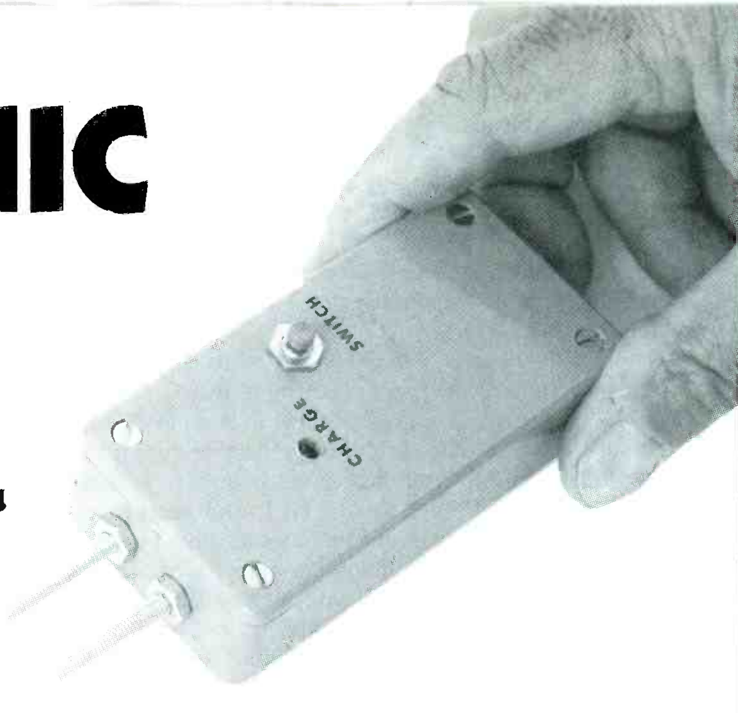
Your laser power supply should never be used without placing it in a protective, insulated enclosure. Electronics stores sell project boxes of all sizes. If you plan on using the supply to power a number of tubes, use heavy-duty (25-amp) banana jacks to provide easy access to the anode and cathode leads. Keep the jacks separated by at least one inch and apply high voltage putty around all of the terminals to prevent arcing. Avoid using power leads longer than 6–9 inches especially for the anode connection. If, for some reason, you intend to test the supply outside of its cover, we suggest you cover the high-voltage section with a piece of plastic, as shown in Fig. 3.

Experiments

With your power supply working, it's time to experiment with laser light. Try doing some simple experiments with optics, mirrors, and lenses. At night, aim the laser at the wall of a distant building to see how far the beam travels before spreading out. Try to measure the width of the beam and calculate its divergence. Then, insert a small telescope or rifle scope backward in the path of the beam (the beam goes in the objective and exits the eyepiece). With some adjustment the beam's divergence should be drastically reduced.

There are many other projects you can try, including holography, metrology (the study of measurement), or a light show. R-E

ELECTRONIC DAZER



Never walk in fear with this one-evening project. It won't kill, but it's an effective way to say "Leave me alone!"

By Rick Duker

THE *ELECTRONIC DAZER* IS A MODERN, PORTABLE, PERSONAL-protection appliance. It generates high potential energy to ward off vicious animals or other attackers. It is an aid to help escape from a potentially dangerous situation. The device develops about 2,000 volts. Higher voltages may be attained by adding additional multiplier stages, but it should be noted that those stages will also increase the overall size of the unit.

The Dazer is very compact, being built into a small plastic case. It is powered a single nine-volt battery, either NiCad or alkaline. The high voltage is applied to two electrodes which require only light contact to be effective. When touched with the Dazer, the victim will receive a stunning, but non-lethal jolt of electricity that will usually discourage any further encounters.

The Electronic Dazer is a power supply which consists of a micro-size regenerative amplifier/oscillator coupled to an energy multiplier section. It should not be confused with cheap induction-type cattle prods. The Dazer is more versatile than other high-voltage stun devices currently being sold. Those devices are basically high-voltage, AC generators which jam the nervous system. However, the Dazer may be used for heating and burning applications, or anywhere a high voltage DC supply is required.

How It Works

Referring to the schematic diagram in Fig. 1, the two power transistors Q1 and Q2, form a regenerative amplifier operating as a power oscillator. When Q1 turns on, Q2 turns on and that shorts the power supply across the primary of T1. That current pulse induces a high voltage in the secondary of T1. As C1 charges, Q1 turns on again and the cycle repeats itself. Therefore, a rapid series of DC pulses are generated and stepped up by T1 to approximately 300 volts at full battery charge. That voltage is rectified and increased by the voltage multiplier section which consists of C2 and C9, and D1 to D8. The final output is approximately 2000 volts. The neon bulb NE1 is used as a charge indicator and indicates that the unit is charged and operating properly.

WARNING

THIS DEVICE IS NOT A TOY. We present it for educational and experimental purposes only. The circuit develops about 2000 volts at a respectable amperage. It can cause you pain and even damage if you become careless and touch its output terminals. The unit can also damage property as well so use it wisely.

You should never use the device on another person! It may not be against the law to possess such a device in your area, but if you use it on someone you may be deemed liable in a civil and/or criminal action suit. Don't just follow the golden rule after constructing the project, instead just don't do unto anyone.

Included in the article are a number of instructions on how to build, test, and operate the Dazer; all of them must be followed to the letter. Do not deviate from the procedure.

Construction

As with all projects start out by laying out and identifying. If you do not wish to make a printed-circuit board, then you

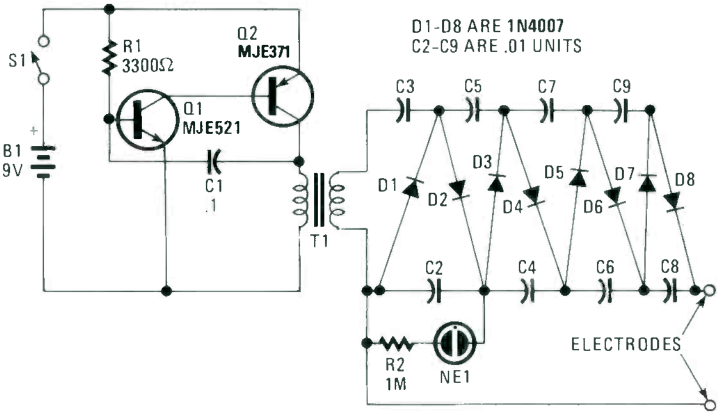


Fig. 1—As you can see, although the Dazer is not complex, it contains enough doubler circuitry to pack quit a punch. The oscillator does nothing more than send sharp current pulses through T1. The back EMF across the secondary winding is then pumped through the multiplier stage to produce the very-high output voltage across the electrodes.

may use a perf board as long as you remember to keep the leads of all high-voltage components isolated. That is to prevent sparks from arcing across your board. A 4 x 7.5 cm of perfboard is suitable for that purpose.

The first components you should mount are the two transistors Q1, Q2, transformer T1, resistor R1, and neon bulb NE1. Solder them in place (for PC construction) being sure that the transformer and transistors are hooked up correctly. Apply a small amount of adhesive to the base of NE1 to hold it securely in place.

Mount D1 to D8 and C2 to C9 on the board and make all solder connections. Note proper polarity of the diodes. The off-board components come next. Solder in leads for S1, and the output electrodes. Also solder in the battery clip for B1.

Build the enclosure from some nonconductive material such as plastic. Drill holes for S1, NE1, and output electrodes. Be sure that the output electrodes are about a cm or greater apart. Connect the output wires to the electrodes and insert them through holes from inside of case. Thread on the retaining nuts and tighten them securely. Set the circuit board in the case and mount S1, securing with nut. That completes the construction.

PARTS LIST FOR THE ELECTRONIC DAZER

C1—0.1-µF monocapacitor
C2–C9—0.01-µF 400 volt polyester capacitors
D1–D8—1N4007 1-kVolt diode
NE1—Type NE-2 neon bulb
Q1—MJE521 NPN power transistor
Q2—MJE371 PNP power transistor
R1—3,300-ohm 1/4-watt resistor
R2—1,000,000-ohm 1/4-watt resistor
S1—SPST monetary-contact, pushbutton switch T1—1200 to 8-ohm audio power transformer

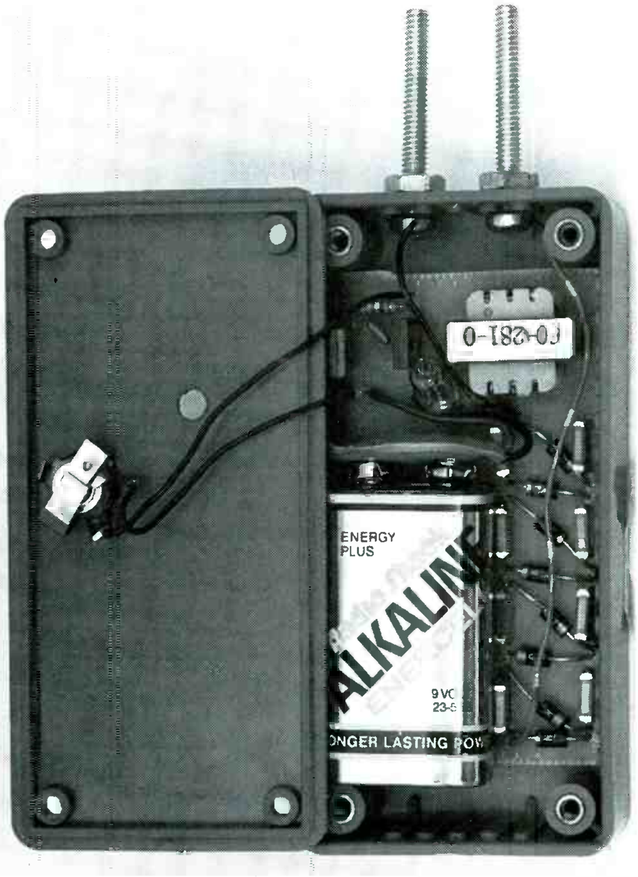
ADDITIONAL PARTS AND MATERIALS
9-volt battery clip, 10 × 5 × 2.5-cm plastic case, 7.5 × 4-cm perfboard or PC board, two 8/32 × 1-1/4 bolts and nuts for electrodes, adhesive for mounting NE1, circuit board standoffs (optional), hookup wire, solder, etc.

The following are available from Quantum Research, 17919-77th Avenue, Edmonton, Alberta, Canada T5T 2S1:
QV100K1—Complete kit without PCB (includes all above parts except those following the electrodes in the above list) $40.00 (includes postage).
QV100K2—Complete kit with PCB (includes all above parts except those following the electrodes in the above list) $45.00 (includes postage)

Testing

Before inserting the battery and closing the case, a few test measurements should be made to ensure correct operation. With the ground clip connected to the battery, connect a VOM between the positive clip and the positive terminal of the battery. Set the meter for current reading, and press S1. You should measure a current of approximately 300 to 500 mA. NE1 should be glowing.

With a high voltage VOM, you should measure about 2000 volts on the output terminals. Those measurements indicate proper circuit operation. Let the unit run for about one minute. Transistors Q1 and Q2 should be warm, but not hot to the touch. Insert the battery in the holder and close the case. That wraps up the Electronic Dazer.



Good parts layout is the secret to any miniature project. If your layout causes the battery to come too close to the high-voltage components we suggest you insulate it with tape.

Operation and Use

Activate the unit by pressing S1. NE1 will light indicating the dazer is fully charged and ready to use. Notice also that only one pole of NE1 will glow indicating DC voltage present. It is important to remember that the device holds a charge even after S1 is off. To discharge, touch the electrodes to a metal object and note the healthy spark discharge.

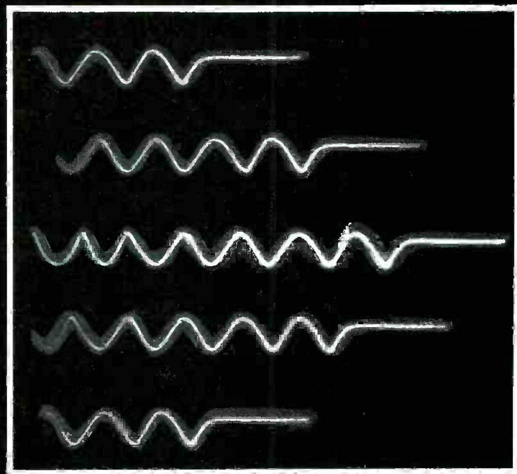
The Electronic Dazer was designed as a self-defense weapon for use against vicious dogs or other attacking animals. The device is most effective when the electrodes contact an area of low resistance such as skin or flesh. Those include the snout or mouth since the resistance of those areas are much lower than areas of hair or fur. The electrodes could be pointed to penetrate these areas better. The dazer generates great stopping power. One contact will give a powerful jolt and should discourage any further attacks.

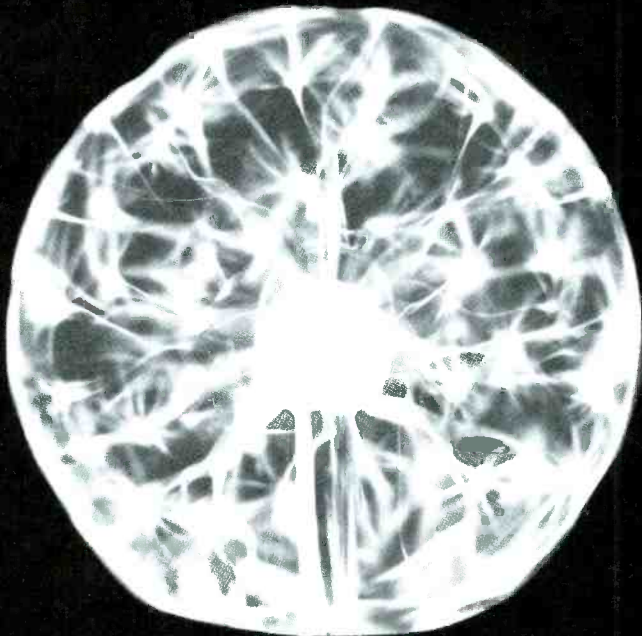
The device can burn and heat materials with low resistance. Those include flesh, moistened paper or wood, etc. That makes the unit potentially hazardous to humans. Remember, the dazer is not a toy but a quality electrical appliance and therefore must be treated accordingly. Use the utmost discretion with this device.

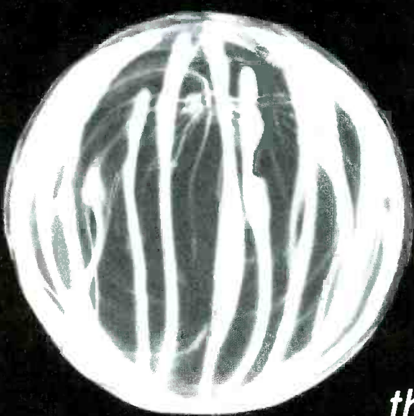
Another use for this device is as a high-voltage DC power supply. It may be constructed as a variable power supply if output taps are taken from various stages of the voltage multiplier section. Remember, always disconnect the battery and fully discharge the capacitors before working with the circuitry. ■

ELECTRONIC TORNADO

PLASMA DISPLAY POWER SUPPLY







A universal power source for an Eye-of-the-Storm-like display, and other unusual plasma and neon lighting devices.

ROBERT IANNINI

You no longer need to go to a local discotheque to see the latest in unusual lighting effects. Whether it's an Eye-of-the-Storm-like display, a Devil's Furnace, or travelling-wave neon lamps, you can now buy them for your own home at the larger department stores and high-tech boutiques. Only problem is, they usually cost big bucks—in the neighborhood of $200; but you can certainly can build them for much less if you have the special kind of power supply that's needed. And that's where our universal plasma power supply comes in: it can drive all three kinds of displays—you simply connect the desired display device to the universal plasma power source.

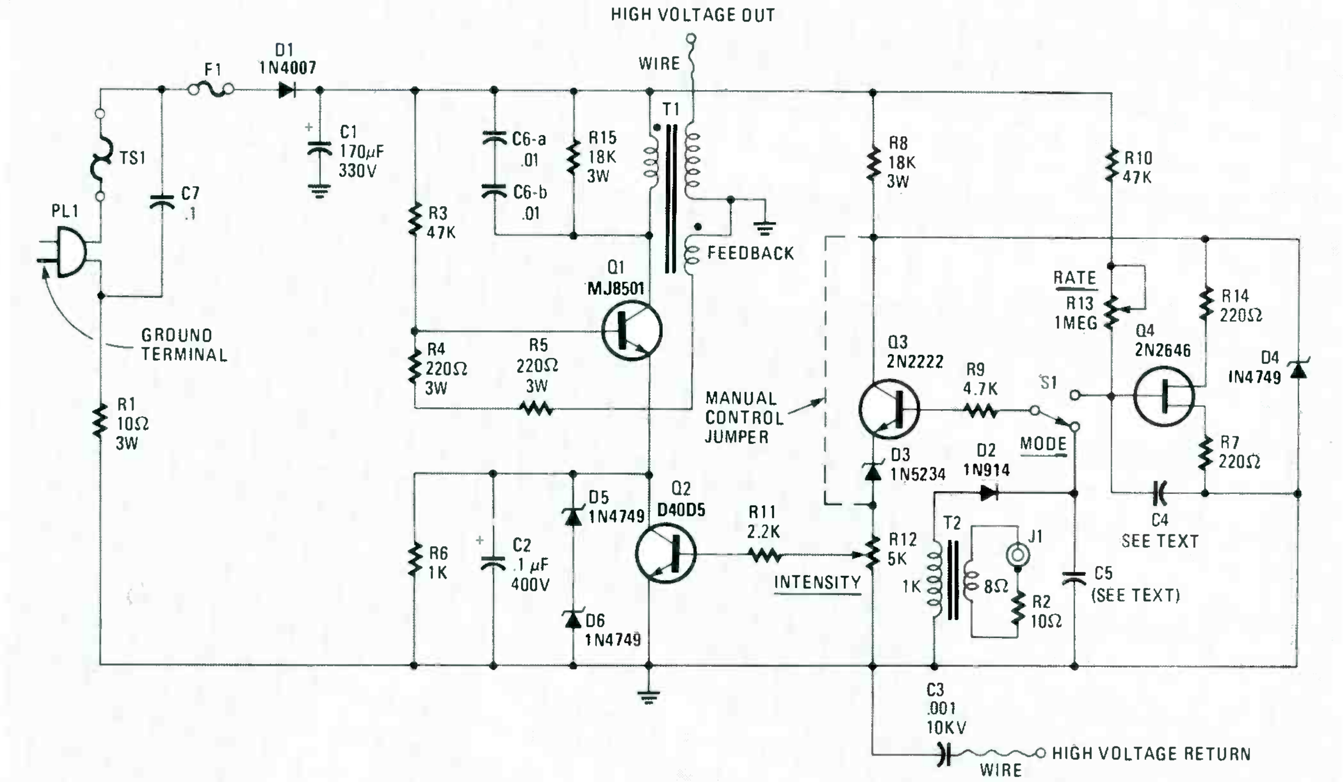


FIG. 1—THE POWER SOURCE USES A COMMON GROUND so make certain PL1 is a polarized linecord plug. The dashed line indicates a shorting jumper that's only installed if the device is to be used only for powering a plasma bulb.

Fire in your hand

For those of you unfamiliar with discotheque lighting, we'll take time out to explain. An Eye-of-the-Storm-type plasma device is a glass bulb that surrounds a small golf-ball-size core. When powered, red and blue streamers resembling flashes of lightning emanate from the ball to the globe. If you move your fingers over the globe the streamers follow your fingers and appear to burst and mushroom at your fingertips.

A Devil's Furnace is also a globe but there is no central ball. Streamers of flame-tipped lightning flow upward from the base and follow the curvature of the globe. As you move your hand or fingers over the globe the Devil's Flame follows them and "explode" against the bulb.

A travelling-wave or tracing neon lamp is a lighting device that illuminates slowly from end to end, then extinguishes, then repeats the cycle. The time it takes for total illumination of the tube and the repetition rate are determined by the characteristics of the power source.

Since the power source for a travelling-wave neon lamp is the most complex, that's the one we'll describe—so that you get the option of using all three devices. The circuit that determines the speed of end-to-end illumination determines the brightness range of the plasma globes, while the repetition-rate circuit for the neon tube can be easily bypassed for full-time plasma-tube display.

The usual power

The usual way to power neon and cold-cathode gas discharge tubes is to use a high-voltage, current-limited transformer operating at 60 Hz that is connected to both ends of the tube; an approach that only allows the full discharge length to be simultaneously energized. Sequential energizing of the display is therefore impossible, and any display motion must be simulated by using individually-segmented discharge tubes, each having a connection to an individual source of power. Timing and power-control circuits determine the distribution of power to the individual segments of the tube.

In our universal power supply, instead of 60 Hz, we substitute high-frequency energy of approximately 20 kHz as the power source, which makes it possible to excite and re-energize the tube's gas via a connection to only one end of the tube. That is made possible by the capacitance between the ionized gas and the surroundings, which produces a low enough reactive impedance so the high-frequency energy can cause plasma ignition.

Since ignition depends on the capacitance of one end of the tube to its surroundings, it allows the ignited plasma display to travel along the tube, creating a defined bright and dark band. The degree or type of travel-effect can be a pre-programmable event that determines where the plasma ignition will start, causes the ignition to travel steadily to the end of the tube, and then repeats the electrical effect; thereby creating the visual effect of *handwriting* or *tracing*.

Varying voltage levels such as those from the output of a radio or audio amplifier can also be used to vary the tracing effect or the plasma-lighting discharge-effect in step with the sound amplitude. That creates bizarre and dazzling special effects.

How it works

Refer to Fig. 1. The 117 volts from the AC powerline passes through

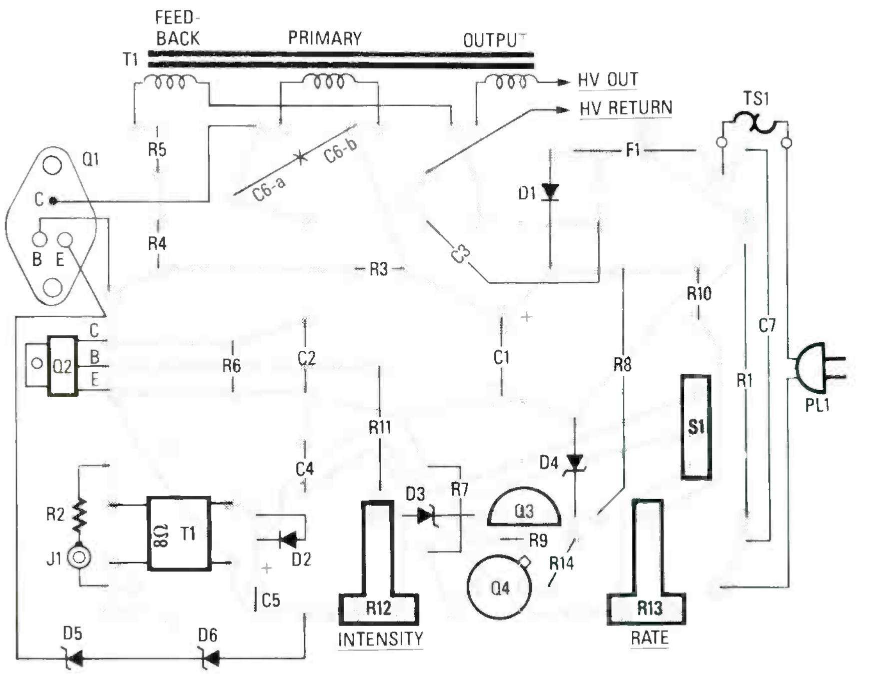


FIG. 2—THE CURVED LINES IN THIS PARTS LAYOUT indicate components that span across other components. That is possible because most of the small-size parts are end-mounted. Capacitor C7 can be placed on top or under the PC board.

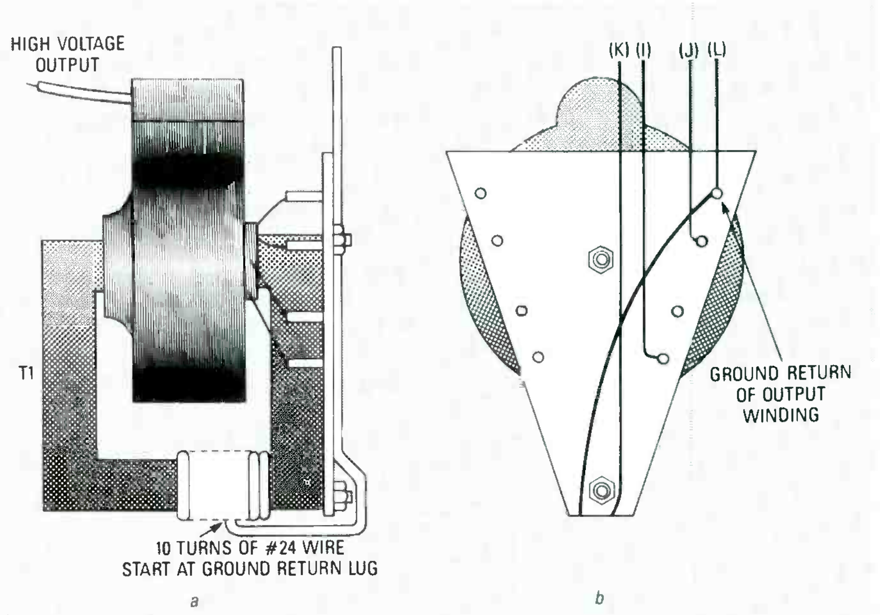


FIG. 3—THE FEEDBACK WINDING, as shown in *a*, is wound directly over T1's core. Its leads, as shown in *b*, are routed under T1's mounting plate. The letters in *b* that identify the wires are the same as those used by the manufacturer; they match the connections shown in Fig. 5.

through thermal safety switch TS1 (which is mounted on the device's heat sink), is rectified by diode D1, and filtered by capacitor C1. Resistor R1 limits the surge current of D1 and C1. Fuse F1 is a *slo-blo* type that allows C1 to charge, yet opens (at 1 amp) if a catastrophic fault exists in the circuit. Thermal switch TS1 turns the device off when the temperature of Q1 exceeds 200°F. (It is necessary when operating the unit in a high-powered mode, or may be required to comply with local electrical codes.) The rectified voltage across C1 is approximately 160-volts DC.

Transistor Q1 is connected as a Hartley-type oscillator. It is biased into conduction when base current is first applied through R3. Feedback to Q1's base is obtained by a tertiary feedback winding on T1 that is in-

PARTS LIST

Resistors
R1—10 ohms, 3 watts
R2—10 ohms, ¼ watt
R3, R10—47,000 ohms, 1 watt
R4, R5—200 ohm, 3 watt, wirewound
R6—1000 ohms, 1 watt
R7, R14—¼ watt
R8, R15—18,000 ohms, 3 watt, wirewound
R9—4700 ohms, ¼ watt
R11—2200 ohms, ¼ watt
R12—5000-ohm trimmer potentiometer
R13—1-Megohm trimmer potentiometer

Capacitors
C1—170 µF, 330 volts, electrolytic
C2, C7—0.1 µF, 400 volts, paper
C3—.001 µF, 10 kV, ceramic,
C4—220-1000 µF, 25 volts, electrolytic (see text)
C5—1 µF, 50 volts, electrolytic
C6-a, C6-b—0.01 µF, 1 kV, polypropylene (see text)

Semiconductors
Q1—MJ8501, NPN high voltage transistor
Q2—D40D5, NPN power transistor
Q3—2N2222, NPN transistor
Q4—2N2646, UJT transistor
D1—IN4007 rectifier diode
D2—IN914 small-signal diode
D3—1N5234, Zener diode
D4-D6—1N4749, Zener diode

Other components
F1—1-amp, *slo-blo* fuse
J1—Phono jack
PL1—Polarized power plug
S1—SPDT PC-mounting slide switch
TS1—Thermal switch
T1—Ferrite transformer (see text)
T2—Miniature audio transformer, 8-ohm primary, 1000-ohm secondary 10 KV; secondary inductance, 1H; primary inductance, 2.5 mH; feedback winding, 10 turns, 20 µH

Note: The following parts are available from: Information Unlimited, PO Box 716, Amherst, NH 03031: An etched and drilled PC board ($5.50): Transformer T1 ($29.50): 0.01 µF, 1 kV, polypropylene capacitor ($2 each): A complete kit containing T1 and all other components as well as the enclosure ($59.50). Add 5% of the total order for for postage and handling.

Plasma globes and custom neon tubes are available from Strattman Design, 791 Trement St. No. E517, Boston, MA 02118. Tel. 617-266-8821. Write or phone for specific information and prices.

phase with T1's primary winding. The positive feedback is what causes Q1 to oscillate. Base current is limited by resistors R4 and R5.

The resonant frequency of T1 is such that the circuit oscillates at a frequency of approximately 20–25 kHz. A resonating capacitor, C6, tunes the primary of T1 to a smooth, soft waveform, while R15 provides the load impedance that is sometimes necessary when the supply powers very small display tubes and globes.

Since the power supply uses a ground circuit that is common to the AC powerline, capacitor C3 is provided to prevent a hazardous condition should polarized line-cord plug PL1 be defeated.

The gain of Q1 determines the output voltage. The gain is controlled by the conductance of transistor Q2, which is determined by the bias applied to Q2's base through the INTENSITY control, R12. Diode D3 prevents any offset voltage that may occur at the beginning of the turn-on cycle from turning on Q2. Capacitor C2 bypasses any high-frequency signal that might be developed across Q2, while Zener diodes D5 and D6 limit Q2's instantaneous collector-emitter voltage to 48 volts.

The control signal applied to Q2's base—which determines the instantaneous system-output voltage—is determined by the ramp voltage produced by unijunction-transistor oscillator Q4. The period of the ramp is determined by capacitor C4 and the setting of the RATE control, R13. The value of C4 should be in the range of 220–1000 μF. A mid-value of 500 μF is suggested as an initial value. Although 500 μF probably will work out best for most applications, you can experiment to determine the exact value for the kind of display that you prefer.

The ramp voltage is applied through the MODE switch, S1, to emitter-follower Q3, which serves as a buffer-amplifier whose relatively high input impedance isolates C4 from variable resistor R12. The voltage produced by Q3 across R12 corresponds to the ramp voltage, thereby providing a relatively linear change in Q1's power output.

Proper biasing of Q2 by R12 is the point of conduction just as the ramp voltage starts to increase. That provides a minimum or zero tube or globe display that steadily increases as the ramp waveform builds. If R12 is adjusted for a "hold off" bias so Q2's conduction does not start until the ramp is well underway, the overall period of the output voltage, and therefore the display, is reduced.

Audio control

An audio signal can be substituted for the ramp control voltage by setting S1 so that Q3's base connects through R9 to D2 rather than to C4. An audio signal, say from a transistor radio, that is applied to J1 will then provide the control signal for Q2, and the system's output voltage will more or less correspond to the amplitude of the audio signal.

Normally, resistor R2 isn't necessary unless the audio signal is so strong that it swamps the unit and produces an output that appears to be *on* most of the time. You only have to install R2 if R12 has little effect on the output when audio is used as the control signal.

As a general rule, the 1-μF capacitor specified for C5 in the Parts List will be satisfactory, but you can experiment with different values to get the plasma or neon display you prefer.

If you have no need for either automatic ramp control by Q4, or audio control via J1, then you can install the shorting jumper indicated in Fig. 1 by the dashed line connecting R8 to R12. With the jumper installed, the brightness of a plasma-bulb display, or the brightness and maximum length of a neon display is determined only by R12.

The display

The plasma arc—the visual display—is created by the electric current flowing through the gas in the tube. In a plasma bulb, the gas can be argon, neon, krypton, or any combination thereof. The colors generated are determined by the specific kind and ratio of gasses. In a neon tube the gas is, of course, neon. When electric current is applied to the gas, the atoms become energized to a level where both electrons and positive-charged atoms are produced. They emit light spontaneously upon returning to their initial energy state. As the electric current is reduced, the display shortens because there is insufficient energy to cause further ionization. Increasing the ionization energy causes the end of the display in a neon tube to lengthen because there are a greater number of free charges. In simple quantitative terms, the number of charges produced in the tube is directly related to the input energy. A smaller-volume tube would theoretically produce a longer discharge for a given ionization energy and vice versa. (That explanation neglects the change in the dynamic impedance of the system due to a change in the volume of gas.)

Construction

Although we provide details for construction of the universal plasma power source prototype shown, keep in mind that a complete kit that includes the cabinet and all prefabricated metal parts is available from the

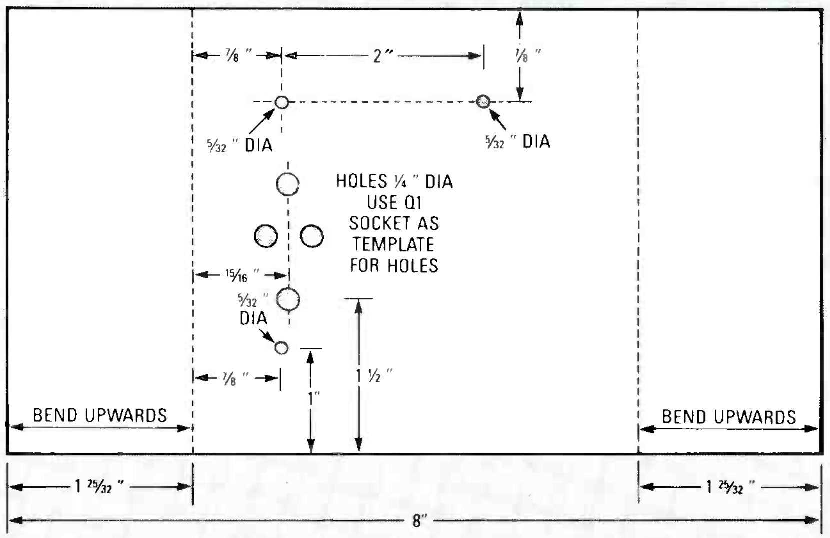


FIG. 4—THIS IS THE TEMPLATE for the metal frame. The holes for Q1 should correspond to the particular socket you use.

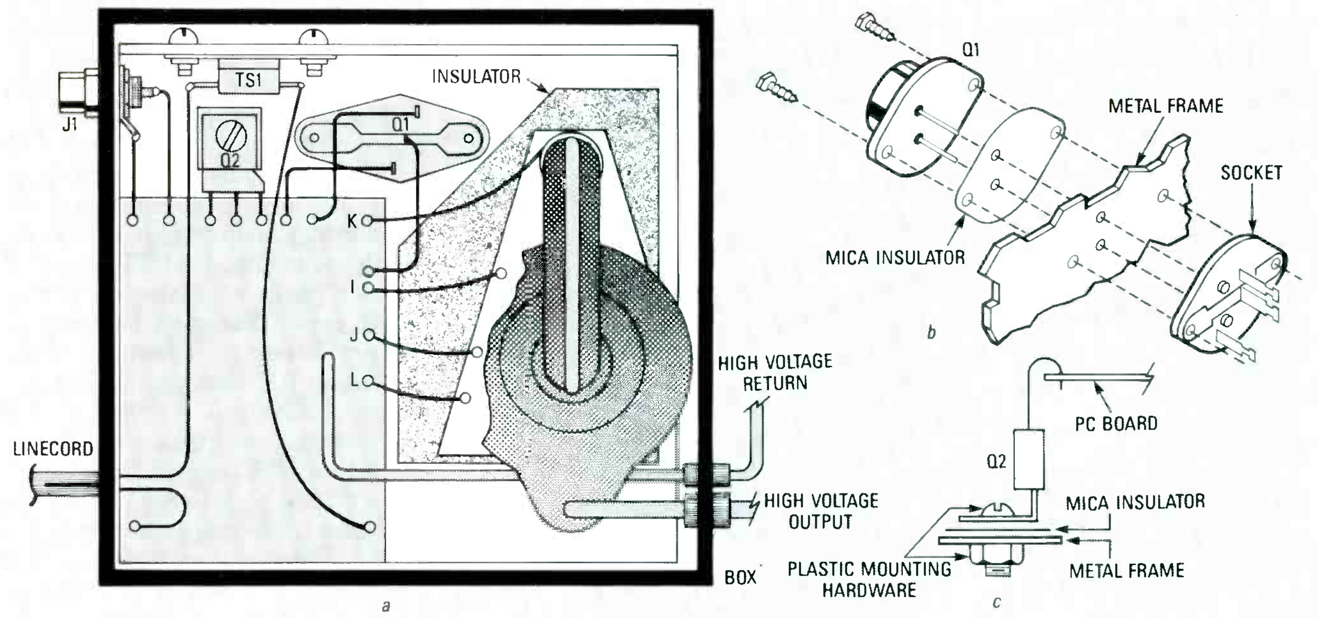


FIG. 5—THE ASSEMBLY ON THE METAL FRAME should correspond very closely to the view shown in *a*. Note in particular how the letter-identified wires from T1 connect to the PC board. If TS1's mounting screws interfere with the frame's installation in its cabinet, eliminate the screws and secure TS1 to the frame with epoxy cement.

source given in the Parts List, which is located on page 45.

The first step is to make the PC board using the template shown in PC Service. Then, using Fig. 2 as a guide, install all board-mounted components. But note that the components are mounted somewhat differently than usual: except for D1, D3, D4, and R1, all components are mounted on end; that is, they stand vertically on the PC board. Although Fig. 2 shows diodes D5 and D6 external to the board, they actually span across the board. They are positioned about ¾-inch above the board and are located between T1 and C4.

Note that although the leads from Q2 are soldered to the PC board, during final assembly Q2 will be folded downwards so it can be heat-sinked to a metal frame. Be sure to leave sufficient lead length—about ½-inch—so the fold can be made without stressing the leads or the board.

In reality, C6-a and C6-b do not exist. There should be only one capacitor, C6, a 0.005-µF, 1-kV tubular capacitor connected across T1's primary winding. Unfortunately, that value isn't among the easiest to locate, so you can substitute the more easily obtained series-connected 0.01-µF, 1-kV capacitors, shown in Figs. 1 and 2 as C6-a and C6-b. They are both end mounted, and are connected together at the top after they are installed on the board. Finish up by using an RTV type adhesive such as G.E.'s Silicon II to cement a sheet of insulating material to the underside of the PC board.

When the PC board is completed, you can set it aside and move on to transformer T1.

A feedback coil

Although the T1 specified in the Parts List is supplied completely assembled, it requires the addition of feedback coil, which, as shown in Fig. 3-*a*, is nothing more than 10 turns of No. 24 solid, insulated wire wound around T1's core. Bear in mind that if you substitute a different transformer for the model specified the required feedback winding might have more or less turns. Also, a substitute transformer should have a primary inductance between 2 and 3 mH. If your T1 has pin connections that interfere with its installation, simply cut them short.

Figure 3-*b* shows letter-coding for the connections of the particular model T1 specified in the Parts List. The letters only serve as a reference when assembling the project; more on that later. (The letters are the same as those used for identification by the kit supplier given in the Parts List.)

Take note that since T1's terminals extend through its own support bracket, they must be insulated from the metal frame that is used as a chassis. The insulation can be a strip of epoxy PC material from which the copper foil has been etched. (The insulator is supplied in the complete kit of parts.)

The frame

The metal frame chassis, which is called a *mounting plate* in the instructions packaged with the complete kit, also serves as the heat sink for Q1 and Q2, which is why thermal-switch TS1 is installed on the frame. If the frame gets excessively hot, TS1 opens and turns the power supply off. Since TS1 is self-resetting, it automatically restores power when the heat sink cools.

Figure 4 shows the measurements for a metal frame made from 1/16-inch aluminum. The indicated holes are for the mounting screws used for Q1, Q2, and T1. The precise layout of the diamond-pattern holes for Q1 will be determined by the particular kind of socket you use; but regardless of the kind or design of the socket, make Q1's holes ¼-inch, and deburr them with a knife or deburring tool before installing the socket.

Make certain you drill all holes before bending the side flanges upwards on the fold marks.

Figure 5 shows how the project is

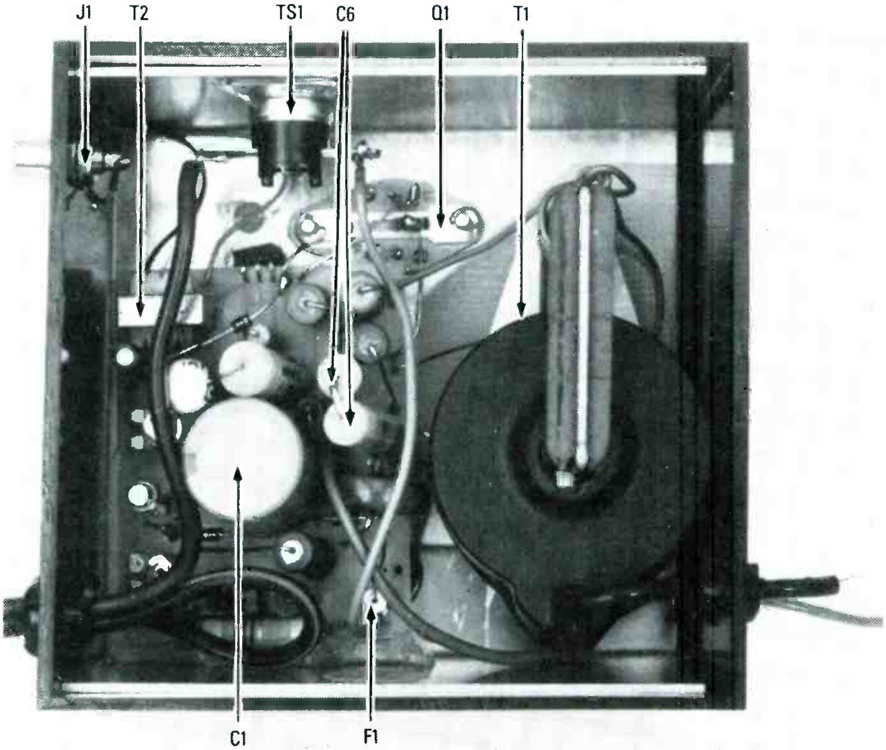


FIG. 6—THE ACTUAL PROTOTYPE. Notice that it is virtually a duplicate of the layout shown in Fig. 5.

assembled. Figure 5-*a* shows that TS1 is secured to the metal frame with screws and nuts. If you have somehow made the frame a smidgen oversize so the mounting screws prevent the chassis from being installed in its cabinet, you can eliminate the screws and use epoxy glue to cement TS1 to the chassis. Its location is not precise, but it should be reasonably close to the top of the enclosure (away from Q2).

Figure 5-*b* shows how Q1 is installed on the metal frame using an insulating socket. However, note from Fig. 5-*c* that Q2 does not use a socket; it is insulated from the frame only by a mica insulator, so a Nylon screw and nut must be used as the mounting hardware.

Finally, use RTV adhesive to cement the PC board to the metal frame. The board must be spaced off the frame because one end is lifted by Q2's mounting; use a stack of rubber grommets for the spacers.

The enclosure

Although the project should not be installed in an enclosure until tested, prepare the enclosure so it is ready as soon as the tests are completed. For safety, the (4½-inch wide × 4¾-inch long × 2¾-inch high) enclosure must be made of plastic; 3⁄32-inch thick will be ideal. (An appropriate enclosure is supplied with the kit.)

Fabricate a cover from perforated aluminum that will snap onto the top of the cabinet, but be certain to drill access holes for R12, R13, and S1 before bending the sides of the cover. Also, if you plan on using a plasma globe, assemble a base large enough to support the globe, and place the power supply within the base box.

Do not pre-size a plasma-globe base before you obtain the globe. Since plasma globes range in size from 7 to 22 inches, you must be certain the base has the proper dimensions to fully support the globe.

Checkout

Before applying power, very carefully check the insulation between the metal frame and the connections to Q1, Q2, and T1. Also, check for continuity between PL1's ground lug (the larger one) and the circuit's common (ground) point. Make certain the circuit ground is not connected to PL1's "hot" terminal.

Next, set R13 fully clockwise, R12 fully counterclockwise, and S1 so its handle points toward R10. Then connect T1's output lead to a neon tube, bank, or sign.

Plug the unit into a variable, current-metered AC supply, such as a metered variac. If that kind of equipment is unavailable we suggested connecting a 60-watt light-bulb ballast in series with the power cord. If there is a catastrophic failure in the device, the light bulb will turn on and drop the voltage at PL1 to a safe value.

Slowly turn the variac up to 120 volts and note that its ammeter should indicate only 50–60 mA. Also note that there should be only a faint glow in the neon tube. **CAUTION—if the meter reads excessive current, a fault exists that must be corrected to prevent severe circuit damage.**

Adjust R12 for a maximum sweep reading of 200 mA. At 200 mA a neon tube should energize out to 15 feet.

Adjust R13 counterclockwise and note that the neon sweep speed should increase to the point where it ceases.

Set S1 to its AUDIO input position. Connect a transistor radio's earphone output to J1 and note that the neon or plasma display intensity should respond to the audio sound level.

If everything checks out, install the unit in its enclosure, using strain relief clamps or devices where the line-cord, high- voltage, and high-voltage-return wires pass through the enclosure. Figures 6 and 7 show the completed protype unit.

Special Instructions

Although the unit can power up to 30 feet of neon tubing, best results are obtained by connecting 10–15-foot sections in parallel because maximum sweep travel is usually limited to 15 feet.

The high-voltage-return wire is intended for connection to the end of larger neon displays. It is not necessary for single electrode-ended tubes such as used for visual audio enhancement. Do not ground the high-voltage return if unused; simply tie-wrap the wire and make sure there are no exposed strands.

Do not allow the power-supply unit to run without being connected to a display tube or globe.

Neon displays

- Set R13 fully clockwise, R12 fully counterclockwise, and S1 to INTERNAL (so that Q3 is fed by Q4).
- Lay out the intended neon sign on a clear non-conductive bench. (Not necessary for pre-installed displays).
- Connect the high-voltage return (the ground wire) to the far end of display. Note that the wire is only

continued on page 68

SOLID-STATE TESLA COIL

Build an updated version of Nikola Tesla's most-famous experiment.

By Charles D. Rakes

NIKOLA TESLA IS CONSIDERED BY SOME TO BE THE greatest inventor of our modern electrical age, and many experts consider him to be the true father of radio. However, today he is best remembered for his fascinating wireless power-transmission experiments, using his famous Tesla coil.

The high-frequency air-core, oscillating Tesla coil is just as exciting today as it was back in 1899, when he used it to successfully transmit electrical energy over 25 miles, without wires, to light a large number of incandescent lamps. The Tesla coil is ideal for demonstrating and exploring the unusual phenomena that occur with high-frequency high-voltage energy.

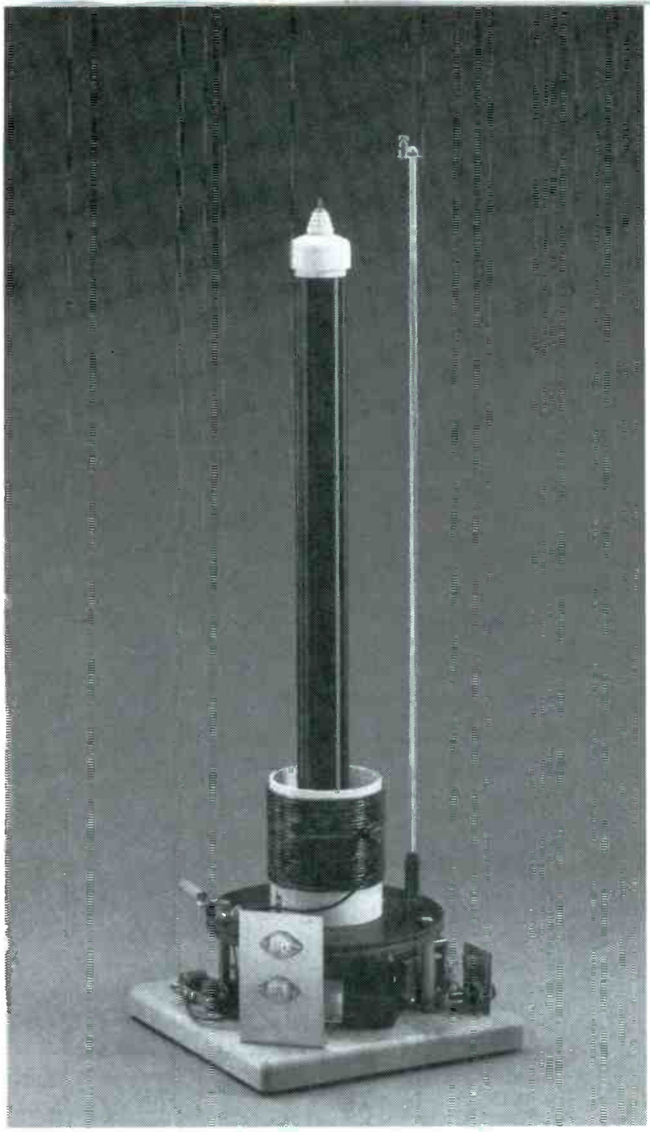
Most Tesla coils designed for educational and experimental purposes use a line-operated, step-up transformer—in setups like that shown in Fig. 1—to generate the high voltage needed for the coil's primary circuit. While there's nothing technically wrong with that approach, it can place the operator in harm's way if the coil's primary circuit is accidentally touched. A shock from the high-voltage winding could prove extremely dangerous and may be fatal.

Our version, the *Solid-State Tesla Coil* (see photos), eliminates the line-operated, high-voltage transformer, making it a safer project to build and to experiment with. Even so, wise operators will keep their digits out of the wiring while the coil is under power.

Solid-State Tesla Coil

The schematic diagram for the Solid-State Tesla Coil is shown in Fig. 2. In that updated version of the Tesla experiment, an 18-volt, 2-ampere transformer (T1), a bridge rectifier circuit (consisting of D1-D4), and filter capacitors (C1 and C3) supply operating power for the coil circuitry.

A 555 oscillator/timer (U1) is configured as a self-oscillating pulse-generator circuit. Resistors R1 and R2 make up a voltage-divider network, which is used to lower the 24-volt DC output of the power supply to a safe operating level for U1. The 555's narrow output pulse at pin 3 supplies drive current to the base of Q1. Transistor Q2 supplies sufficient



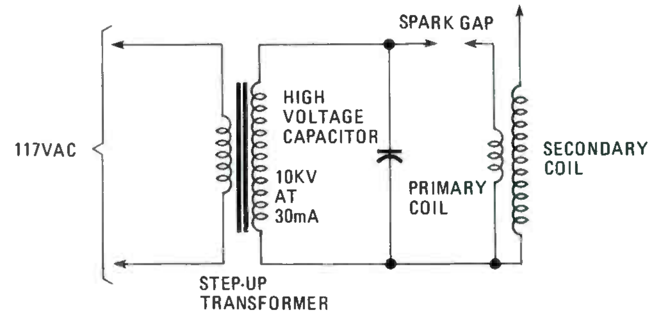
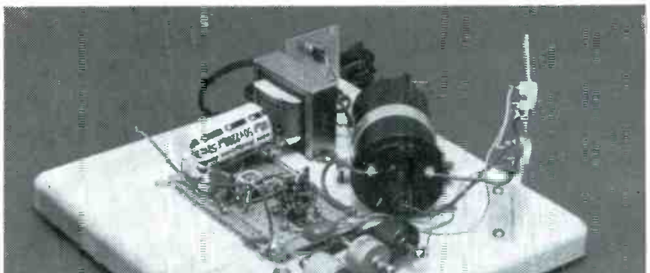


Fig. 1—Shown here is a basic design for a Tesla Coil circuit, using a line-operated, step-up transformer to generate the high voltage needed for the coil's primary.



Here is the author's prototype of the Solid-State Tesla Coil with the 9-inch circular deck removed. The two heavy wires running the length of the top and bottom of the board serve as the ground and +V bus.

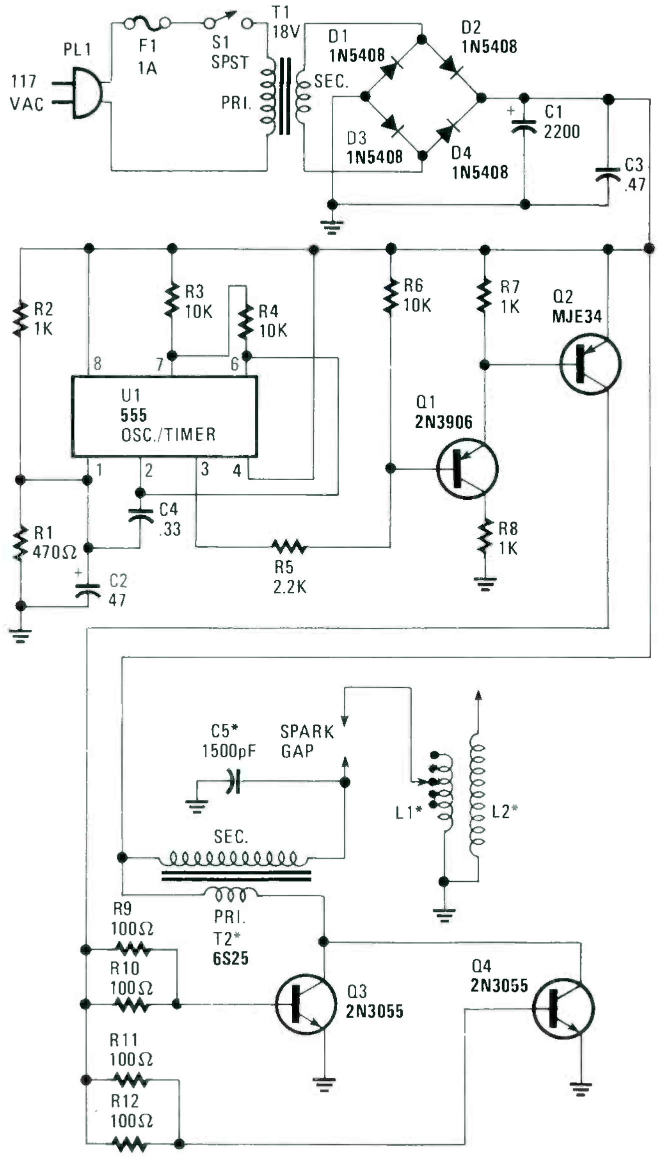


Fig. 2—Our updated version of the Tesla experiment uses an 18-volt, 2-ampere transformer (T1), a full-wave bridge rectifier (consisting of D1-D4), and filter capacitors (C1 and C3) to supply operating power for the Coil's circuitry.

current to transistors Q3 and Q4 to drive those components into full saturation.

The primary winding of T2 (an automobile-ignition coil) is connected in series with Q3 and Q4, and across the power supply. Transistors Q3 and Q4 operate like a toggle switch, connecting the coil across the power source at the rate and on-time set by U1.

That high-current pulse generates a rising and collapsing field across the primary winding of T2. The field causes a current to be induced in the secondary winding of T2. The secondary output of T2 is fed across three 500-pF, 10-kilovolt doorknob capacitors (collectively designated C5) that are parallel connected and tied across the high-voltage output of T2 as an energy-storage device. Those capacitors charge up to T1's secondary voltage and are then discharged through the spark gap and the primary (L1) of the Tesla coil, producing higher voltage in the secondary of the coil (L2).

The secret of producing a successful Tesla coil is in the tuning of the primary coil to the natural resonance frequency of the secondary coil. Because variable 10-kilovolt capacitors are about as common as Condor eggs, some other means must be used to tune L1. The simplest method is to tap the primary coil on every turn and select the tap that produces the greatest voltage at the hot end of L2.

Perfboard Assembly

The author's prototype was built breadboard style on an 11 × 11 × 1-inch wooden cutting board (see photos), but any similar non-conducting material (perhaps plastic) will do. The majority of the small components, as shown in the photos, were mounted on a 3 × 5-inch section of perfboard, and point-to-point wiring techniques were used to complete the connections. Refer to the schematic diagram (in Fig. 2) and the photos for wiring and general parts-layout details. Note: Components T1 and T2, C5, Q3 and Q4, F1, and S1 are not mounted to the perfboard (see photos).

Figure 3 shows the positioning of the perfboard and off-board components on the baseboard. Mount the fully-populated perfboard assembly to the baseboard using four ¼-inch plastic spacers and wood screws. The location of the sub-assemblies on the baseboard isn't too critical, so long as the general layout is followed. Keep all wire leads as short as possible, especially around the high-voltage circuitry.

A 2½ × 2-inch piece of aluminum is formed into an "L" bracket, which is used to hold S1 and F1 (see photo), and is mounted on one corner of the baseboard. A 5 × 3-inch piece of aluminum mounts to the opposite corner and functions as the heat sink for the two power transistors (Q3 and Q4). A simple band is formed from aluminum to hold T2 in place.

Recall that C5 is really three 500-µF doorknob capacitors.

PARTS LIST FOR THE SOLID-STATE TESLA COIL

SEMICONDUCTORS

U1—555 oscillator/timer, integrated circuit
Q1—2N3906 general-purpose PNP silicon transistor
Q2—MJE34, ECG197 (or similar) audio-frequency PNP silicon power transistor
Q3, Q4—2N3055 NPN silicon power transistor
D1-D4—1N5408 3A, 100-PIV silicon rectifier diode

RESISTORS

(All resistors are ½-watt, 5% units, unless otherwise noted.)
R1—470-ohm
R2, R7, R8—1000-ohm
R3, R4, R6—10,000-ohm
R5—2200-ohm
R9–R12—100-ohm, 1-watt resistor

CAPACITORS

C1—2200-µF, 50-WVDC electrolytic
C2—47-µF, 25-WVDC electrolytic
C3—0.47-µF, 100-WVDC mylar
C4—0.33-µF, 100-WVDC mylar
C5—1500-pF, 10K-WVDC (three parallel-connected 500-pF doorknob capacitors, see text)

ADDITIONAL PARTS AND MATERIALS

F1—1-ampere fuse, 3AG
L1, L2—see text
S1—SPST miniature toggle switch
T1—117-volt primary, 18-volt 2-ampere secondary stepdown transformer
T2—Automobile-ignition coil (Ford #6S25, or similar)
Perfboard, #12 wire, #26 wire, aluminum, Fahnestock clips, spacers, solder, hardware, etc.

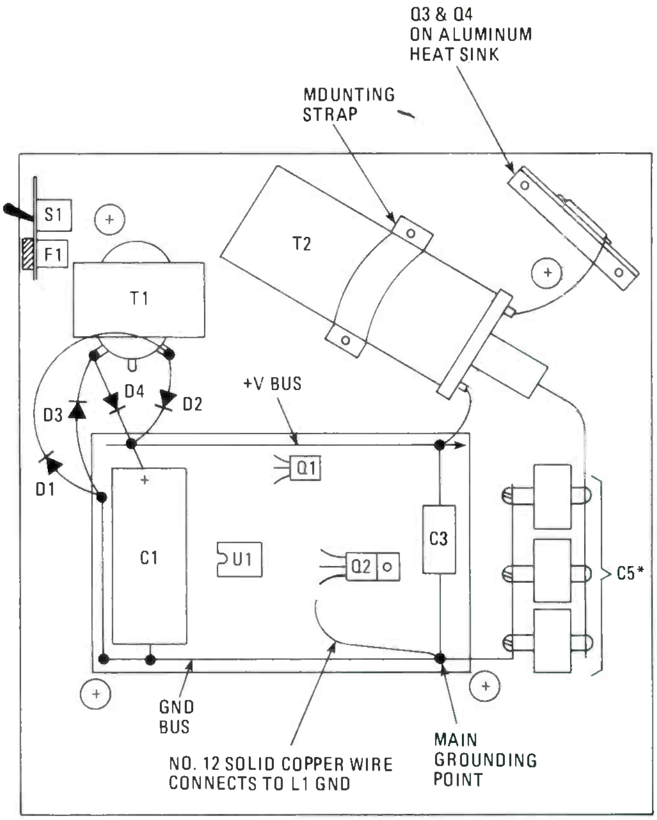
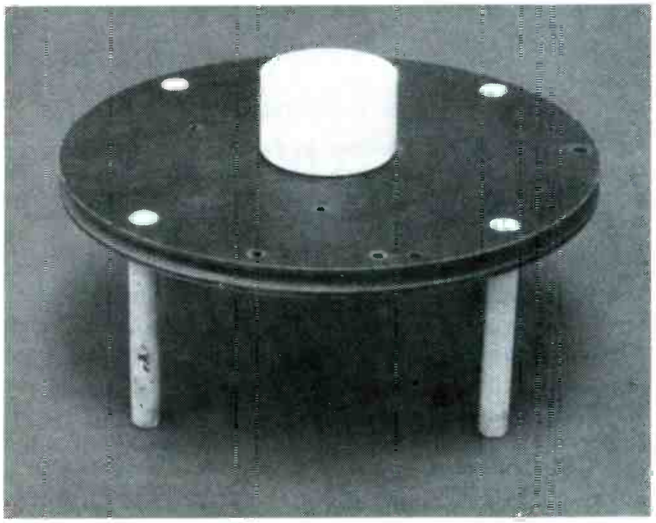


Fig. 3—The author's prototype was built breadboard style on an 11 × 11 × 1-inch wooden cutting board, and most of the components were mounted on a 3 × 5-inch piece of perfboard.

Two brass strips, about ⅜-inch wide by 3-inches long, are used to tie the three high-voltage capacitors together. If doorknob capacitors cannot be located (often they can be salvaged from older black-and-white TV's), a substitute can be made from window glass and aluminum foil.

To fabricate C5, take a 10-inch square piece of glass, like that of a picture frame, and glue a 9-inch square piece of aluminum foil to the center of the glass on both sides, leaving an equal border around each aluminum plate. Cut two 6-inch lengths of #22 insulated stranded wire. Strip about 3-inches of insulation from one end of each wire and tape the stripped end to each of the aluminum plates.



Shown here is the 9-inch circular deck supported by four dowel rods, and an end cap positioned at its center.

The Deck

Figure 4 and the photos show the top deck of the author's prototype, where the two air-core coils (L1 and L2) are mounted. The top deck consists of a 9-inch diameter circle cut from ½-inch thick fiber board. Four 3¾-inch lengths of ⅜-inch dowel hold the 9-inch coil base above the perfboard.

Select a drill bit slightly smaller than the dowel rod's diameter and drill the four mounting holes in the 9-inch circle to match the illustration. Position the 9-inch circle on the baseboard at about the center, and mark the location of each hole. Drill each location on the baseboard with the same bit to a depth of about ½-inch.

If the two-layer Tesla coil seems like too much bother to

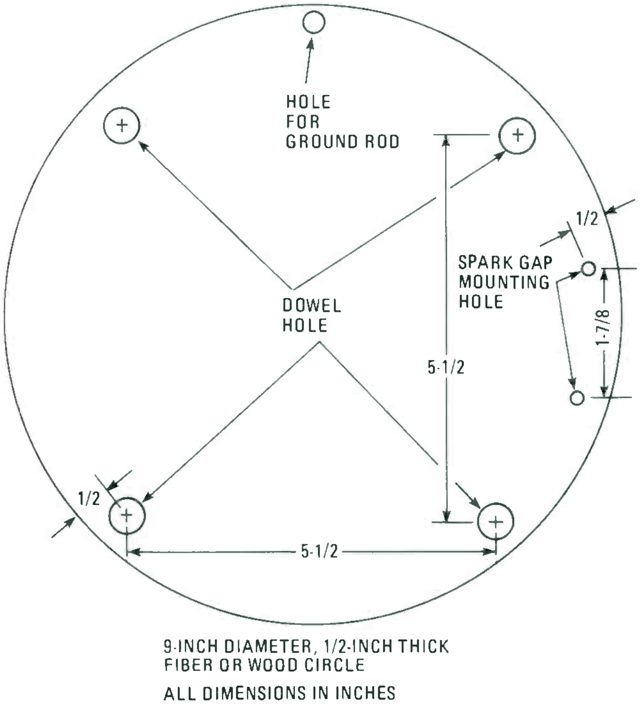
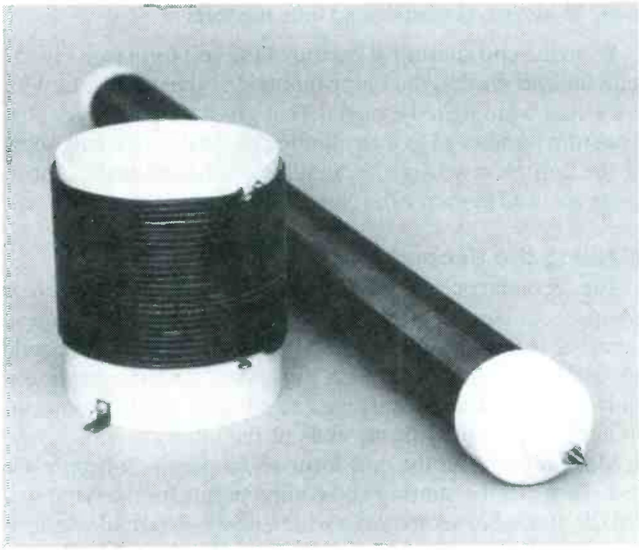


Fig. 4—Shown here is the general layout of the top deck of the author's prototype, which supports coils L1 and L2. Four 3¾ × ⅜-inch wooden dowel rods hold the 9-inch circular base above the perfboard and other components.



Here is what L1 (left) and L2 (right) should look like once completed. Although winding L2 may appear difficult, it can be done in an hour by hand or in 15 minutes by lathe.

duplicate, then build a single-level unit on a larger wooden base to suit your own needs. Actually, any good layout scheme that respects the dangers of high voltage should do quite well.

Winding the Primary Coil

The primary-coil (L1) is wound on a form cut from a 4-inch diameter, plastic sewer pipe to a length of five inches (see Fig. 5). Take a 27-foot piece of #12 insulated solid-copper wire and strip away a ⅛-inch section of insulation at about every 12 inches, continuing for one-half the length of the wire (12 times total). Those stripped areas serve as tap points for tuning the coil.

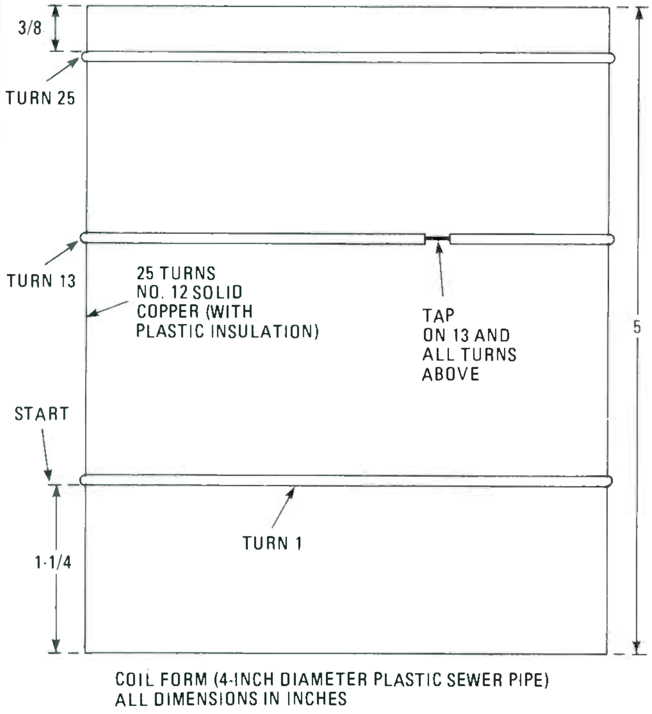


Fig. 5—The form on which L1 is wound is a five-inch length of four-inch diameter, plastic sewer pipe. A 27-foot length of #12 insulated solid copper wire (with 12 quarter-inch sections of insulation stripped away at intervals of about every 12-inches) is then wound onto the form.

Wind the coil starting at the top of the coil form (see Fig. 5) with the end that has the 12 tap points. In other words, turn 25 is the first winding to be made. That gives a tap on every turn from turn number 13 to turn number 25. Drill two small holes in the coil form where the winding starts and ends. Those holes are used to secure the ends of the windings (see photos).

Winding the Secondary Coil

The secondary coil form (see Fig. 6) is cut from a section of 1½-inch diameter, plastic water pipe (which actually measures 1⅞-inches in diameter). So when selecting your secondary coil form, take a ruler with you and be sure to come home with the correct-diameter pipe. You'll also need two plastic end caps that snugly fit the ends of the tubing.

Make a mark on the coil form about one inch from each end. That sets the starting and ending points for the winding. Fill the space between marks with a neat solenoidal winding of #26 enamel-covered copper wire. Winding the coil by hand shouldn't take over an hour, and if a lathe is handy, you should be able to complete the job in about 15 minutes. Leave

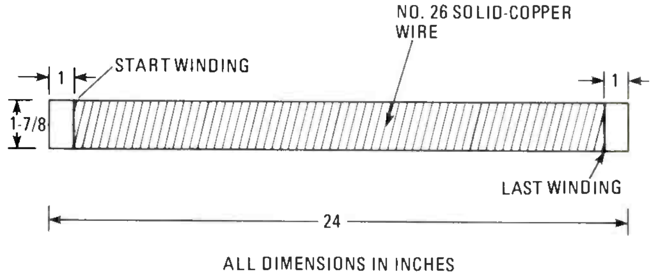


Fig. 6—Using #26 enamel-coated copper wire, L2 is wound on a 24-inch length of 1½-inch diameter, plastic water pipe, either by hand or (if available) using a lathe.

about 6-inches of wire at both ends of the winding for making connections.

Spray several coats of Krylon clear #1301 acrylic on the coil for added insulation and protection against moisture. Always let each coat dry completely before applying the next. Two or three coats are sufficient.

It's Coming Together

Mount one of the 1½-inch, plastic end caps to the center of the 9-inch circular deck with a 1-inch long #8-32 screw, washer, and nut. Take two small metal "L" brackets and mount the primary coil centered around the end cap on the 9-inch base. Drill a small hole through the end cap and baseboard near the rim of the cap. Take the secondary coil and push one end of the coil's lead through the hole in the end cap, and then set the coil in the end cap.

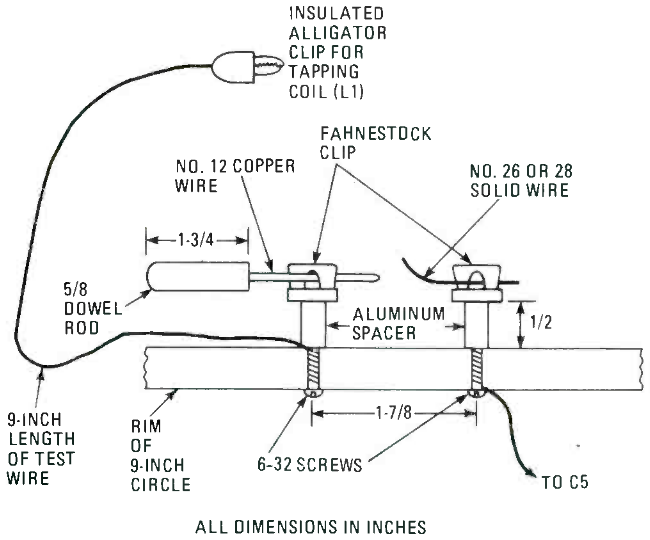


Fig. 7—The spark gap is formed by mounting two fahnestock clips to the 9-inch circular deck; one tied to the main grounding point, and the other connected to an alligator clip, which is used to change taps on L1.

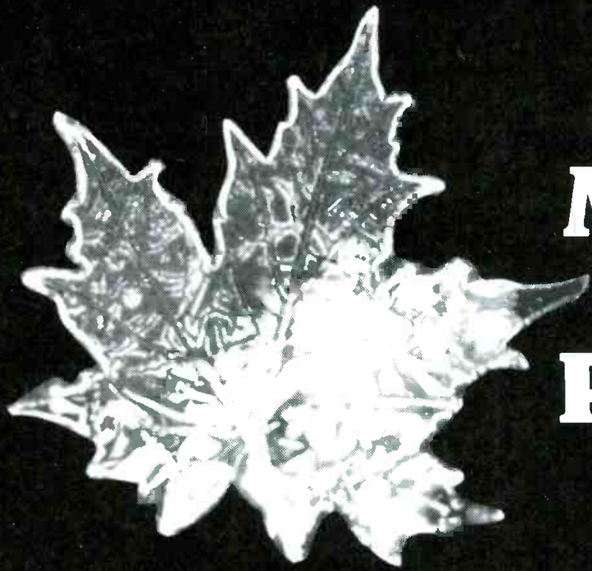
Take the other end cap and drill a hole in the center to clear a #8-32 screw, and mount a feed-through insulator (see photo) on top. Select a #8-32 screw long enough to stick through the top of the insulator by about ½-inch, and grind the end to a nice sharp point. Connect the top end of the secondary coil to the bottom of the #8-32 screw with a small solder lug and tighten in place. Place the cap on top of the coil.

The spark gap is shown in Fig. 7. Two holes are drilled to clear a #6-32 screw to match the drawing in Fig. 4. Two

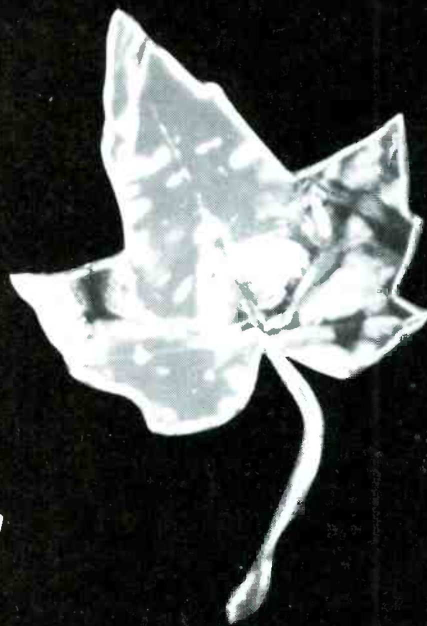
(Continued on page 67)

HOW TO

Make Kirlian Photographs



John Iovine



In this article we explore the mysteries of Kirlian photography and show you how you can investigate the phenomenon yourself!

LABORING IN RELATIVE OBSCURITY, Seymon Kirlian (pronounced keer-lee-an) began his work in electro-photography in 1939. Over 40 years later, that work is still the source of much speculation and controversy. That's because it has been claimed that Kirlian was able to use auras that surrounds the objects in his electro-photographs to detect illness in plants and animals before any other outward symptoms were visible. Whether those claims are true or not, they sparked a good deal of interest in the field of electro-photography; so much so that electro-photography is today commonly called Kirlian photography.

What is it?

In Kirlian photography, a variable-frequency high-voltage source is use to produce images on photographic film. It does so without the benefit of a camera, lenses, or light, so it can, in some ways, be likened to X-ray photography. The resulting photograph is a recording of the cold electron emission created by the high-voltage source. How the emission is modified by the subject or object used in making the photographs is the focal point of Kirlian photography.

Many of the theories used to explain the effect read like excerpts from a science-fiction novel. One theory put forth by Dr. F Cope, who was investigating the Kirlian aura at the Bio-Chemistry Laboratory at the Naval Air Development Center, in Warminster PA, felt that all substances and, in particular, living organic matter, contain and are surrounded by what can best be described as a matter energy field. When a high-voltage charge is introduced into that field, it becomes or behaves like a superconductive plasma. The laws of physics that pertain to such a plasma are complex, involving an extended form of Einstein's Theory of Relativity. It's possible that the aura recorded around objects may be a physical manifestation of that matter field.

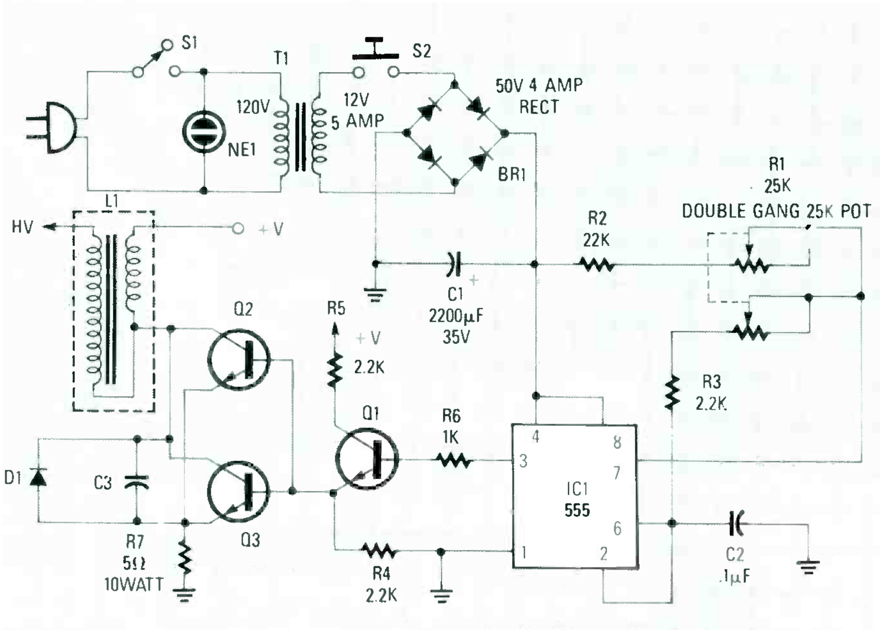


FIG. 1—YOU CAN MAKE YOUR OWN Kirlian photographs using this circuit. Coil L1 is an automotive ignition coil that can be obtained cheaply from an automotive junkyard.

FIG. 2—THE "CABINET" for L1 can be fashioned from a cardboard tube. The end caps can be made of plexiglass.

Unfortunately, when Dr. Cope died, the research unit disbanded. While Dr. Cope was alive, though, he was one of a few scientists with the courage to do research into what is considered, at best, a fringe science.

It is that fringe-science category that impedes research into the field, in addition to quickly becoming associated with the quacks, psychics, and pseudo-scientists that permeate the field. It is easy to see that any scientist wanting to seriously investigate electro-photography is going to be met with serious opposition, and could possibly lose their standing in the scientific community.

But is the opposition justified? Is it possible that the procedure has no merit whatsoever? I don't think so and, to make my point, allow me to draw a few analogies. We analyze light from stars to determine their composition, and their doppler shift to determine speed. Those two facts have created a foundation upon which modern cosmology in the last century stands. We typically perform spectrographic and colormetric analysis to determine a compound's composition. It is therefore my belief that the Kirlian effect may provide a tool with which we can probe nature.

Despite the opposition to electro-photographic research, Kirlian images have been used experimentally, as a diagnostic tool, in medicine, and for non-destructive testing of materials in engineering. One interesting aspect of electro-photography is that, while all objects appear to produce an electro-photographic aura, the aura of inanimate objects appears constant over time, while living creatures give off an aura that is time varying. In humans, emotional stress, illness, and alcohol or drugs all appear to have an effect on the aura.

One of the U.S. government's studies in the area involved using the Kirlian aura to ascertain the physical and mental health of military personnel, and to determine their level of fatigue. That was done by measuring the diameter of the aura or corona, at the fingertip. At the end of the test, the results were analyzed and two statistically valid conclusions could be drawn. One was that the corona of those suffering physical stress (exercise) was larger in diameter than the test average; the other was that those suffering mental stress (fatigue, etc.) had coronas that were smaller in diameter than the test average.

It may appear obvious than those test results could be due to the dilation or constriction of the blood vessels. Another study proves that assumption incorrect. Compounds given to individuals to dilate or constrict blood vessels do not produce a statistical difference in the corona diameter, according to a report.

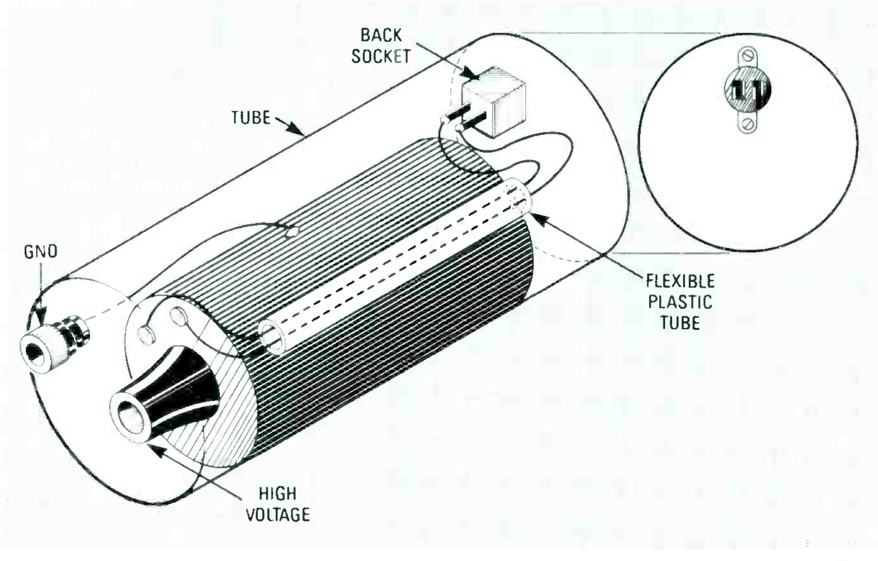


FIG. 3—THE AUTOMOTIVE IGNITION COIL is mounted inside its cabinet by gluing it to one side. Make the ground connection by soldering a wire to the side of the coil housing and connecting the other end to the cabinet-mounted binding post.

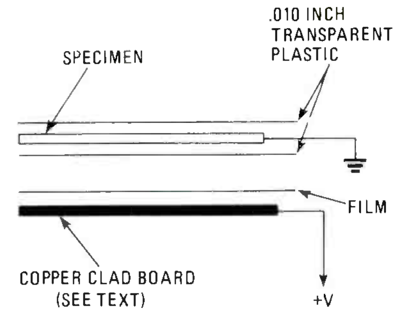


FIG. 4—THE SPECIMEN to be photographed should be sandwiched between two sheets of thin (0.01-inch) transparent plastic.

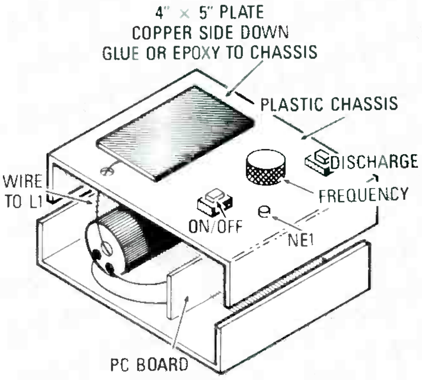


FIG. 5—TO MAKE THEM EASIER TO FIND in the dark, cluster the unit's operating controls around NE1.

While the results of the tests were interesting, there is still not enough data to hail Kirlian photography as a "fool-proof" diagnostic test. Although other similar tests have been reported, the results have been incomplete. For instance, in one study, the fingertip coronas of 120 adult humans were photographed. Of the sample, 20% had a corona diameter that was markedly below the average. It was later determined that 50% of that 20% suffered from some sort of medical problem.

There are several obvious flaws with that study. For one, no report was made on the health of the 80% whose corona diameter was not reduced; it would have been informative to know what percent of those, if any, also suffered from some medical problem. Also, no follow-up appears to have been done on those whose corona diameters were decreased and who had no ascertainable medical problems. It would have been interesting to see how many of them developed some kind of difficulty, and in what time frame following the experiment.

The most dramatic experiment in Kirlian photography, and one that has garnered the most attention, is the so-called phantom-leaf phenomenon. In that experiment, a small part (approximately 2% to 10% of the total surface area) of a leaf is cut off. Electro-photographs subsequently taken will sometimes show the energy pattern or aura of the missing section. The reason for that is unknown, and it is the subject of much speculation, and although the effect is exceptionally rare, it has been demonstrated enough times by different people to prove its existence. One important fact must be kept in mind if you wish to attempt to replicate the phantom-leaf effect. The leaf must still be attached to the parent plant when shooting the photograph.

Making your own

There are probably quite a few doubters still out there. To those we offer the following challenge: Why not build your own Kirlian-photography unit and prove or disprove the existence of the effects yourself? The worst-case scenario is that you will build a device that takes exceptional, beautiful, and exotic photographs of the most-common items lying around. In the balance of this article we will present a simple set up that will allow you to do just that. Although the equipment is not on par with that used in research labs, it is still more than sufficient to provide startling results. The color photographs that accompany this article showing the Kirlian aura of some common leaves, were produced using the apparatus as described.

The circuit for the setup is shown in Fig. 1. The heart of the circuit is a 555 timer in astable mode whose frequency is controlled by a double-ganged pot. The output of the timer is fed into Darlington-transistor T1. The Darlington transistor controls two TO-3 power transistors that switch the current on and off to a three-terminal automotive ignition coil, L1.

Construction is straight-forward, and the circuit is simple enough that a PC board is not required—although you can use one if you wish. Note that the transistors can get hot, so they should be heat sinked. The only other point that merits special mention is that a plastic chassis is essential, to provide adequate shock protection from the coil and is also essential to properly mount the exposure plate on top of the chassis (see Fig. 2).

Figure 3 shows the internal mounting of the components. The ignition coil is epoxied or glued to one side of the chassis so that the high-voltage

continued on page 165

FIG. 6—ALTHOUGH THE RESULTS are not visually striking, Kodalith film is easy to work with. Here is a Kirlian aura captured on that film.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—25,000 ohms, double-ganged potentiometer
R2-R5—2200 ohms
R6—1000 ohms
R7—5 ohms, 10–20 watts

Capacitors
C1—2200 µF, 35 volts
C2—0.1 µF
C3—0.01 µF, 2000 volts

Semiconductors
IC1—555 timer
Q1—TIP-120 NPN Darlington transistor
Q2, Q3—3055 NPN transistor
D1—2.5-amp, 1000-volt silicon diode
BR1—4-amp, 50-PIV bridge rectifier

Other components
NE1—red neon-lamp assembly
T1—120-volt/12-volt, 3-amp transformer
S1—SPST pushbutton switch
S2—momentary N.O. pushbutton
L1—three-terminal, 12-volt automotive ignition coil (see text)
Miscellaneous: Chassis, knobs, 4 × 5-inch single-sided copper-clad PC-board plate, line cord, etc.

Note: Complete assembled and tested Kirlian unit available for $187.50 from Images Co., P.O. Box 313, Jamaica, NY 11419. Plastic chassis $30.00 each plus $2.50 postage and handling.

If you've ever wanted a high-voltage generator to create neat lightning effects, perform Kirlian photography experiments or play with neon lights, then this one's for you!

A HIGH-VOLTAGE PULSE GENERATOR

By Dale Hileman

We will describe a laboratory pulse generator using an auto-ignition coil and capable of delivering a train of pulses having a peak potential up to 30,000 volts. With a couple of minor circuit and construction variations, the project is suitable for use as an electric-fence charger, operating at a lower voltage, but capable of much higher output current.

Applications for a high-voltage spike are numerous: electromagnetic and radio-frequency interference studies, electrostatic-discharge simulation; investigation of insulation breakdown; flammability experiments; strobe effects; etc. A DC power supply or battery is required, and pulse potential may be varied simply by changing the supply voltage. With a 12.6-volt input, the ignition-coil model delivers its maximum pulse, but a unique multivibrator-driver circuit makes operation possible down to a supply voltage as low as 1.5 volts, yielding an output pulse of only a few hundred volts. Its pulse frequency is set by a front-panel control, with a range from about 0.3 Hz to 20 Hz.

An ignition coil, however, is not well adapted to the fence-charger application since its output resistance is so high: typically 10,000 ohms. Thus its output pulse is strongly dependent on loading. With a short fence, long sparks might be struck at risk of igniting brush; while on the other hand, with a long fence, shunting by weeds or by dirt and moisture may reduce its output voltage below an effective value. Hence for the fence-charger version the RATE prf control must be omitted for reasons of safety.

No-load output of the fence-charger option is typically 4 Kv pk (kilovolts peak), or about half that value when connected to a 1-mile fence. A car battery powers the fence-charger model for about four months before recharging is needed (at recommended pulsing rate of 20 pulses/min.)

Two lamps mounted on the circuit board and visible through the see-through front panel are important indicators of the unit's performance.

Precautions

While a single jolt from an ignition coil is itself rarely traumatic, the resulting-reflex muscle contraction could have unfortunate consequences. If a continuous train of pulses causes you to involuntarily grasp the high-voltage conductor, for instance, you might not be able to let go. On the other hand, if a proper return circuit is not provided, an equally distressing shock could be had by contact with the primary circuit. Because the ignition coil is an autotransformer, the return circuit for the high-voltage pulse includes the power leads. Therefore, one side of the power supply should, if possible, be Earth grounded. That precaution, besides preventing shock by contact with the power leads, also precludes arcing within the power supply itself as the high-voltage pulse seeks the shortest return path.

Applying that reasoning to the fence-charger option, we can see why a fixed pulse rate is specified, as there is a strong likelihood of accidental human contact with the fence wire; a rate of 60 pulses per minute or less being considered safe. Also, since there is a good chance of personal contact with the power or battery leads, a good ground connection is essential, as with any electric-fence system.

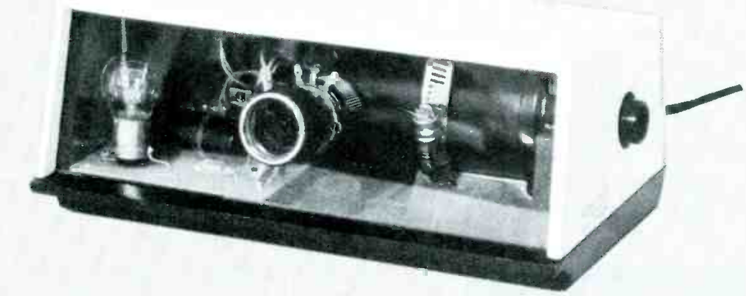
For maximum safety, we recommend a battery supply for the fence-charger system.

If you should happen to reverse the power-supply leads to either project, the current-limitation lamp, a large automotive bulb easily seen in the photos, lights brightly to warn you. However, the equipment must not be allowed to remain in this condition for more than a few seconds. Even if you never expect to make this mistake, the lamp should be included because it limits excessive surge currents that could otherwise occur under some operating conditions and which could blow the power transistor.

About the Circuit

As shown in Fig. 1, free-running variable multivibrator Q1 and Q2 drive Darlington power amplifier Q3, which makes and breaks the primary current to coil T1 as in an auto ignition system. Duty, or "dwell" is a few miliseconds, and the high-voltage pulse is generated at the end of the period when the circuit is broken and the field of T1 rapidly collapses through the winding.

An unconventional multivibrator circuit was developed to provide high saturation currents over a wide range of supply voltages. In this design both transistors Q1 and Q2 conduct at the same time and both cut off at the same time. Another unique feature: For safety in the fence-charger application, the circuit is designed to automatically shut down if driver Q2 should fail to conduct for any reason (fluctuation



of supply voltage, intermittent connection, etc.)

Starting with both transistors cut off; C3 is discharging, its negative plate rising toward ground at a rate determined by various series resistances; while its positive plate is held near zero volts by a relatively low-resistance path through R6 and R7 and a resistor internal to Q3 across its emitter-base junction.

The series combination of C5 and C6 (discussed later) has negligible effect on the charging rate, which is therefore determined mainly by C3 with the series combination of RATE control R9 and resistor R2 (or R2 alone, in the fixed-frequency version).

Capacitor C3 discharges fully, and then begins charging in the opposite direction as its negative plate rises above zero volts. When Q1 begins conducting, and its collector voltage has dropped far enough to start Q2 conducting also, then a positive-feedback action is initiated, forcing both transistors into saturation. At the same time, power transistor Q3 is turned on by the current supplied through R7.

Dwell is determined by the time constant R6 × C3. When the charging current of C3 diminishes below the value which will sustain conduction of Q1, then a regenerative action is again established, this time cutting off all three transistors. It is at that moment the high-voltage pulse is generated.

Further Details

Capacitors C5 and C6 form a voltage divider which ensures rapid cutoff of Q1; while C6 acts as a bypass to prevent Q1 from being retriggered by pickup of the high-voltage pulse.

Dwell must be long enough to permit the field around

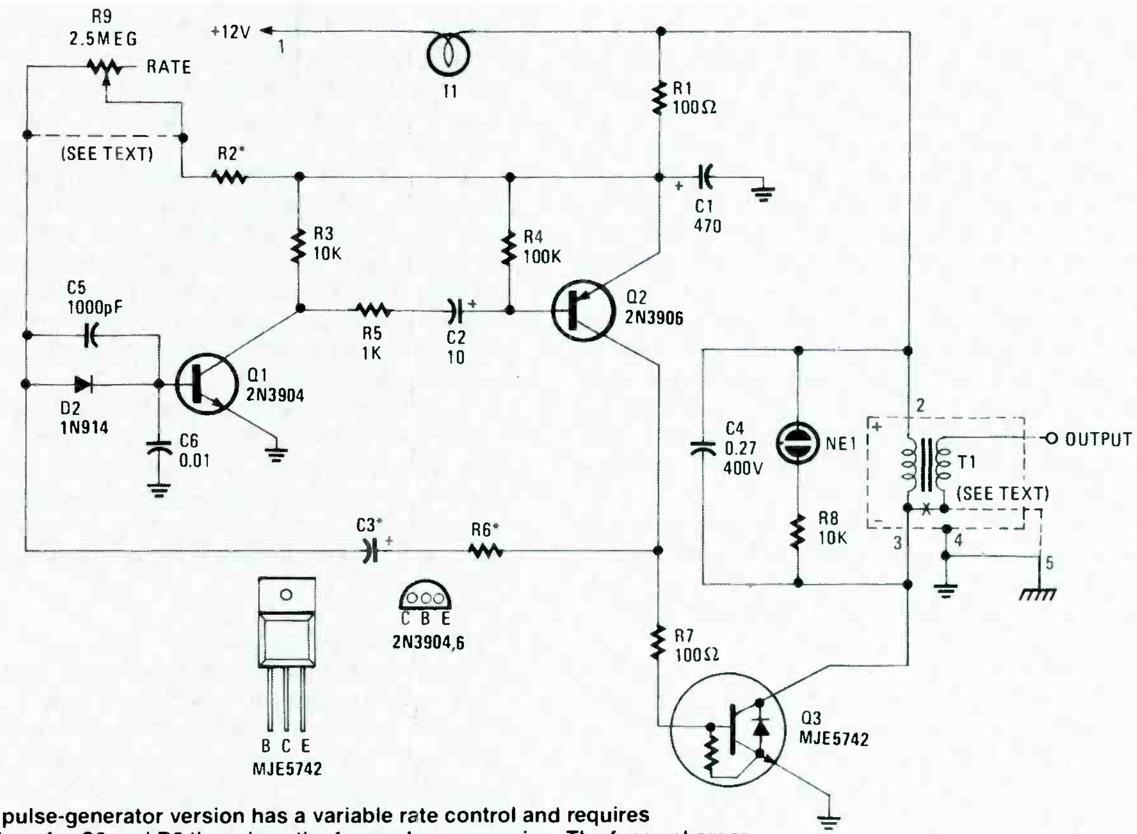
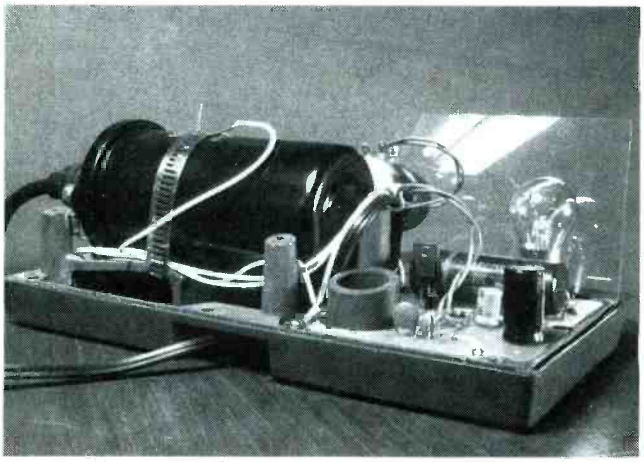


Fig. 1—The pulse-generator version has a variable rate control and requires different values for C3 and R6 than does the fence charger version. The fence charger version has a fixed rate and uses a conventional transformer instead of an auto coil (see dashed lines).

T1 to be fully developed to its steady-state condition under all anticipated conditions of loading. Although the period is not critical, it may be set for optimum results with a particular coil or transformer, as described later.

A higher capacitor value at C3 is specified with the fixed-frequency, or fence-charger version, for reasons of safety. It allows the use of a lower resistance value for R2, reducing the shunting effect of dirt or moisture which might otherwise cause a significant increase in the repetition rate. That is the reason we specify an axial type for C3, so that its pads are more widely spaced than they would be with a radial.



The frequency control is mounted on the see-through front panel behind the ignition coil here. The auto lamp on the circuit board limits current, and lights if the power leads are connected backward. The chimney protruding through the hole in the corner of the circuit board accommodates the 1/2-in. pipe used in the fence-charger version.

Power Amplifier

Because the field of T1, as might be supposed, collapses through the primary as well as the secondary, the inductive "kick" comprises a positive pulse on the collector of Q3. Capacitor C4 is required, as in the conventional auto-ignition system, to prevent excessively rapid voltage build up. Nevertheless, that reactive voltage reaches several hundred volts, and we take advantage of it to light neon indicator NE1. Thus, each flash verifies the integrity of the power-amplifier circuit.

If no arc is drawn, the positive pulse on the collector of Q3 is followed by a negative-going excursion. Transistor Q3, designed for inductive loads, contains a shunt diode which prevents that "backswing" from being applied to the base through the base-collector junction. That diode also protects Q3 if the power-supply leads are accidentally reversed.

Automotive lamp I1, as we said, limits surge currents occurring as a result of various normal operating conditions, as well as accidents, such as the reversal of power-supply polarity. Also, it absorbs the energy of the backswing.

The Transformer

Practically any 12-volt ignition coil having a primary resistance of around 1.5 ohms will work as T1 for the high-voltage pulse generator, but there's a minor consideration in the choice of a transformer for the fence-charger project. A common 12-volt 1-amp transformer with 115-volt primary can be used here—hooked up backward of course, so that the 115-volt winding serves as secondary. The rapid collapse of its field when Q3 cuts off, as compared to the relatively slow 60-Hz sinewave for which it is designed, explains how several thousand volts can be developed across the 115-volt winding ($E = L\, di/dt$). That winding will typically be found to measure 30 to 120 ohms DC, while the 12-volt winding will have a resistance of around 1 ohm. The author has tried many such transformers for T1, including the Stancor P-8392 and P-8393. (The latter provides a somewhat bigger jolt although it costs more than the former.) The problem, however, lies in the breakdown rating of the 115-volt winding.

In most transformers of the species, the winding is rated for breakdown at 1500-volts RMS (corresponding to 2100-volts pk), with a safety margin that may vary depending on the manufacturer; the Stancor rating proving remarkably conservative. The author subjected the winding of a P-8393 to 40 million pulses of 4-Kilovolt amplitude without breakdown. However, he does not guarantee equally good luck in your application.

One way to preclude breakdown with such a transformer is to always operate the fence charger with an appropriate load. If your fence isn't long enough to load T1 to 2-3 Kv pk, you could reduce the supply voltage: Say, use a 6-volt battery instead of 12 volt. Or you could substitute for bulb I1 a type having a lower current rating, and therefore a higher resistance. Either of those approaches, naturally, will somewhat reduce the effectiveness of the unit.

Otherwise, the author offers a transformer specially wound for the fence-charger option and rated at 5 Kv pk (see note at end of parts list).

Other parts

A type MJE5742 transistor is specified for Q3, rated at 400-volts under heavy inductive load. However, you can at some risk substitute the cheaper MJE5741 (350-volt rating) or MJE5740 (300-volt rating), depending on T1. In any case, breaking the circuit to an inductive load is tricky and so if you plan extensive experimentation you should obtain a few spare Q3's.

Potentiometer R9 for the variable pulse generator project can be any 2.5-megohm unit from the junk box. If you use one with a linear taper, though, you will find the control very touchy at the high end of the frequency range. The simplest resolution of that minor inconvenience is to use an ordinary audio-taper potentiometer connected backward; that is, with the high end of the frequency range at the *CCW* (counter clockwise) end.

For reasons already mentioned, the time constant C3 × R6 determines dwell, or "on" time. As we have said, dwell is not critical; but if the capacitor you use for C3 is a low-quality part with an excessively high equivalent series resistance (ESR), then dwell may turn out to be greater than necessary to serve the needs of T1. If in doubt, use a tantalum type for C3.

The Incandescent Lamp

We have emphasized the importance of I1, the current-limiting lamp, and have specified a type 1156 auto bulb. The merit of an incandescent bulb as a protective device lies in the dependence of its resistance upon the value and duration of applied current. With a cold resistance of only about 1/2-ohm, the Type 1156 degrades performance only slightly; but in the case of a current surge or accidental short circuit, its resistance quickly rises to a "hot" value of around 6 ohms, sparing power amplifier Q3 from the devastating requirement of breaking an excessive current into an inductive load. Nevertheless, there is some leeway in the selection of I1.

For instance, in the lab-generator version where the load has a DC resistance of 1.5 ohms, a lower-resistance bulb will give a slightly better spark at high frequencies. The author has used a Type 1157 bulb here, connecting its two filaments in parallel, with satisfactory results. On the other hand, as we have indicated above, to prolong the life of T1 in the fence charger, you may elect a lower-current or higher-resistance bulb. Try the smaller of the two 1157 filaments, alone before experimenting further. After the unit is built feel free to try others.

PARTS LIST FOR THE FENCE CHARGER

SEMICONDUCTORS

D1—No D1 in project; please ignore
D2—1N914 silicon diode or similar
Q1—2N3904 NPN silicon transistor or similar
Q2—2N3906 PNP silicon transistor or similar
Q3—MJE5742 8 amp, 400-volt, NPN Darlington power transistor (see text)

CAPACITORS

C1—470-μF, 16-WVDC electrolytic
C2—10-μF, 16-WVDC electrolytic
C3—For lab model: 2-μF; for fence charger: 10-μF, both 16-WVDC electrolytic, axial (see text)
C4—0.27-μF, 400-WVDC film
C5—1000-pF disc
C6—0.01-μF disc

RESISTORS

(All fixed resistors are 1/4-watt, 5%)
R1, R7—100-ohm
R2—Selected (see text)
R3, R8—10,000-ohm
R4—100,000-ohm
R6—For lab model: 470-ohms; For fence charger: 150-ohm
R9—2.5-megohm pot (see text)

ADDITIONAL PARTS AND MATERIALS

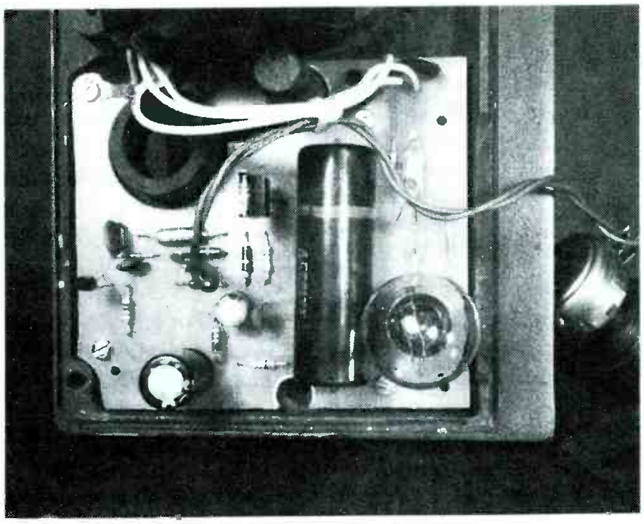
T1—For lab model: Wells C1819 or similar ignition coil; 1.6-ohm primary, 10,000-ohm secondary; For fence charger: 12-volt, 1-amp transformer (see text)
NE1—Neon glow lamp; Type NE-23 or equivalent
I1—12-volt, 2-amp automotive bulb, Type 1156 or equivalent

Cabinet or case; circuit board; solder lugs of various gauge, with internal teeth; cable to power supply, #14 to #18-gauge zip cord or whatever suits, spacers, screws, nuts, lockwashers, hookup wire, cable ties, solder, etc.

Additional parts for the lab model only: 1-in. to 2-3/4-in. radiator-hose clamp to mount ignition coil; 7-mm spark-plug wire, coil clip, coil nipple, alligator clip, alligator insulator; knob for R9; two banana plugs or other suitable terminations for cord to power supply.

Additional parts for the fence charger only: two battery clips, Mueller #46C or the like; 1/2-in. pipe, 1 1/2-in. large nipple, coupling, etc., for grounding system.

All parts except water pipe, caulk, hookup wire, and solder are available individually or in kit form from Maps and Zaps, 1132 Roseta Dr., Topanga, CA 90290. Please write for price list, sending self-addressed envelope with 45¢ postage.



This is a top view of the circuit board. Note the ample space provided between components. That is to prevent arcing between the leads of high-voltage components.

Circuit Construction

All parts for either version of the project are available, including the 2-piece plastic cabinet having provisions for mounting at the end of an ordinary 1/2-in. water pipe or upon a standard camera tripod. You may choose to build either version of the project in whatever kind of cabinet suits your needs. If you decide to use wire-wrap construction however, the ground bus and all connections in the power-amplifier circuit should be made with wire no smaller than #24 gauge.

In the author's prototypes, power transistor Q3 stands off the circuit board; but if space limitations permit, a slight margin of safety is affordable by bolting it down flat so that the circuit board provides a measure of heat dissipation.

Omit R2 from circuit board and don't connect the supply conductor to the plus end of T1 until ready to fire up. Also, leave the secondary leads unconnected for the fence charger.

In planning chassis layout, keep high-voltage output conductors well away from the circuit board, especially in the version using an ignition coil as output transformer. A metallic or otherwise conductive cabinet must be connected to the circuit common. Since a 30-kv pulse is capable of jumping a 1-in. gap, however, you may have some difficulty finding a feedthrough insulator big enough to handle the high-voltage conductor. One way to meet that requirement is to use a spark-plug wire, which may be passed through the cabinet wall using only a grommet to prevent chafing. Or the neck of the coil itself may be used as a feedthrough device, as in the author's mode of construction.

Lab Cabinet Loading

If you are using the author's recommended cabinet, situate the circuit board in the left end of its bottom. The board itself can be used as a template for drilling the four mounting holes in the bottom of the cabinet. Mount the board assembly on four 7/16-in. metal spacers. The conductive coating in the cabinet bottom may be grounded with a solder lug placed under one of the screws securing the board to a spacer.

For variable-frequency or lab model, situate the RATE control R9 in the clear-plastic front panel. Bring the power cable into the cabinet through the hole in the bottom rear, using a suitable grommet.

The coil mounts on a platform toward the other end and is secured with a hose clamp. Using the coil called out in the parts list, some filing of the platform is required. The coil case must be grounded or internal arcing may occur. Do not depend on casual contact between the coil case and the conductive coating. A grounding connection can be made by inserting an internal-tooth solder lug between the clamp and coil case. At its base, the coil is stopped by its neck passing through a hole drilled in the end of the cabinet top. Hence, it's not likely to come loose with normal handling.

At the free end of spark-plug wire install an alligator clip or other suitable connector. At the other end, first slide the coil nipple onto the wire, and then install the coil clip. Important: To preclude arcing, solder the end of the wire to the clip. Push it into coil neck and slip the nipple into place. When the top is installed later, the nipple provides a tight seal.

Fence Charger Version

Construction of the fence-charger version is somewhat simplified by less-stringent needs for insulation and by the more conventional mounting means for T1. Whatever chassis layout scheme you employ, however, the Earth grounding requirements described above also apply to this model: If you use a conductive cabinet, it must be connected to the circuit Earth, and so must the case of T1. Don't forget that a means must be provided to connect that common to an *external* ground.

In the author's model of the fence charger, T1 is mounted in the cabinet bottom. To ensure a good connection to the transformer case, first scrape any varnish or wax from the mounting flanges. Then mount with 1/2-in. metal standoffs and 8-32 hardware. Use two or three solder lugs as required for various grounding connections.

Mount a ceramic feedthrough insulator in middle of the platform for fence connection. The underside of the platform comprises a recess which, in an outdoor installation, keeps the output end of the insulator clean and dry.

The chimney referred to earlier provides the means for connection to an external ground. A pipe nipple and coupling are required. First solder a length of hookup wire to the inside of the nipple. A hot iron (say 200 watts) is required for good wetting. Loosely engage the coupling to the nipple; and passing the wire up through the chimney, screw the nipple into the opening by turning the coupling. The nipple may engage the coupling as it engages the chimney. Although the chimney hole is not threaded, the nipple will nevertheless seat securely. Turn the coupling until it is tight up against the bottom of the cabinet. If desired, apply super glue sparingly around top edge of the nipple, bonding it permanently to the chimney. Now, if you later need to remove the coupling for any reason, the nipple will remain in place. Solder other end of the wire to common at the circuit board or at one end of the lugs on the transformer flanges.

High-Voltage Attenuator

Before proceeding with test and adjustment, you may wish to provide yourself with some means for measuring voltage pulses beyond the range of your oscilloscope. To that end, you can build a 90-megohm attenuator, as shown in Fig. 2. When used with a standard 10-megohm probe, the device extends the vertical range of your scope by a factor of ten.

The attenuator consists of nine 10-megohm resistors connected in series. A length of spark-plug wire provides support for the resistor array and also serves to introduce distributed capacitance for AC equalization. To preclude arcing, each end should extend an inch or two beyond the terminal.

Once you have commissioned your pulse generator or fence charger, you can fine tune the attenuator by adjusting the bus-wire gimmicks at either end of the spark-plug wire. That is most easily done by generating a high-voltage pulse within the range of your oscilloscope (say 1600 volts peak), measuring with only the 10-megohm probe; then, trimming the length of the gimmicks to give the same defection with the probe connected to the 90-meg attenuator (setting the sensitivity 10 times higher, of course).

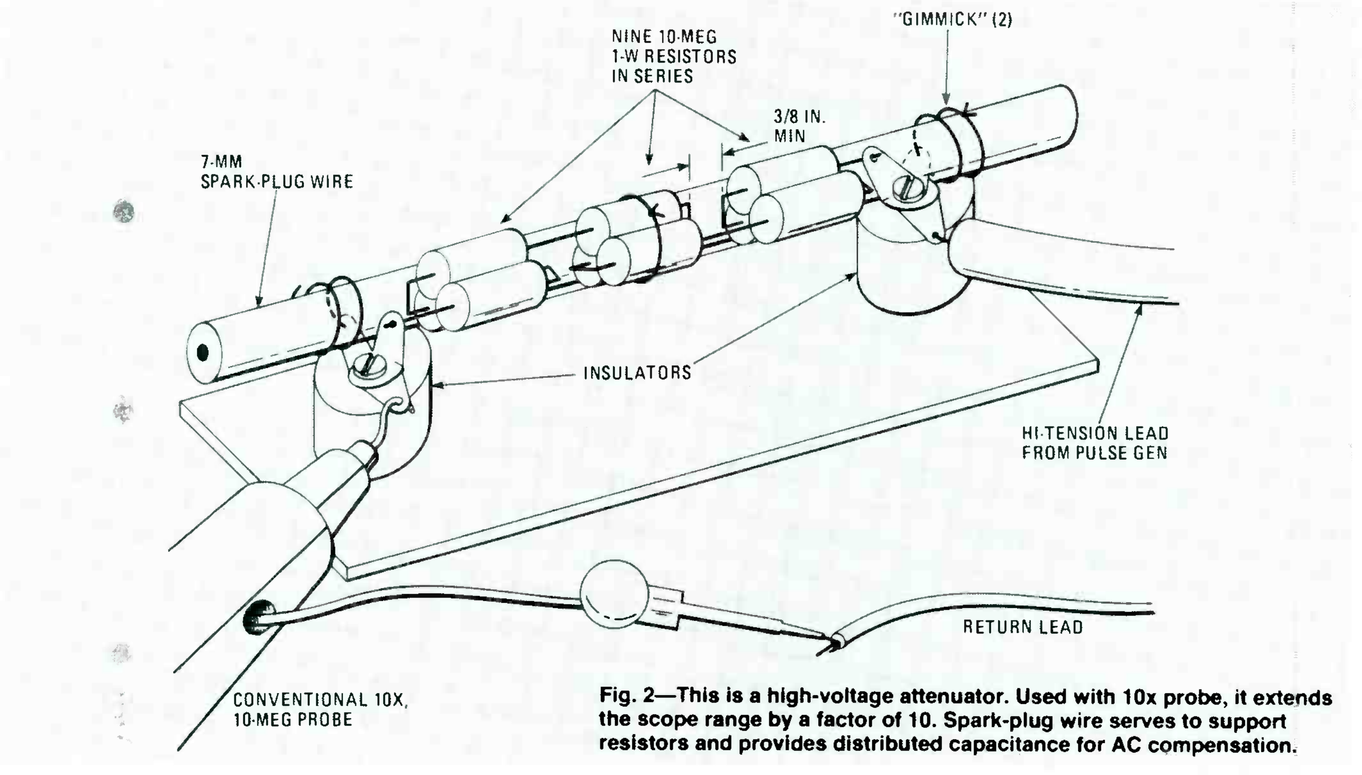


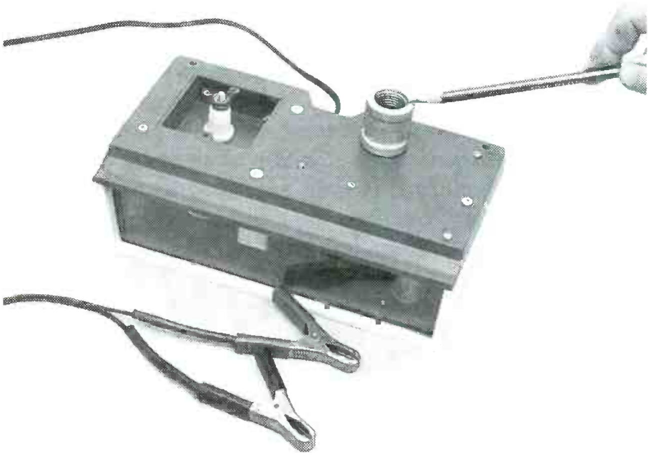
Fig. 2—This is a high-voltage attenuator. Used with 10x probe, it extends the scope range by a factor of 10. Spark-plug wire serves to support resistors and provides distributed capacitance for AC compensation.

Selecting R2

We had advised you during construction to omit one connection to the primary of T1 so that you can now select R2 without energizing the power amplifier. Using clip leads, first connect typical value shown in parts list. Then connect your 'scope to the junction of R6 and R7, and apply power.

For the lab pulse-generator version, now set the RATE control to maximum frequency and select a value for R2 which gives a repetition rate of about 20 Hz. For the fence-charger model, select a value which gives the desired rate, but no higher than 60 times per minute. Remember that the slower the rate, the longer between recharging.

Now turn the supply off and add the missing wire to the power-amplifier circuit. In the author's lab-generator chassis layout, it is necessary to first loosen the coil in order to free the circuit board. If you plan to test the unit with the circuit board loose, be sure to temporarily replace the lugs grounding the coil case and cabinet. Place a cardboard sheet under the circuit board to insulate it from accidental contact with the cabinet coating, etc. The unit is now ready for a performance test.



The fence charger model has a nipple for mounting on a length of water pipe. It effectively grounds the system.

Testing

Connect the high-voltage output to the 90-meg probe or whatever instrument you wish to use to observe the high-voltage pulse. Turn the power supply on and gradually increase the voltage (adjusting the lab-generator rate as desired), synchronizing the 'scope to display the largest excursion. (When you don't know exactly what to expect, it's easy to be fooled into syncing on the backswing or some other minor lobe.)

The unit should start working at a supply voltage of 1.5 to 3 volts, but it will shut itself down down if you vary the voltage too abruptly. If that happens, just turn the power off and then back on.

At a 12-volt input you should get a pulse of about 20 to 30 Kv pk from the lab generator or 3.5 to 5 Kv pk from the fence charger. In the latter version, proceed as follows to decide which secondary lead should be grounded:

1. Turn power off and disconnect scope from both ends. Turn power back on, and using an insulated tool (to avoid getting zapped), bring each end in turn to the transformer case, leaving the opposite end free. One will probably draw a small arc and the other won't.

2. Turn power off and ground the one which drew the smaller arc. Connect the other to the output feedthrough.

3. Reconnect scope, apply power, observe polarity of output pulse. If you get a positive pulse, reverse the primary connections. A negative pulse jumps a longer gap from a small object (the fence wire) to a larger one (the victim) than does a positive pulse (believe it or not).

If you wish to view the current pulse, temporarily hook 0.1 to 0.2-ohm resistor in series with negative power-supply lead, and connect a 'scope across it (being careful to avoid ground loops, as can arise though test connections or via the power-line safety ground). With fence-charger option, if possible, stimulate 1-mile wire by connecting 0.015-µF, 2000-WVDC capacitor across its output. A rising waveform characteristic of *inductor charging* should be obtained—the abrupt drop at its trailing edge of course representing the cutoff of Q3 and the generation of the high-voltage pulse.

With the lab-generator version, dwell is not critical thanks to the relatively low inductance of the typical ignition-coil primary. In the fence-charger option, however, primary inductance will probably be much higher and will vary considerably depending upon your choice of a transformer. Fig. 3 shows the current waveform typical of such a primary. If it ends too soon, that is before the field has reached its steady-state value (A), then maximum output capability cannot be attained. If it ends too late (B), then average current consumption is higher than necessary. To get optimum results (C), adjust the width by changing R6 as needed.

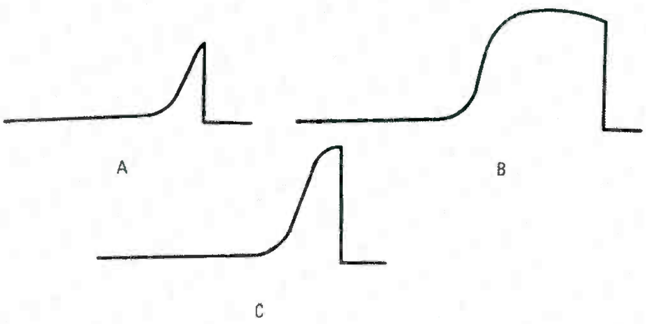


Fig. 3—For the fence-charger option, this is a current pulse seen across the small resistor in series with the supply: In A the pulse width is too short; in (B) The pulse width is too long; and in (C) the pulse width is correct.

If you know the exact value of the small resistor, given the peak voltage appearing across it you can now calculate peak current ($I = E/R$). A typical value is 4 to 6 amps.

Buttoning Up

Reinstall the circuit board, remembering to replace the lugs which ground the cabinet, pipe coupling, T1, case, etc., and to secure the coil. Test the unit once more, then assemble the cabinet.

If you're using the author's recommended cabinet with the pulse-generator option, leave the high-voltage cable and nipple connected to the coil, passing the other end through the hole in the cabinet top as you bring the top into place. Slide the front panel up into the cabinet top. Now, close the cabinet by swinging the left side down. Moderate force is required to push the coil nipple into the hole. Make sure tongues in the cabinet top engage the mating slots in the bottom, and hold it together with one hand while installing the cabinet hardware with the other. Turn the five bottom screws snug, but not tight.

Cabinet assembly of the fence-charger version is easier cause you don't have to cope with the coil neck or connections to the front-panel potentiometer. For outdoor use, however, you will have to caulk seams against the weather. Silicone rubber is good for that purpose because it can later be peeled off if servicing becomes necessary. Acrylic rubber makes a better seal, but because it sticks more tenaciously, it makes later disassembly more difficult.

Carefully apply a very thin bead first along the inside edges of the opening in the top front, and install the front panel. Then, again very carefully and sparingly, apply a bead along the slot in the cabinet bottom; and finally, assemble the top and bottom. Depending on your skill in the application, there may be some squishing around the seams. Surplus material around the outside can be peeled off later, after the sealant has set.

Installation and Operation

For maximum safety, you should, if feasible, connect one side of the lab-generator power supply to Earth ground. If not, then be sure to provide a return path for the spark to one of the power-supply leads. Set the RATE control to get the desired rate, and the power-supply voltage to get the desired output potential. If the output is not excessively loaded, the small in-circuit neon lamp flashes with each pulse. The auto lamp may glow dimly when the rate is set near its upper limit, but otherwise it should never light during normal operation. It does light brightly to warn you when the power leads are reversed or if there is an internal short.

If you need one pulse at a time, or bursts of pulses, connect a pushbutton or momentary switch in series with one of the power-supply leads.

If you have trouble getting lower output voltages, but not higher, the spark-plug cable may have pulled loose. When that happens, high voltage settings give what appears to be normal performance because the spark path is completed by jumping within the neck of the coil; while at the lowest voltage settings it appears not to be working at all. If that difficulty is encountered, pull the cable out, inspect the solder joints, then simply push it back into the coil.

Fence Charger Ground

Using the author's cabinet and construction techniques, the fence-charger ground connection is made through the pipe fittings sticking out of the bottom end of the chimney. An Earth-ground means is provided by an ordinary $^1/_2$-in. water pipe. The length should be chosen to permit the pipe to be driven at least 3 ft deep, but the deeper the better, depending on estimated conductivity of the soil; with enough pipe rising above ground to place the unit at a comfortable viewing level. Thus a pipe of at least 7 ft is required. A more effective ground can be had by adding salt to the soil.

Temporarily screw a pipe cap onto top end so as to protect the threads during hammering operation. Pound it into the ground, remove the cap, and screw the fence-charger assembly onto the end. Connect the fence and battery to the unit.

The neon lamp flashes with each pulse to assure you that everything is working okay, except in absolute darkness, since a few photons of light are necessary to *prime* the neon. That apparent drawback, however, has the definite earmarks of an advantage because when it's pitch black the unit cannot call itself to the attention of an interloper.

To test the battery it is only necessary to momentarily reverse the battery leads and observe how brightly the protective lamp lights. Again, however, don't leave it connected backward.

If you are cautious in building and using this project it can serve a wide variety of uses and provide many hours of service. Be careful and use common sense. ■

"On the contrary, I'm quite impressed that you can change channels with your toes."

STUNGUN

continued from page 33

board is shown in "PC Service;" alternatively, a PC board can be purchased from the source mentioned in the Parts List. If you build the circuit on a perfboard, follow our parts layout closely; otherwise you may have problems with arcing.

Due to the critical nature of the three transformers, we are not providing details on winding them. They are available from the source mentioned in the Parts List.

Referring to the parts-placement diagram in Fig. 2, and the photos in Fig. 3 and Fig. 4, mount all components except C2, T1, T2, and T3 on your board. Note that several components mount on the foil side of the PC board: C1, D7, and J1. Do not install those parts yet either.

After all components (except those mentioned above) are installed, check your work very carefully, especially D1–D6, R1, and R3, because T1 will be installed above them, and there will be no chance to correct errors later. After you're absolutely sure that they're installed correctly, install T1 with the black mark on the windings mounted toward C2.

Foil-side components

One of J1's tabs shares a hole on the PC board with resistor R8, which should be mounted already. Solder the tab of J1 that corresponds to the tip (not the barrel) of an inserted plug to the indicated pad. Then mount C1 and D7. Last, solder a 1¾-inch piece of 18-gauge wire to the barrel pin of J1, and connect the opposite end of that wire to the appropriate pad beneath S1, the FIRE switch.

Preliminary check-out

WARNING: While measuring voltages and currents, keep your face, hands, and all metallic objects away from the high-voltage end of the stun gun. If if you want to prod a component, use a non-conductive rod such as a plastic TV alignment tool. High voltage behaves very differently than low voltage. Any material that retains moisture can serve as a discharge path. THAT INCLUDES WOOD! Also, never work on or use the unit when your hands are wet.

Connect a voltmeter (set to a 1000-volt DC range) to ground and to the output of the D3–D6 diode bridge. Then power up the circuit using either a freshly-charged battery or an external supply capable of delivering 9.8 volts at one amp. If everything is working properly, you should measure about 400-volts DC at the output of the bridge when you press S1.

If you don't measure that voltage, connect an oscilloscope to the collector of Q1 or Q2. You should see a squarewave with a period of about 100 μs. If that waveform is not present, the switching circuit is not operating correctly. *Remove power* and check your wiring again. *Do not debug the circuit with a battery connected!*

Resistor R6 controls the rate at which the UJT (Q3) discharges, and R3 controls the rate at which C2 charges. You can experiment with the values of those components if you are not satisfied with the circuit's high-voltage output. R3 can vary from 2.2 to 4.7K. You can also experiment with the value of C2. See Table 1.

After the circuit is operating correctly, attach J1 to the board with high-voltage potting compound or RTV. And before you mount the circuit in a case, make sure there's no arcing on the PC board. If there is, you can stop it with a liberal application of RTV, paraffin, or epoxy.

Conclusion

The stun gun's discharge is very impressive. The spark is highly visible and each discharge produces a sharp, resounding crack. The circuit can teach you much about voltage-multiplying circuits and power supply design. But don't ever forget that the stun gun is not a toy. It can cause much damage to both you and others. Never leave it lying around where children, pets, or anyone unfamiliar with how to use it can handle it. It's a good idea to remove the battery before storing the stun gun. Above all: be careful! **R-E**

SOLID-STATE TESLA COIL

continued from page 56

fahnestock clips are mounted to the board on ½-inch aluminum spacers, using #6-32 hardware. A 1¾-inch length of #12 solid-copper wire is fitted in one end of a 1¾-inch piece of dowel rod to produce the adjustable terminal of the spark gap. The other gap wire must be made from a #26 or smaller wire for the gap to perform properly.

Place the four dowel rods in the baseboard, position the 9-inch deck on top, and press down until all four dowel rods are even with the top of the circle. Connect the bottom of L1, using a short length of #12 wire, to the main grounding point (see Fig. 3). Also connect the bottom end of L2 to the same point.

A separate vertical ground rod can be positioned on the deck (see photos) for additional experimenting. The vertical ground was made from a 29-inch length of ¼-inch threaded rod, and covered with a section of aluminum tubing to give a neat appearance. At the top, a binding post was mounted for versatility. That allows the ground rod to accept a number of different experimental items.

Checking It Out

Before we start this stage of construction, a word of warning is in order:

Do not touch or make any adjustments while power is applied to the Solid-State Tesla Coil. Remember that you'll be dealing with high voltages, so caution is the watchword.

With the power off, set the spark gap for a ⅛-inch gap and connect the tap clip to turn 15 or 16. Plug in the power cord and turn S1 on. A loud electrical discharge should be heard, and a blue brush discharge should be seen at the top of the pointed screw that's connected to L2.

Turn the power off and move the tap wire (that's connected to L1) up or down one turn at a time until the greatest blue discharge is obtained at the top of L2. Form a 1½ to a 2-inch vertical gap between the ground rod and the top of the coil to aid in tuning up the coil. When the Tesla coil is properly adjusted, it should produce a 2-inch arc between the top of L2 and the ground terminal.

The coil discharge is most dramatic in a darkened room, and you should be able to light a fluorescent lamp at a distance of about two feet from the secondary coil. A clear incandescent lamp moved to within a few inches of the secondary coil will produce a beautiful blue lightning array from the lamp's filament to the outer edge of the glass envelope. Neon lamps glow around the coil without wires. Experimenting with the coil can be an almost endless adventure. But remember, always put safety first! ■

PLASMA DISPLAY

continued from page 52

used if the display does not completely ignite or is weak.

- Connect the high-voltage output (the black HV lead) to the beginning of the display. *CAUTION: Always route that lead away from any conductive object. The lead must be short and direct.*
- Set R13 fully clockwise (longest trace time). Set R12 fully counterclockwise (minimum display). Set S1 to its INTERNAL position.
- Connect the device to a polarized power outlet and adjust R12 for a full-length neon display. (It will take several trace periods to obtain the correct setting.)
- Adjust R13 for the desired speed of the trace time. Note that a point on the control will cause the system to shut down. Maximum speed occurs right after that point.
- Allow the unit to cycle for about an hour. Remove power and check the temperature of power transistor Q1. It

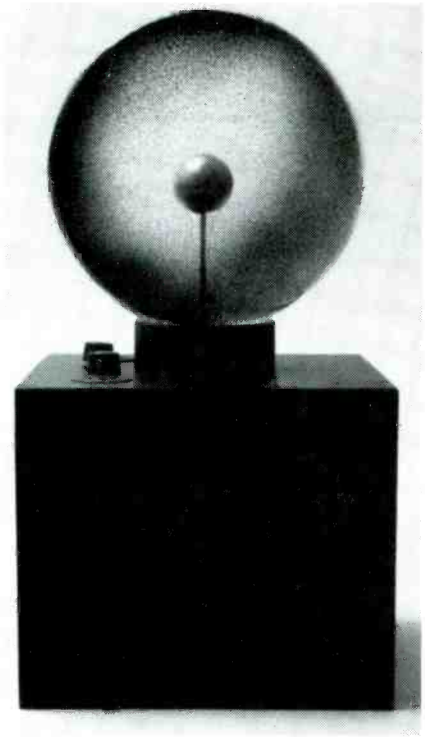


FIG. 7—THE COMPLETED DISPLAY should resemble this author's prototype. Be sure that the globe base you select can support the size of plasma globe that you intend to use.

should only be warm to the touch. If it is running hot, it may be necessary to decrease the setting of R12.

The length of the display that can be operated will vary considerably. The kind of gas, the diameter of the glass tubing, and stray capacitance can greatly effect operation. It might be necessary to experiment when energizing larger displays.

Modulation effect

Set S1 to its AUDIO position and feed in a signal from the 8 ohm output of a radio or a stereo. Adjust the radio's volume for a display that seems to track the intensity of the sound.

Special note

The output energy of this device is 25 kHz at approximately 10,000 volts. For safe operation, adequate insulation of the output lead is mandatory for safe operation. Silicon or teflon insulation having a rating of at least 25 kV is recommended. Route the output lead so it isn't near any conductive objects, and splices should be sealed in high voltage putty or silicon rubber. R-E

BUILD THIS

THOMAS A. NERY

VIDEO-EDIT CONTROLLER

Here's a low-cost device for professional-quality video editing.

EXCITING HOME VIDEOS USUALLY REquire heavy editing—leaving the deadly-dull stuff "on the cutting-room floor." Unfortunately, the commercial video-edit controllers needed for *pro*-quality editing are usually priced beyond the budget of most video hobbyists, which means that most videos usually end up looking like just another home movie—or worse.

But there *is* a low-cost alternative to commercial video editing. It's our video-edit controller; a relatively simple device that requires the use of only two VCR's, or a VCR and camcorder, to edit video tapes electronically like a professional.

Home videos are usually edited by pausing the recording VCR at the point where recording is to begin, and pausing the source (player) VCR at the point where the new video starts. Once satisfied with the edit points, both pause buttons are released simultaneously to allow the playback and recording to start.

Although the procedure for "pause-editing" is theoretically correct, real life proves that theory and practice are not one and the same, because machines—particularly when dealing with precise timing—don't necessarily function the way we would like them to. The variations in the pause-timing characteristics of VCR's and camcorders usually result in several seconds of lost picture at the edit.

Editing controller

But use our video-edit controller and you will eliminate the lost snatches of picture when editing. That's because our controller allows video editing by frames, rather than by time periods.

To understand the operation of the video-edit controller, it's necessary to understand why several seconds of video are lost when using the simultaneous-pause-release method of videotape editing.

When the source (player) VCR's *pause* is released, the machine starts playing slightly after the point where the tape is positioned. The "slightly after" is a function of the tape getting up to speed before the video is output. The recorder, on the other hand, must synchronize itself to the source. To accomplish that, most newer VCR's—as well as camcorders—use a feature known as *preroll*.

Preroll

Preroll means that the recorder is rewound a predetermined number of frames, put into the play mode, and then shifted into *record* at the point where the recording is actually to start. When editing by dual-pause control, the additive "true start" delays of the source and record machines usually result in several seconds of missed video from the source.

There is also a synchronization problem associated with the dual-pause method of editing. Specifically, the recorder is being asked to synchronize itself to two different sources: the video prior to the source-VCR's getting up to speed, and then the video once speed is attained. That complicates the recorder's operation, and can result in video-breakup at the edit point.

Pro-quality editing

On the other hand, our video-edit controller does not depend on pause controls: It edits in a way similar to some professional editors. First, it rewinds the source-VCR for a fixed amount of time and then switches the VCR to the *play* mode. At the appropriate time, while the source-VCR is playing, the controller starts the recording VCR. The recording VCR uses up its preroll, comes up to speed, and then switches to the *record* mode. If all the timings are correct, the source-VCR is feeding the selected edit frame at the precise instant that the-recording VCR switches to the *record* mode.

Overall editing accuracy is dependent on the ability of the source- and recording-VCR's to consistently repeat their operations in exactly the same time periods. Since the recording- VCR's preroll is designed by the manufacturer to always start the recording after a fixed time interval, it is the source-VCR that's the main synchronizing problem.

Review to time

But we can make the source-VCR's rewind timing more or less consistent if we use the machine's *review* function—rather than the *rewind* function—to back up the tape. That is due to the fact that *review* is a *capstan-driven* function that always operates at a predetermined multiple of the nor-

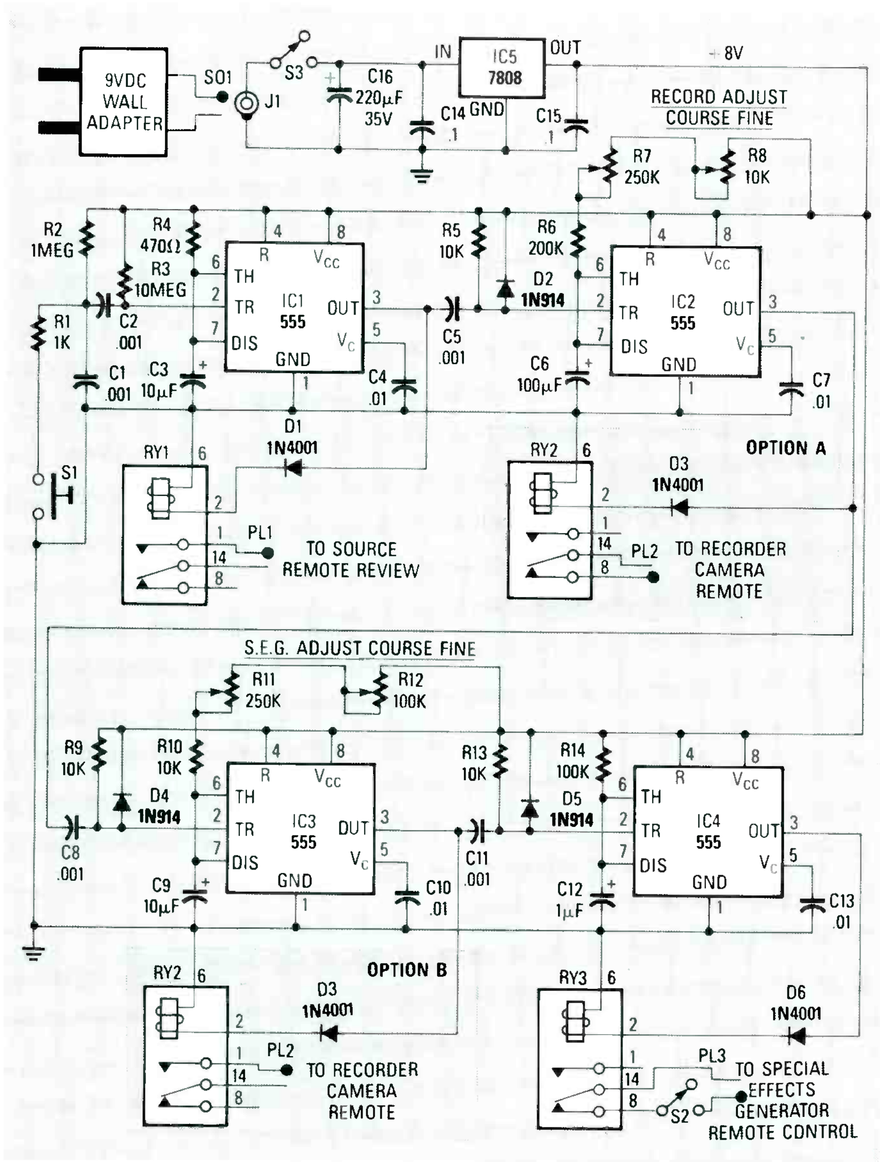


FIG. 1—THE VIDEO-EDIT CONTROLLER basically consists of four similar timer circuits. Both the OPTION A and OPTION B circuits for relay RY2 are built into the PC board. Simply plug the relay into the appropriate socket.

mal play speed. During *review*, the tape is always backed up the same length per period of time; whereas, during *rewind*, the actual amount of tape backed up per unit of time depends on how much tape is left on the supply reel.

In addition to the edit function, the controller also provides a switching circuit for a special-effects generator, such as you might use to cause a fade from, or to, black at the correct time.

How it works

The edit-controller, shown in Fig. 1, consists of four monostable timers. Each timer has the capability to drive a relay, although only three relays are used to interface to the controlled devices. To accommodate different remote-control circuits, relay RY2 can be installed at the locations labeled OPTION A, or OPTION B—more on that later.

The edit operation is started by closing switch S1, which causes a rapid drop to ground of the voltage across capacitor C1. C1's discharge causes a negative-going spike through C2, which triggers timer IC1. The triggering of IC1 causes RY1's contacts to close, and they remain closed during IC1 timing period. The timing period is determined from the equation:

$$\text{time} = 1.1(R4 \times C3)$$

The source-VCR's remote-control *review* jack is connected to RY1's contacts through PL1. The VCR will be held in the *review* mode during IC1's timing period. At the end of the timing period, RY1 is released, its contacts open, and the VCR automatically switches from the *review* to the *play* mode. Also at the end of the timing period, IC1 triggers timer IC2.

Timers IC2–IC4 operate in a similar manner as IC1, the major difference being that IC2 and IC3 have *course* and *fine* adjustments for tweaking the time-period. Also, RY2 can be driven either by IC2 or IC3, depending on the requirements of the recording-VCR. If the recorder is started by opening its remote control, RY2 is installed at the OPTION A location. If the recorder is started by closing its remote control, then RY2 is installed at the OPTION B location.

The editor's timing constants are a function of both the type and the speed of the VCR's. While the principles can be applied to any combination of VCR's and speeds, the prototype assumes VHS machines operating at the SP speed. Should a different combination be desired, it will be necessary to adjust the timing components for the selected speed.

Construction

Before building anything, you must make certain that your source-VCR is compatible with the controller. Place a tape in the VCR and start the play. After about 30 seconds, depress the *pause* button. Once the VCR has come to a complete stop—as indicated by a frozen frame on the screen—press and hold the *review* (or dual-function *review/rewind*) button for about five seconds and then release it. The VCR is compatible with the video-edit controller if it rewinds and then automatically enters the *play* state when the *review* button is released. If releasing the button did not cause the VCR to switch automatically into the *play* mode, then it can't be used with the controller.

If the VCR passes the compatibility test, you must make a review-switch modification. Disconnect the VCR from the powerline, open the VCR's case, and locate the *review* switch's contacts. Use a VOM to verify that you have selected the correct contacts. (In some VCR's the *review* switch has DPST contacts that are wired in parallel.) Solder a pair of thin, insulated, stranded wires (i.e. 22 gauge) to the switch's contacts. Then route the wire to an accessible blank portion of the VCR's rear apron. Carefully drill a hole in the apron for a miniature phone jack that will mate with PL1. If the cabinet is metal, use two contacts of a 3-circuit jack and change PL1 to a 3-circuit miniature phone jack. (The plug's *sleeve* connection—which is connected to the VCR's grounded cabinet—should not be used.)

Complete the modification by soldering the wire pair to the phone jack. Then, replace the VCR's cover. At that point, the VCR should be tested for normal operation. Check the modification for a short-circuit if the VCR doesn't operate correctly.

The controller is assembled on a PC board, for which a full-scale template is provided in PC service.

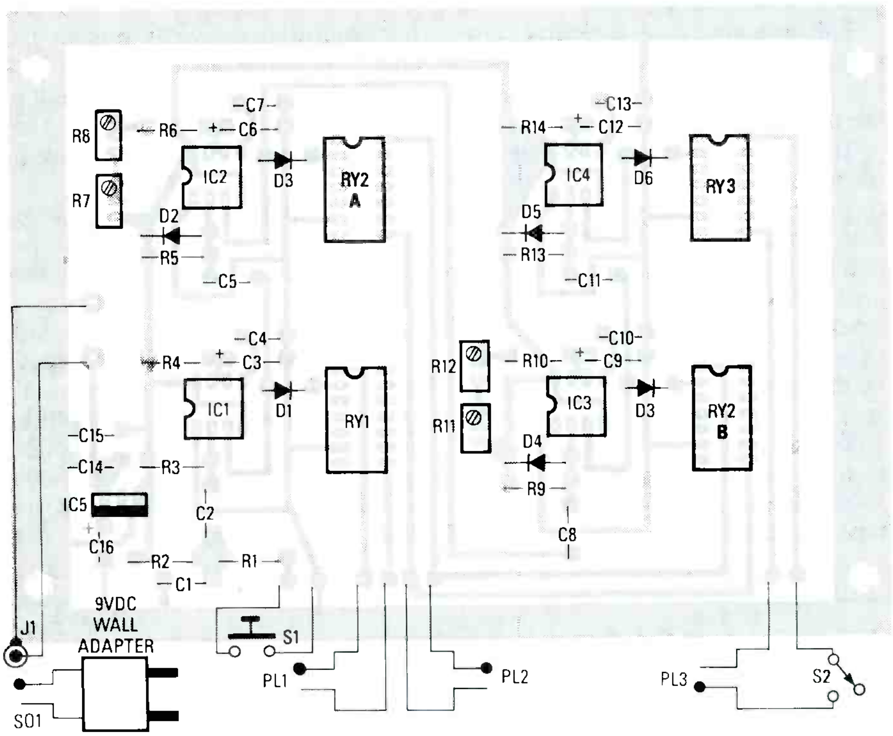


FIG. 2—THE CONTROLLER'S PARTS LAYOUT. Select only one location for RY2; the other remains empty.

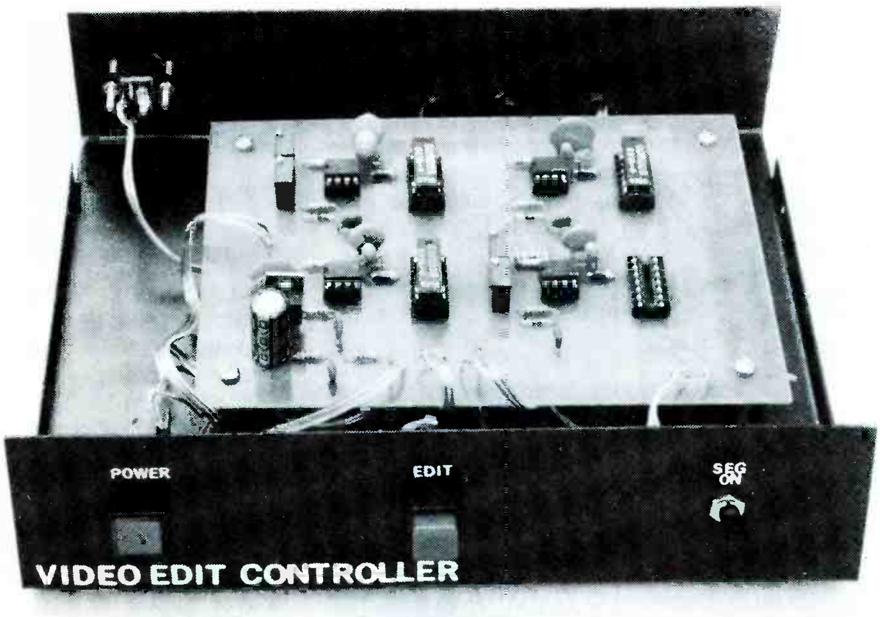


FIG. 3—THE PRINTED-CIRCUIT BOARD is mounted in the cabinet using spacers at each mounting screw. Make certain that there is some kind of wire between the PC board's ground trace and the metal cabinet.

PARTS LIST

All resistors 1/4-watt, 10%, unless specified otherwise.
R1—1000 ohms
R2—1 megohm
R3—10 megohms
R4—470,000 ohms
R5, R9, R13—10,000 ohms
R6—200,000 ohms
R7, R11—250,000 ohms, multiturn potentiometer
R8, R12—10,000 ohm, multiturn potentiometer
R10—47,000 ohms
R14—100,000 ohms
All capacitors rated 10 volts, unless specified otherwise.
C1, C2, C5, C8 ,C11—0.001 µF, disc
C3, C9—10 µF, tantalum
C4, C7, C10, C13—0.01 µF, disc
C6—100 µF, tantalum
C12—1µF tantalum
C14, C15—0.1 µF
C16—1000 µF, 35 volts, electolytic
Semiconductors
IC1–IC4—555, timer
IC5—7808, 8-volt regulator
D1, D3, D6—1N4002, silicon rectifier
D2, D4, D5—1N914, rectifier
Other components
J1—male power-supply mini-jack to match SO1
PL1, PL2, PL3—miniature phone plugs to match VCR equipment
RY1, RY2, RY3—SPDT DIP relay, GORDOS 831A-4
S1—N.O. momentary switch
S2, S3—SPST switch
SO1—power socket, part of 9-volt wall adapter
Miscellaneous
Printed-circuit materials, WA1—9-volt DC wall adapter, DIP sockets, cabinet, wire, solder, etc.

The parts layout is shown in Fig. 2. Notice that there are two locations—labeled A and B—for RY2. If you use DIP sockets for mounting the relay, you will then be able to switch RY2's location easily to conform with the remote-control circuit of the associated VCR.

Figure 3 shows how the prototype's fully assembled PC board looks when it's finished, and also how it is installed in its cabinet.

VCR modification

The controller requires a special, though quite simple, modification to the source-VCR's *review* switch. But be aware that opening the case of the VCR and installing the modification will void the warranty (if it is still in effect).

Remote jack

The recording-VCR or camcorder should have a camera-controlled remote jack. Also, for best results the recorder should also perform a preroll operation prior to initiating the recording action. That feature can often be verified by the recorder's user's manual.

The recording-VCR will run-record when the camera-controlled remote jack is switched by RY2's contacts. The location of RY2 is determined by the requirements of the remote jack. If recording is started by opening a contact, RY2 should be installed in the OPTION A location, which is controlled by IC2. If recording is started by closing a contact, RY2 should be installed in the OPTION B location, which is controlled by IC3.

Calibration

The only items required for calibration are two prerecorded tapes. One is a *source* tape, which contains a clean transition of scenes. The tape can easily be made by making an off-the-air recording of about five minute of program up to a commercial, the commercial, and then five minutes of program. The commercial is only needed so that you can easily recognize a scene transition—from program to commercial and vice versa.

The other tape is the recording tape. It should be pre-recorded with about five minutes of programming.

Connect PL1 to the *review jack* that was added to the source-VCR. Connect PL2 to the recording VCR's camera-controlled remote jack.

Roll the source tape, locate the start of the commercial as closely as possible, and place the source recorder into the *pause* mode.

Then play the second tape in the recording VCR. Locate the end of the recording, set the recorder to *pause*, then activate the record function.

Set the *coarse* adjustment associated with RY2 (R7 or R11) to its smallest value and the *fine* adjustment (R8 or R12) to the center of its adjustment. Press S1. Each of the recorders will do its thing—controlled by the video-edit controller.

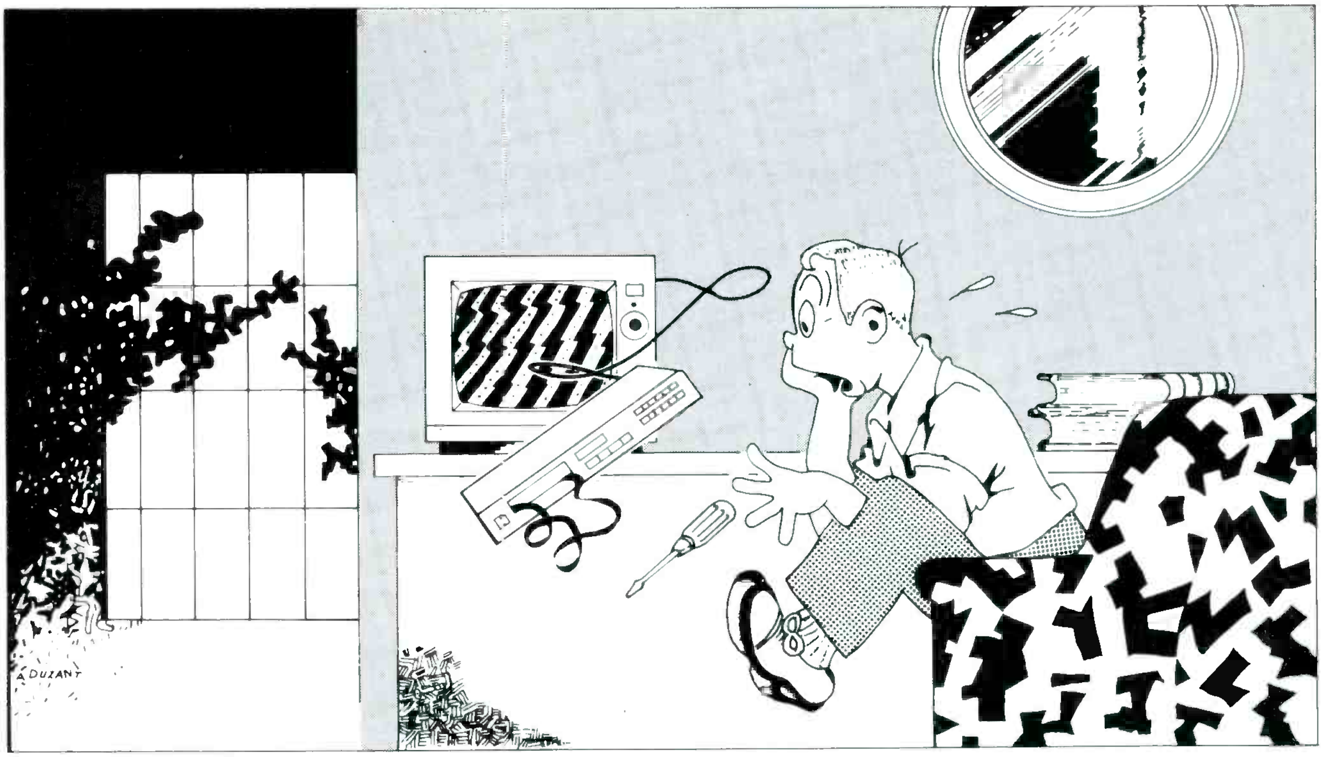
After the recording VCR runs for about 30 seconds, stop and rewind its tape to the point where the recording was inserted and press the *pause* button. Then release the *pause* button and time the playing time from the source-tape's entry point until the source-tape's commercial appears.

Using the equation given earlier, calculate the combined resistance value of R7 and R8 (or R11 and R12) that is needed to eliminate the pre-commercial timing. Set the *coarse* adjustment to that value.

Repeat the procedure until the editing controller correctly locates the edit point within about one-half second. At that point, the procedure should be repeated once more, using the *fine* adjustment, until the edit point is "on the nose."

That completes the calibration. A similar method is used to calibrate the switch-in of a special-effects generator via PL3.

Now you're ready to edit some video tapes, and it may take a few tries to become familiar with the system. However, in no time at all, you'll be getting rid of unwanted commercials, splicing together your favorite movie scenes, or removing scenes that you don't want your kids to see. **R-E**



VCR SERVICING BASICS

This quick six-step approach can help you to isolate VCR failures.

BRIAN PHELPS

PEOPLE OFTEN HAVE QUESTIONS DEALING with VCR problems. One of the most frequent is: "How can I tell which circuit in my VCR is causing the symptoms I see on my TV or monitor?" This article will provide some of the answers to that question, and also discuss some valuable servicing tips.

One reason why it's sometimes so difficult to isolate a VCR failure is that almost any circuit can cause many different problems, and, quite often, the symptoms are misleading. Sometimes something unusual, such as a shorted switching transistor or a capstan- or cylinder-servo problem, may confuse a servicer into replacing a good component. Therefore, to avoid any unnecessary procedures, some kind of step-by-step process is required.

A step-by-step method

One way to isolate problems is by checking out the unit in the following order:

1—Visual inspection
2—Check microprocessor
3—Servos (cylinder and capstan)
4—Luminance
5—Chrominance
6—Audio

Visual inspection

Looking for the obvious includes things such as foreign objects that may be jammed inside the VCR. (You would be surprised what children might manage to stick inside an appliance). The tracking control may be out of the center-detent position, or the consumer may have locked-up their VCR in a program mode. At any rate, failure to check for the obvious problems first can send you on a wild goose chase.

Microprocessor analysis

There are some very basic things to check that concern the microprocessor.

- The B+ supply for DC level, ripple, and any high-frequency glitches.
- The clock input for any DC voltage that should be there, the amplitude of the clock signal, and the frequency.
- The data inputs and outputs. We're mostly concerned that there is activity on those lines, and that the activity changes when different functions of the VCR are selected, rather than how the actual signals look.
- The reset pulse; it usually occurs between 0.5 and 1 second after B+ is applied to the microprocessor. If the reset pulse is absent, the microprocessor may start its routine at any point, yielding some strange symptoms—if anything at all.

Servos

When troubleshooting servos, it is often helpful to use a block diagram (see Fig. 1). Before you start, however, you must decide which servo or servos you should be looking at.

You can determine if the problem is caused from the capstan or the cylinder servos by listening to the audio. The audio quality is dependent upon the rate at which the tape is being pulled by the capstan across the audio head. If the speed is incorrect, the

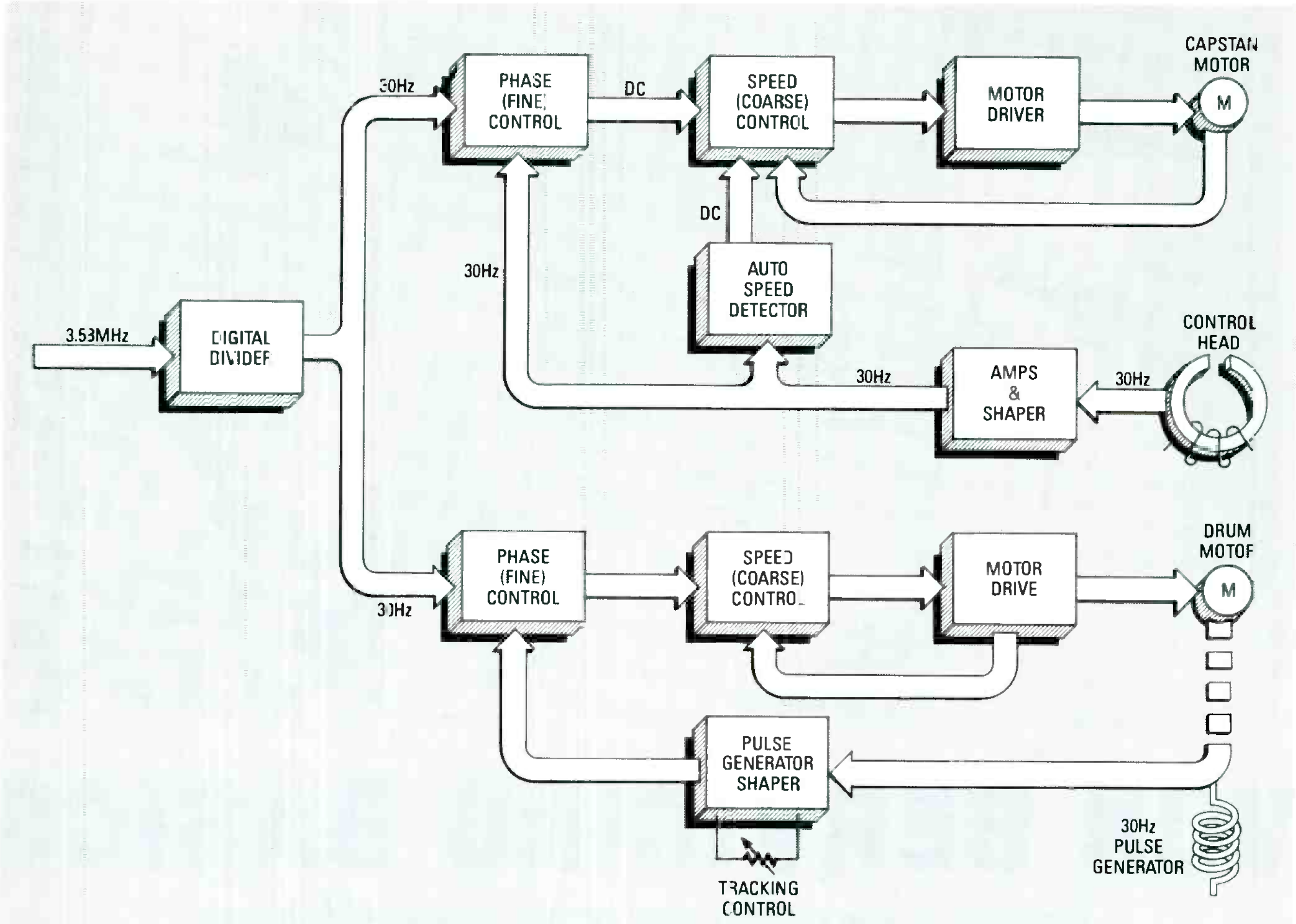


FIG. 1—THE BLOCK DIAGRAM of the servo circuits inside a VCR. A block diagram is often very helpful in troubleshooting because it shows you how the different sections of a circuit are interconnected.

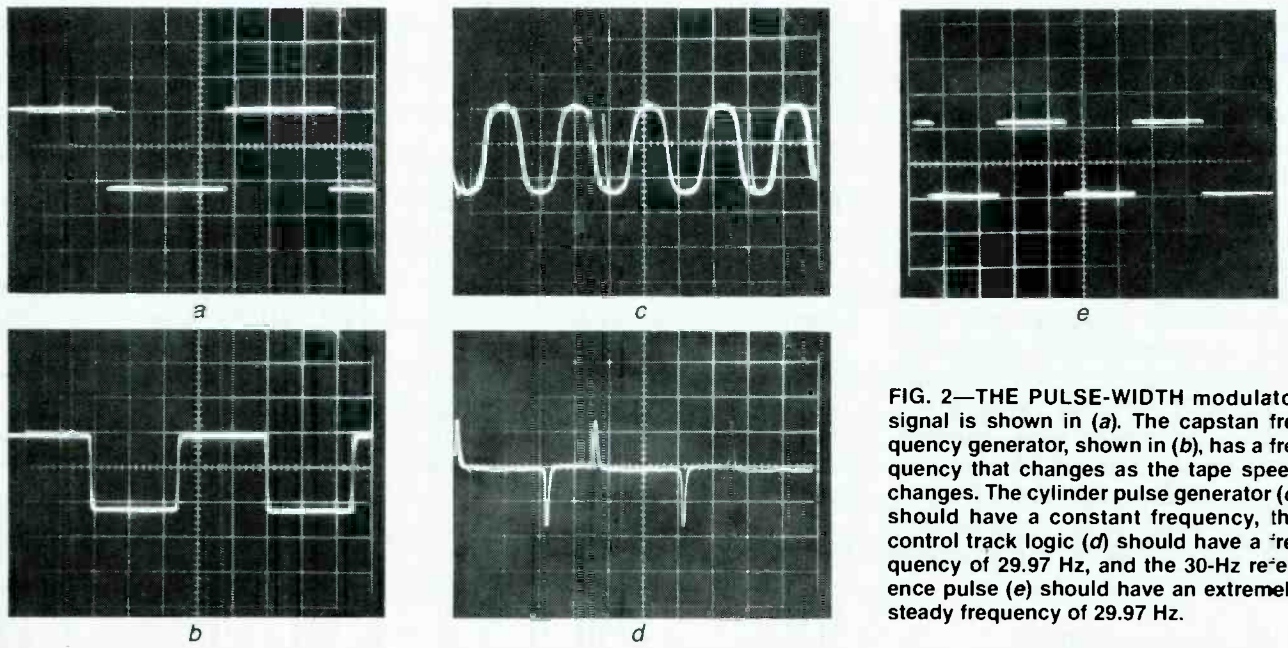


FIG. 2—THE PULSE-WIDTH modulator signal is shown in (*a*). The capstan frequency generator, shown in (*b*), has a frequency that changes as the tape speed changes. The cylinder pulse generator (*c*) should have a constant frequency, the control track logic (*d*) should have a frequency of 29.97 Hz, and the 30-Hz reference pulse (*e*) should have an extremely steady frequency of 29.97 Hz.

audio will sound distorted. But, if the audio sounds good, you should look at the cylinder servo circuitry.

When analyzing the servo circuits, there are some key signals to check. Those include the pulse-width modulator signal (PWM), the capstan frequency-generator signal (FG), the cylinder pulse-generator signal (PG),

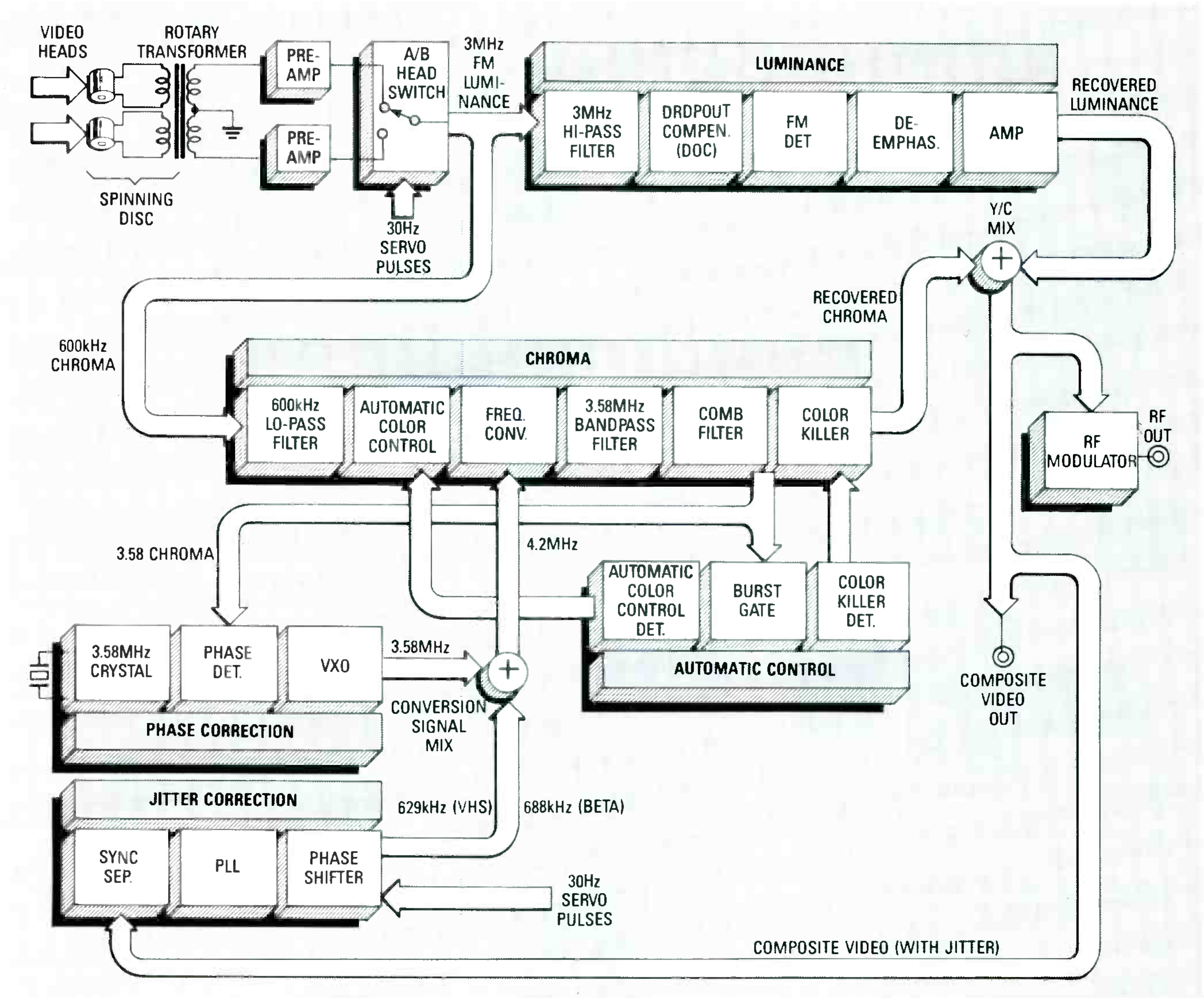


FIG. 3—THIS BLOCK DIAGRAM shows the video-processing circuitry inside a VCR. The circuitry inside all VCR's is similar.

the control-track logic pulse (CTL), and the 30-Hz reference signal. Figure 2 shows how those signals should look for proper servo operation.

Luminance circuitry

The luminance circuits typically produce failures ranging from noisy video to a lack of video. However, failures such as those can also be caused by anything from the video-head circuitry to the RF modulator.

A good approach to troubleshooting luminance circuits is to inject a signal that would be present at various test points if the VCR were operating properly. That way you can determine which circuits are and aren't working by checking every point where the signal is supposed to appear.

One example of troubleshooting by using signal injection is substituting a known good signal in place of the one coming from the video heads (see Fig. 3). Sencore's *VC63* VCR test accessory provides a signal to inject into the video preamps. (You should use equal levels for both preamp inputs and if one of the inputs needs a greater signal level, that's the path to follow.) That simple procedure tells you whether or not the preamps were receiving a good signal from the video heads. If everything checks out after the signal is injected, that would probably indicate a bad video head.

If, after injecting a signal into the preamps, there is still a problem, the chances are good that the video heads are all right. For example, suppose that one of the playback/record switching transistors has a short. That would put 10 ohms between the playback path for one of the heads and ground. The resulting picture on the monitor is similar to that of a bad video head, and many repairmen would prematurely clean and/or replace the video heads—a procedure that is costly and time-consuming.

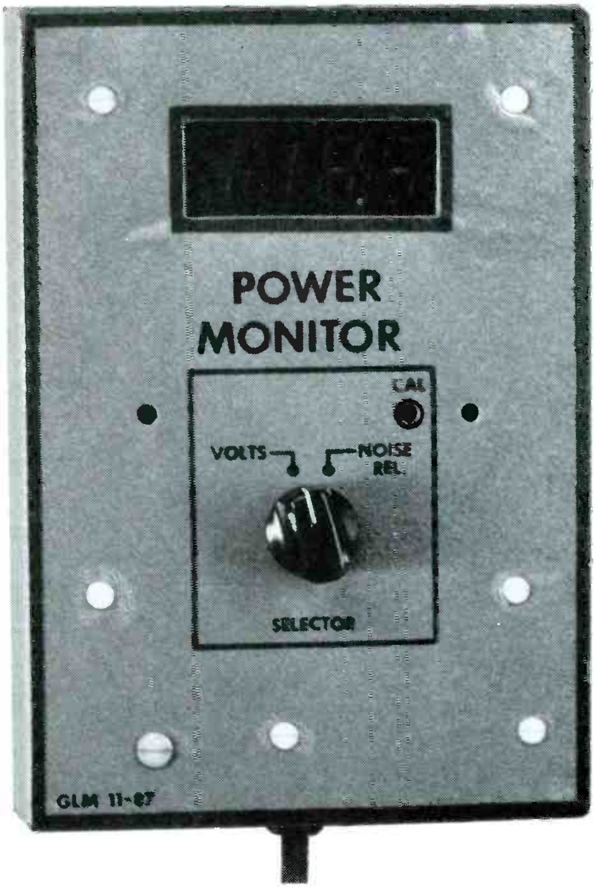
Chrominance

Defects in the chrominance and audio circuits can be detected by looking at the color or listening to the audio. Quick checks for the chrominance include testing the 3.58-MHz oscillator, the 4.2-MHz conversion signal, the 30-Hz and 15-kHz reference signals, and the 629-kHz VHS color subcarrier.

If you troubleshoot a VCR following the procedures in the correct order, you can quickly and accurately isolate defective stages in the circuitry. After a couple of trial runs on known-good VCR's, you should be able to tackle the "Tough Dog" problems that you may come across. Just be sure that you learn any new techniques and procedures on a known good unit, so that you are not led astray by erroneous readings and strange results. **R-E**

BUILD THIS

POWERLINE MONITOR



Solve those power problems with this power monitor!

GARY McCLELLAN

UNTIL RECENTLY WE SAFELY could give little thought to the quality of the AC power coming out of our wall outlets. But the world is changing, and so are the power requirements of electronic equipment. Noisy, fluctuating, line power may not bother lamps, irons, or other appliances, but dirty power can raise havoc with sensitive electronic devices such as personal computers. If you have ever lost data or "trashed" a program running on your computer, you may have been a victim of a power brownout or excessive line noise, without realizing it. That could cause you to waste time troubleshooting the unit for an intermittent problem, when all that was wrong was a power glitch.

Power monitors

A power monitor lets you keep an eye on the condition of your AC power. At a glance you can read the line voltage and be aware of brownouts and surges that might damage your equipment. It even lets you monitor the relative noise level on the line; a feature that helps you spot high-noise conditions that cause equipment problems. Also, as we'll show later, a power monitor's noise-level feature lets you test line filters quickly and easily.

Although a professional-grade power monitor having those features is usually very clostly, this month we'll show you a hobbyist-grade version of the device that can be built for as little as $45. Even so, if precision components are used it can read the powerline voltage down to tenths of a volt with an accuracy that exceeds ±0.5%. Also, relatively large 0.56-inch LED's displays make it easy to read the line voltage and relative noise levels at a glance.

How it works

The schematic of the circuit is shown in Fig. 1. The dashed lines represent the edges of a printed-circuit board. The lettered terminals on the dashed lines correspond to lettered solder pads on the PC-board to which the external components are connected. For example, switch S1-b connects to solder pads on the PC board labeled A, B, and C.

The power monitor is a simple, straightforward device using an Intersil ICM71076 digital voltmeter (IC2), which reads 0–1.999 volts DC. For AC-voltage measurements, the applied voltage is simply rectified to DC before being fed to the digital voltmeter. For noise readings, a high-pass filter and peak-reading rectifier circuit are substituted for the conventional AC rectifier. A regulated power supply, IC1, provides the reference voltage needed by IC2.

The basic digital-voltmeter circuit is built around IC1 and IC2. DC inputs from the volts- or noise-measuring circuits appear across resistor R8 and capacitor C9. Those components attenuate and filter the signal from the volts- and noise-measuring circuitry. The signal is then applied to IC2, pin 31, via resistor R11 and is measured. (Resistor R11 and capacitor C10 provide overload protection for IC2.) The applied voltage is converted by IC2 into driving signals for displays DSP1 and DSP2.

A key part of the digital voltmeter is a reference voltage source from IC1. It determines the overall accuracy of the unit because IC2 makes measurements by comparing a known reference voltage with the unknown input. In this instance the reference voltage is provided by adjustable voltage regulator IC1, a low-cost adjustable voltage regulator. The regulated output voltage of 1 volt appears at the wiper of potentiometer R6 and is applied to IC2 pin 36. Because IC1 will not regulate the output voltage if too little current is drawn, resistor R4 ensures

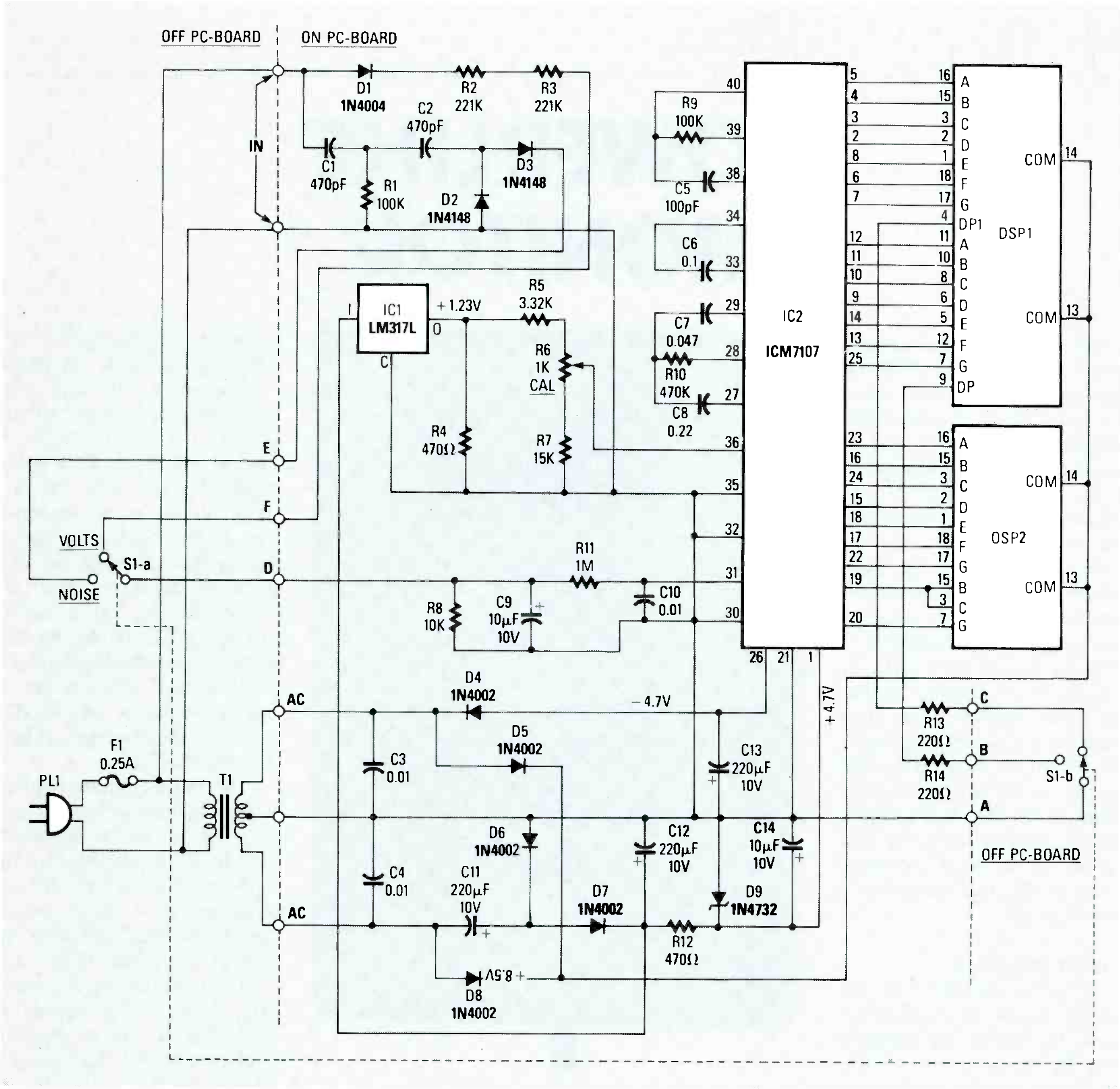


FIG. 1—THE POWER MONITOR INDICATES either the applied line voltage or the powerline noise. The noise level is determined by passing the line voltage through high-pass filter C1/R1/C2.

regulation by providing a minimum output current drain for IC1; the current loading caused by R4 ensures that IC1 will provide a constant 1.23-volt output.

The AC-voltage circuit is simple and easy to understand. Line voltage appearing across the IN terminals on the PC board is rectified by diode D1. The pulsating DC output from D1 is scaled down to the 1.2-volt range by resistors R2, R3, and R8. Capacitor C9 filters the pulsating DC so it can be measured. For improved safety and reliability, two separate resistors, R2 and R3, are used instead of a single resistor. That is necessary because small precision resistors are usually rated at only 250 volts DC, which is marginal for use in this application.

Noise measurements

The noise-measuring circuit consists of a high-pass filter and a voltage-doubler rectifier circuit. Capacitors C1 and C2, and resistor R1, filter out the 60-Hz hum component, leaving only line noises to be measured. Diodes D2 and D3 rectify noise components into DC values. The output from D3 drives resistor R8 and charges capacitor C9 to the peak value of the noise signal.

Understand that the noise readings are relative because they are determined by the duration, waveshape, and peak value of the noise pulses. In normal use, that limitation should not cause problems for the user.

The power supply

Both regulated and unregulated voltages are used. Diode D4 and capacitor C13 provide −4.7 volts for the analog circuitry inside IC2. Diodes D5 and D8 provide pulsating DC for powering LED displays DSP1 and DSP2. Using pulsating DC for the

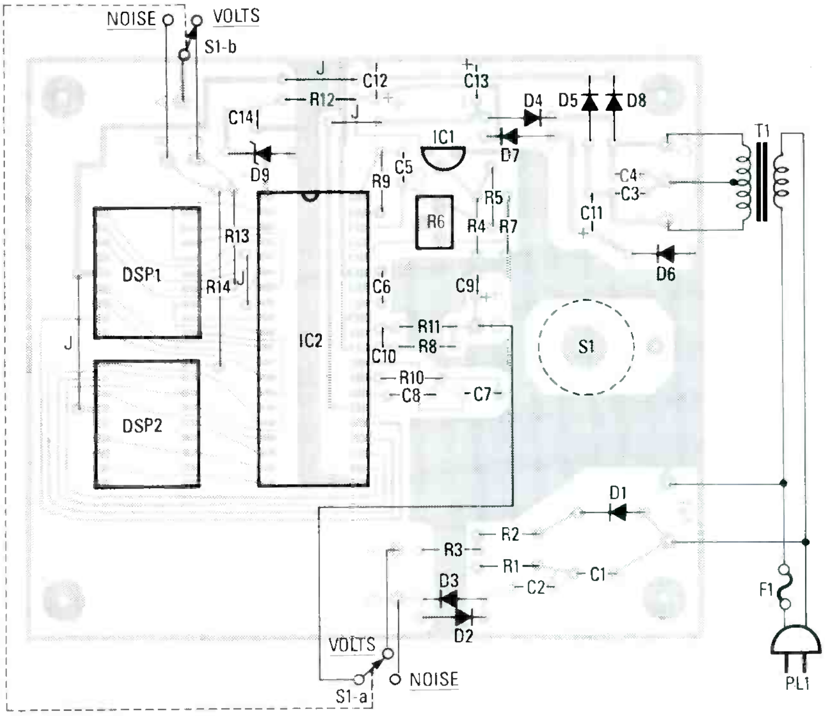


FIG. 2—USE A SOCKET FOR IC2, and do not install the IC itself until all other PC-board components are installed.

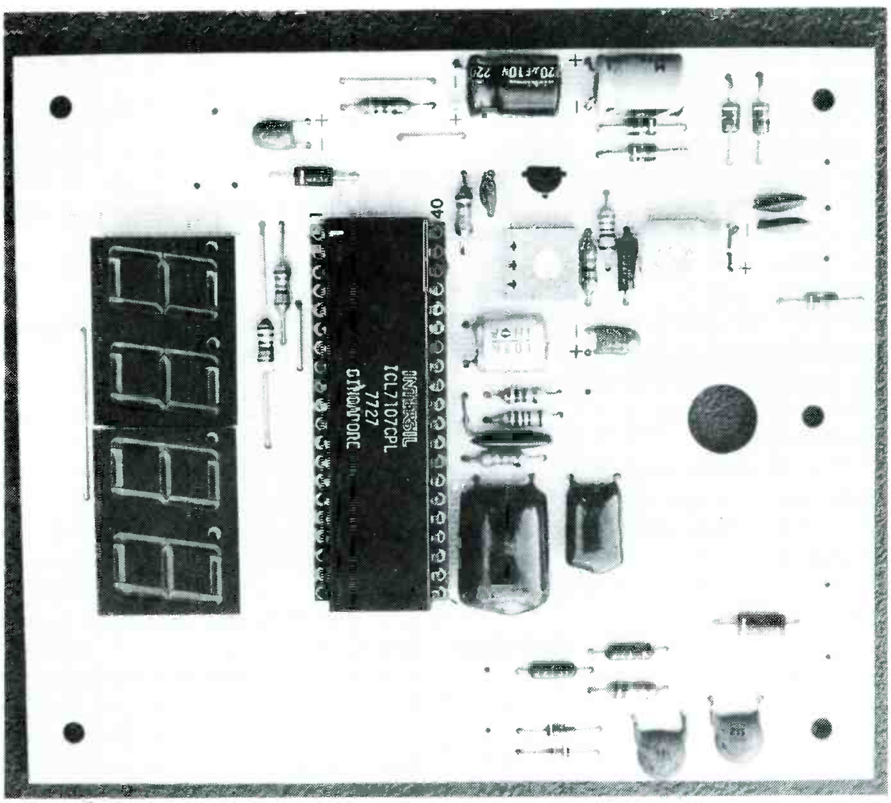


FIG. 3—FOLD THE CAPACITORS FLAT AGAINST THE BOARD to ensure clearance between the board and the cabinet. To prevent strain on the leads, bend them before soldering.

displays rather than using a steady DC voltage lowers IC2's power dissipation. Finally, a regulated +4.7-volt source for IC2 is provided via Zener diode D9.

Parts

A few parts that might prove difficult to get are the precision resistors and capacitors, and the plastic case. Precision resistors tend to be tough to buy in small quantities from local sources, but several **Radio-Electronics** advertisers do stock them. In a pinch, you can substitute the nearest value ¼-watt carbon-film resistors, but then the unit's precision will suffer. The polyester capacitors are widely available from many sources, but the electrolytic capacitors may prove difficult to get. You may prefer to use 220-µF, 16-volt units and mount them on the foil side of the board where there is more room. And finally, the

PARTS LIST

All resistors ¼-watt, 5%, carbon film unless otherwise noted.
R1—100,000 ohms
R2, R3—221,000 ohms, ⅛-watt, 1% metal film
R4, R12—470 ohms
R5—3300 ohms, ⅛-watt, 1% metal film
R6—1000-ohm cermet trimmer potentiometer (Digi-Key OFA13)
R7—15,000 ohms, ⅛-watt, 1% metal film
R8—10,000 ohms, ⅛-watt, 1% metal film
R9—100,000 ohms
R10—470,000 ohms
R11—1 megohm
R13, R14—220 ohms
Capacitors
C1, C2—470 pF, 1000 volts, ceramic disc
C3, C4, C10—0.01 µF, 50 volts, ceramic disc
C5—100 pF, 500 volts, ceramic disc
C6—0.1 µF, 50 volts, polyester film
C7—.047 µF, 50 volts, polyester film
C8—0.22 µF, 50 volts, polyester film
C9, C14—10 µF, 16 volts, radial tantalum
C11–C13—220 µF, 10 volts, radial electrolytic
Semiconductors
IC1—LM317L, voltage regulator
IC2—ICM7107CPL, A/D converter
DSP1, DSP2—Dual 0.5-inch common-anode LED display (Digi-Key P337ND or equivalent)
D1—1N4004 rectifier diode
D2, D3—1N4148 switching diode
D4–D8—1N4002 rectifier diode
D9—1N4732 Zener diode
Other components
F1—Fuse, ¼ ampere
PL1—Linecord plug
S1—3P3P rotary switch, see text
T1—Filament transformer: 6.3 VCT, 600 mA, Stancor P-6465 or equivalent part
Miscellaneous: Cabinet, printed-circuit materials, IC socket, hardware, wire, solder, etc.

plastic case is a product from LMB/Heeger, Inc. Their products are widely available from distributors, so ask your local dealer if it can be special-ordered. Otherwise, you can substitute any kind of plastic case and plastic mounting hardware.

Construction

The circuit should be assembled on a printed-circuit board. The template is provided in PC Service.

For ease-of-assembly, using Figs. 2 and 3 as a guide, mount the PC-board's components in the following order: First, the socket for IC2, then all other semiconductors. (Do not insert IC2 into its socket until the entire board is stuffed.) Next, all resistors and jumper wires; then the capacitors. To ensure clearance between the board and the cabinet's front panel, install the electrolytic capacitors and the larger Mylar/polyester types so they lie flat on the board.

Finally, install the LED displays. Position the displays so that their decimal points (dots) are at the bottom.

As shown in Fig. 4, switch S1 is installed on the foil side of the board and its terminals are connected by short lengths of insulated wire that are tack-soldered to the foils. Although S1 can be any kind of DPDT switch, a 3P3P rotary switch is recommended because they are inexpensive and generally available. (One section of the switch is not used.)

The cabinet

Finally, install the PC board and its external components in a plastic cabinet. First, drill all the necessary holes in the front of the cabinet and smooth the edges of the display cutout with a file. Then use press-on letters to label the project. Mark a location in the center of the rear case half and drill a ¼-inch hole that will be use for a hanger bracket.

To install the parts in the case, install threaded spacers on the component side of the board and then push the board into the case and secure it with nylon screws. Turn S1 fully counter clockwise and install the knob on its shaft so it's pointing to VOLTS. Then install the fuseholder and transformer T1 adjacent to the PC-board with nylon screws. Push the linecord through a hole in the bottom of the case and knot it inside the case for extra security.

Finish the project by wiring the

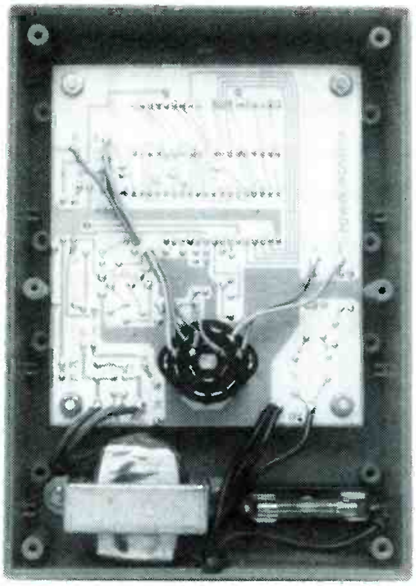


FIG. 4—VOLTS-NOISE SWITCH S1 is mounted on the foil side of the PC-board. Its connections are tack-soldered to the appropriate solder pads.

cord, fuseholder, and transformer to the board. Double check your work to make sure that the green secondary wires from T1 go to the board's AC solder pads and ground terminals, while the AC linecord go to the IN terminals.

Before closing the case, install the fuse and cut a piece of scrap plastic so that it fits over the PC-board, between the switch and the sides of the cabinet. The material provides an extra margin of safety by insulating the circuit from any screw or nail passing through the back of the case. Close up the case and you are done!

Calibration

Plug the power monitor into an AC outlet and note that the display lights up and indicates some value. If the display doesn't light, quickly turn off the power and check for a wiring error, or a solder bridge.

For best calibration accuracy you will need a high-quality digital multimeter. Set the multimeter to the 200-volt AC range and connect it to the same AC outlet to which the power monitor is connected. Insert a screwdriver through the case hole that allows access to CAL control R6 and adjust R6 until both meters read the same value.

Troubleshooting

If the power monitor doesn't work at all, or is inaccurate, and the problem doesn't appear to be a wiring error, check the power-supply voltages and the reference voltage at IC2 pin 36. If the voltages are good, either IC2 is bad or installed wrong. Lastly, if displays continually show 000, check the position of the knob on S1's shaft, it is probably wrong.

Operation

The power monitor is easy to set up and use. Simply insert a screw in the wall where you want it, then hang the project on the screw. Connect the plug and you are ready to monitor power-line conditions.

So what line voltage limits and noise levels are acceptable? As far as voltage is concerned, all equipment will work on voltages from 110–125 VAC with no problems. But as you go beyond those limits, your chances of problems increase tremendously.

Understand that typically most appliances are erratic at 100–105 volts and run hot at 130–135 volts. As for noise levels, the values are highly variable.

Generally up to a few volts of noise will cause no problems, but if the noise level exceeds 20 volts peak, which will cause the display to blank, you will probably have operating problems. (Exactly what happens due to an incorrect line voltage or high line noise depends upon the equipment you are using.)

You should be aware that the noise circuitry will also respond to carrier-current devices such as wireless intercoms and *X10*-type home-control systems or other communication devices such as line carrier modems or wireless intercoms. However, the signals from those devices should not bother other equipment, despite the high noise readings you get.

As mentioned earlier, the power monitor is useful in testing noise filters. The procedure is simple; here's how to do it. Plug the power monitor into a duplex outlet; then plug a noisy device such as a shop vacuum into the same outlet. Turn on the vacuum and note the noise level's meter reading. Disconnect the power monitor and connect the noise filter between the outlet and the power monitor. If you see the same noise-level reading on the meter as you did before you connected the noise filter, then something's wrong with your noise filter. The power monitor's reading will be lower if the noise filter is working properly. R-E

BUILD THIS SPEECH SYNTHESIZER

Make your computer truly user-friendly: Teach it how to talk!

DAVID A. WARD

Computerized voice synthesizers are turning up everywhere. Perhaps you've heard one at the grocery store check-out stand, in an automobile, or from an educational toy. Other uses include text-to-speech converters for the visually impaired, talking clocks, calculators, radar detectors, chess and other games, blood-sugar and pressure-monitoring devices, and automotive test equipment.

It's a lot of fun experimenting with voice synthesizers; in fact, the author has built and experimented with four different voice synthesizer IC's, and has listened to at least ten different synthesizers in all.

So that you can share in the fun too, we'll present theory and construction details of a stored-word speech system that you can connect to any personal computer having a parallel printer port. A simple BASIC program then uses LPRINT statements to create speech output. A number of terms relevant to electronics are included: ampere, kilo, milli, volt, circuit, connect, farad, hertz, meg, mega, micro, nano, ohms, pico, as well as letters of the alphabet, numbers, and numerous others. The project can be built for about $75.

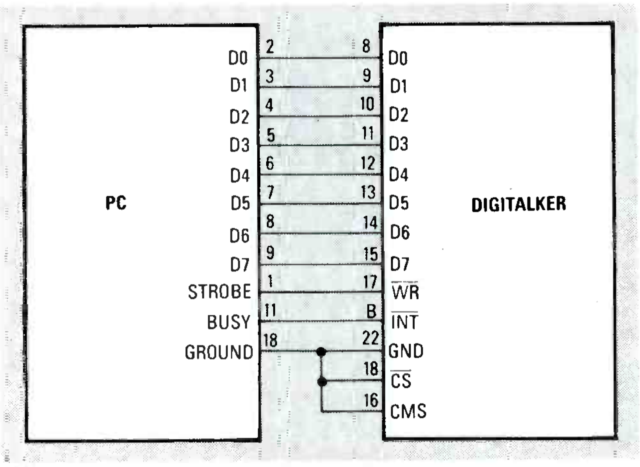


FIG. 1—THE PARALLEL PRINTER PORT of any personal computer can drive the Digitalker.

Speech systems

Most speech synthesis systems operate in one of two ways: the stored-speech method or the allophone method. The allophone method uses *allophones,* little chunks of sound that can be combined to form words. The stored-word system stores entire words and phrases.

Each system has advantages and disadvantages. Allophone synthesis can offer an unlimited vocabulary and yet require very little memory. However, allophone speech synthesis is usually artificial sounding, monotone, and difficult for the untrained ear to understand. Probably the best application for allophone synthesis is in converting text to speech. Text-to-speech conversion can be a great aid for the visually impaired, allowing them to operate word processors and other computer programs.

By contrast, a stored-word synthesizer can offer excellent speech quality with intonation or feeling. However, a stored-word system requires tremendous amounts of memory for just a few minutes of speech. Typically, that limits a stored-word system to a vocabulary of several dozen words. The best application for a stored-word synthesizer is one that requires the clearest possible speech and a limited vocabulary, such as in an automobile, or a supermarket check-out stand. A stored-word synthesizer

TABLE 1—WORD LIST (SSR1 AND SSR2)

THIS IS		Q	48	IS	96
DIGITALKER	0	R	49	IT	97
ONE	1	S	50	KILO	98
TWO	2	T	51	LEFT	99
THREE	3	U	52	LESS	100
FOUR	4	V	53	LESSER	101
FIVE	5	W	54	LIMIT	102
SIX	6	X	55	LOW	103
SEVEN	7	Y	56	LOWER	104
EIGHT	8	Z	57	MARK	105
NINE	9	AGAIN	58	METER	106
TEN	10	AMPERE	59	MILE	107
ELEVEN	11	AND	60	MILLI	108
TWELVE	12	AT	61	MINUS	109
THIRTEEN	13	CANCEL	62	MINUTE	110
FOURTEEN	14	CASE	63	NEAR	111
FIFTEEN	15	CENT	64	NUMBER	112
SIXTEEN	16	400 HZ TONE	65	OF	113
SEVENTEEN	17	80 HZ TONE	66	OFF	114
EIGHTEEN	18	20 mS SILENCE	67	ON	115
NINETEEN	19	40 mS SILENCE	68	OUT	116
TWENTY	20	80 mS SILENCE	69	OVER	117
THIRTY	21	160 mS SILENCE	70	PARENTHESIS	118
FORTY	22	320 mS SILENCE	71	PERCENT	119
FIFTY	23	CENTI	72	PLEASE	120
SIXTY	24	CHECK	73	PLUS	121
SEVENTY	25	COMMA	74	POINT	122
EIGHTY	26	CONTROL	75	POUND	123
NINETY	27	DANGER	76	PULSES	124
HUNDRED	28	DEGREE	77	RATE	125
THOUSAND	29	DOLLAR	78	RE	126
MILLION	30	DOWN	79	READY	127
ZERO	31	EQUAL	80	RIGHT	128
A	32	ERROR	81	SS (NOTE 1)	129
B	33	FEET	82	SECOND	130
C	34	FLOW	83	SET	131
D	35	FUEL	84	SPACE	132
E	36	GALLON	85	SPEED	133
F	37	GO	86	STAR	134
G	38	GRAM	87	START	135
H	39	GREAT	88	STOP	136
I	40	GREATER	89	THAN	137
J	41	HAVE	90	THE	138
K	42	HIGH	91	TIME	139
L	43	HIGHER	92	TRY	140
M	44	HOUR	93	UP	141
N	45	IN	94	VOLT	142
O	46	INCHES	95	WEIGHT	143
P	47				

NOTE 1: "SS" (#129) can be used to make singular words plural

TABLE 2—WORD LIST SSR5 AND SSR6

ABORT	0	FARAD	44	PER	88
ADD	1	FAST	45	PICO	89
ADJUST	2	FASTER	46	PLACE	90
ALARM	3	FIFTH	47	PRESS	91
ALERT	4	FIRE	48	PRESSURE	92
ALL	5	FIRST	49	QUARTER	93
ASK	6	FLOOR	50	RANGE	94
ASSISTANCE	7	FORWARD	51	REACH	95
ATTENTION	8	FROM	52	RECEIVE	96
BRAKE	9	GAS	53	RECORD	97
BUTTON	10	GET	54	REPLACE	98
BUY	11	GOING	55	REVERSE	99
CALL	12	HALF	56	ROOM	100
CAUTION	13	HELLO	57	SAFE	101
CHANGE	14	HELP	58	SECURE	102
CIRCUIT	15	HERTZ	59	SELECT	103
CLEAR	16	HOLD	60	SEND	104
CLOSE	17	INCORRECT	61	SERVICE	105
COMPLETE	18	INCREASE	62	SIDE	106
CONNECT	19	INTRUDER	63	SLOW	107
CONTINUE	20	JUST	64	SLOWER	108
COPY	21	KEY	65	SMOKE	109
CORRECT	22	LEVEL	66	SOUTH	110
DATE	23	LOAD	67	STATION	111
DAY	24	LOCK	68	SWITCH	112
DECREASE	25	MEG	69	SYSTEM	113
DEPOSIT	26	MEGA	70	TEST	114
DIAL	27	MICRO	71	TH (NOTE 2)	115
DIVIDE	28	MORE	72	THANK	116
DOOR	29	MOVE	73	THIRD	117
EAST	30	NANO	74	THIS	118
ED (NOTE 1)	31	NEED	75	TOTAL	119
ED (NOTE 1)	32	NEXT	76	TURN	120
ED (NOTE 1)	33	NO	77	USE	121
ED (NOTE 1)	34	NORMAL	78	UTH (NOTE 3)	122
EMERGENCY	35	NORTH	79	WAITING	123
END	36	NOT	80	WARNING	124
ENTER	37	NOTICE	81	WATER	125
ENTRY	38	OHMS	82	WEST	126
ER	39	ONWARD	83	SWITCH	127
EVACUATE	40	OPEN	84	WINDOW	128
EXIT	41	OPERATOR	85	YES	129
FAIL	42	OR	86	ZONE	130
FAILURE	43	PASS	87		

NOTE 1: "ED's" 31 and 32 work best with words that end with "T" or "D" "ED" 34 works best with words that end with soft sounds.

NOTE 2: "TH" (#115) can be added to words like; six, seven, and eight to make sixth, seventh, and eighth etc.

NOTE 3: "UTH" (#122) can be added to twenty, thirty, and forty to make twentieth, thirtieth, and fortieth, etc.

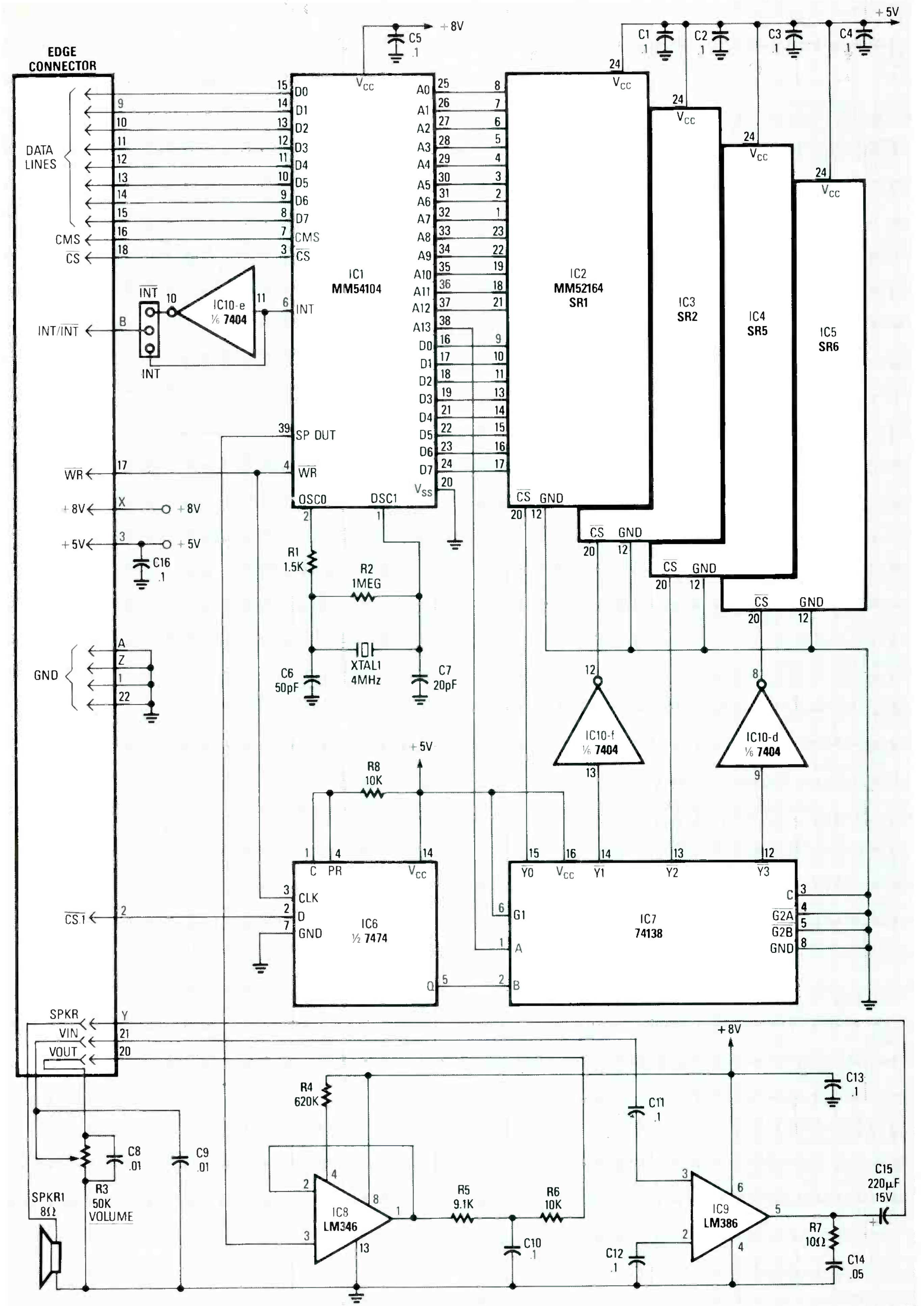


FIG. 2—SCHEMATIC DIAGRAM OF THE DIGITALKER. The speech processor (IC1) reads data from the ROM's (IC2–IC5) and delivers speech output via pin 39.

is useless for text-to-speech conversion because of the large amount of memory that would be required.

The Digitalker

National Semiconductor's Digitalker is a stored-word speech synthesis system that produces an exceptionally clear "voice." In fact, the Digitalker's quality exceeds Texas Instrument's *Speak & Spell* speech synthesizer. The Digitalker's voice has intonation or feeling, is not monotone, and even uses a female voice for the phrase "This is Digitalker."

The MM54104 SPC (*S*peech *P*rocessor *C*hip) is the heart of the Digitalker system. It's a 40-pin IC having 8 data lines (pins 8–15) that can be programmed manually with switches, or by connecting the device to a computer. For best results, a computer should be used to control the SPC so that sentences can be formed by stringing words together rapidly.

The SPC also has 14 ROM address lines (A0–A13, pins 25–38) that are to address ROM's containing speech data. Through those 14 address lines, the SPC can directly access 128K bits of speech data, which is good for about one minute of continuous speech. The SPC receives its data from the ROM's through eight data lines (pins 16–19 and pins 21–24). A number of other lines (pins 3, 4, and 7) are used for handshaking with a host computer, for connecting an external crystal oscillator (pins 1 and 2), and for speech output (pin 39)—which is connected to a filter and an audio amplifier. For more information on the SPC, see National's 1982 Linear Databook.

The right words

One key to a good stored-word speech-synthesis system is to choose the right words to store, convert them from an analog source, and then compress them into digital data suitable for the SPC.

National Semiconductor will convert analog tapes into custom digital data for customers, but that's an expensive proposition for hobbyists. However, the company has developed four general-purpose 64K-bit ROM's that contain data for 273 words, phrases, tones, and pauses. National's Linear databooks list several different ROM sets, but the SSR1, SSR2, SSR5, and SSR6 provide the best selection of words and are easy to obtain. The four ROM's together contain nearly two minutes of continuous speech; the words contained in each ROM set are shown in Tables 1 and 2.

Hooking it up

As shown in Fig. 1, the simplest way to use the Digitalker is to connect it to your computer's printer port. There are several advantages to doing so. First, handshaking between the computer and the Digitalker is automatic, so it isn't necessary to place timing loops in the software.

Second, most printer ports have a $\overline{\text{STROBE}}$ line that goes low when data at the port is valid. The strobe line can be connected to the SPC's $\overline{\text{WR}}$ line. When it is asserted, the SPC reads the ROM data for the selected word over its eight data lines (D0–D8), and then delivers the word to the audio output (pin 39).

The SPC's INTR line (pin 6) goes high after the entire word has been pronounced. By connecting the INTR line (or, if necessary, the inverted $\overline{\text{INTR}}$) to the printer port's BUSY input, the host computer will wait until each word has been spoken before sending more data to to the SPC.

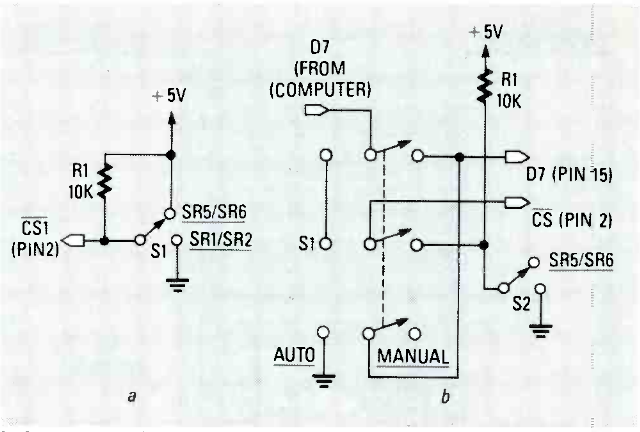


FIG. 3—ROM-SELECT CIRCUITS: Use the circuit shown in (*a*) to select between ROM sets manually. The circuit shown in (*b*) allows manual or automatic computer control, but only the first 128 words and phrases are accessible in the auto mode.

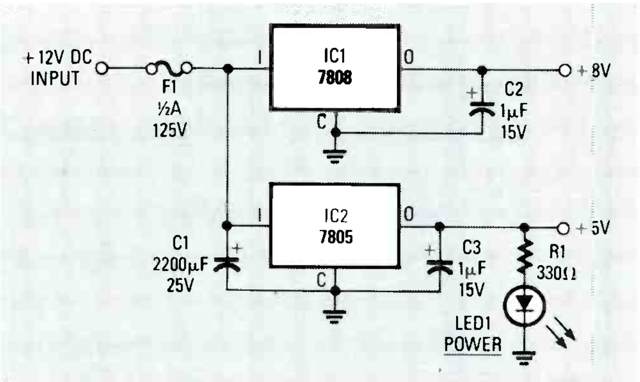


FIG. 4—POWER SUPPLY for the Digitalker. A +12-volt wall transformer provides the raw DC input.

Two SPC pins provide options. First, $\overline{\text{CS}}$ is the chip-select line;it must be grounded momentarily when the computer addresses the SPC. $\overline{\text{CS}}$ is provided to allow the SPC to share the data bus with other devices.

Second, CMS (command select) resets the interrupt and starts a speech sequence when it is low, and only resets the interrupt when it is high.

The PC board layout brings both $\overline{\text{CS}}$ and CMS out to the edge connector. For normal operation from a parallel-printer port, it's most convenient to ground both pins at the edge-card connector.

Now let's look at the circuit, shown in Fig. 2. The SPC's speech output drives IC8, which buffers the audio signal and drives a volume control. Final audio output is provided by IC9.

Flip-flop IC6 and 3-to-8 line decoder IC7 select the speech ROM's, depending on whether SPC address line AD13 is high or low, and on the state of the $\overline{\text{CSI}}$ signal (edge connector pin 2). AD13 picks the high or low ROM of a pair, and $\overline{\text{CSI}}$ picks one pair or the other.

There are several ways to select which ROM pair you want to use. If you have an extra output bit available on your PC (perhaps a bit from a second parallel port), you can program $\overline{\text{CSI}}$ directly. Otherwise, you can use a manual switch, as shown in Fig. 3-*a*.

A combination approach is shown in Fig. 3-*b*. With switch S1 in the Manual position, you can use S2 to switch between ROM's. But with S1 in the Auto position, you can switch between ROM's using a single eight-bit port. The upper data bit (D7) provides the switching function, so only the first 128 words (0–127) in each ROM set will be accessible using that approach.

The power-supply schematic is shown in Fig. 4. An inexpensive wall transformer provides the raw DC power. Voltage regulators inside the project's cabinet provide the required voltages: +5-volts DC for the digital circuits, and +8-volts DC for the audio circuitry. The entire circuit draws about 300 mA when the volume is turned up, so use a +12-volt DC, 500-mA power supply.

Construction

PC board patterns are shown in PC Service. An etched and drilled PC board is also available from the source given in the Parts List. Figure 5 shows how the parts are mounted on the board. **Note:** six jumper wires must be soldered to the circuit board before the IC sockets are installed. An additional jumper must be soldered from the center INT terminal to either INT or $\overline{\text{INT}}$, depending on the handshaking requirements of your computer's parallel port. Most computers use an active-high BUSY signal, so try the INT setting first if you're not sure which one to use.

Observe normal precautions when handling the SPC and ROM IC's.Leave the chips in their protective "rugs" until they are ready for use. To protect the components against damage caused by static electricity, make sure to ground yourself before removing the IC's from from their rugs, or when handling or moving the PC board.

After mounting all components, check your work carefully for solder bridges and cold joints. Fix any problems before applying power to the board.

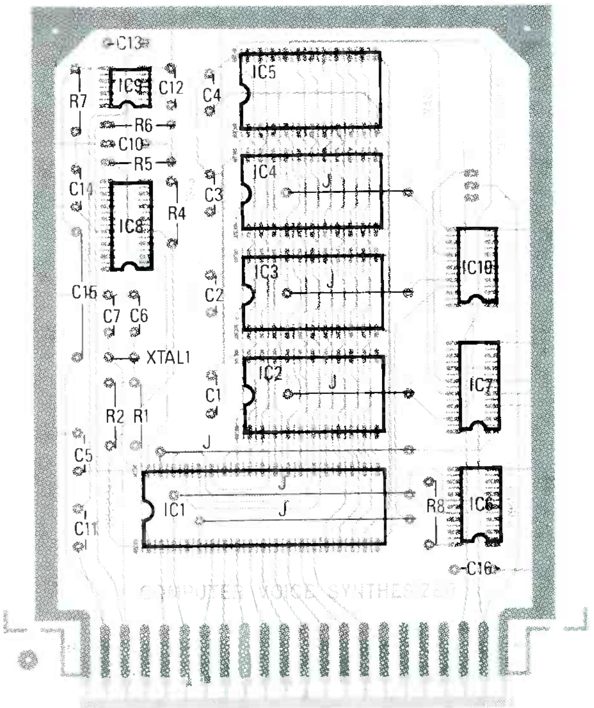


FIG. 5—PARTS LAYOUT: Note that six jumpers must be installed on the component side of the board before installing the IC sockets. (Sockets mount over five of the six jumpers.)

DIGITALKER PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
R1—1500 ohms
R2—1 megohm
R3—50,000 ohms, potentiometer
R4—620,000 ohms
R5—9100 ohms
R6, R8—10,000 ohms
R7—10 ohms
All capacitors are rated 15 volts or higher
C1–C5, C10–C13, C16—0.1 µF, ceramic disc
C6—50 pF, ceramic disc
C7—20 pF, ceramic disc
C8, C9—0.01 µF, ceramic disc
C14—0.05 µF, ceramic disc
C15—220 µF, 15 volts, electrolytic
Semiconductors
IC1—MM54104, speech processor
IC2—MM52164-SSR1, speech ROM
IC3—MM52164-SSR2, speech ROM
IC4—MM52164-SSR5, speech ROM
IC5—MM52164-SSR6, speech ROM
IC6—7474, dual D flip-flop
IC7—74138, 3-to-8 line decoder
IC8—LM346, programmable op-amp
IC9—LM386, audio power amplifiere
IC10—7404, hex inverter
Other components
XTAL1—4.00 MHz crystal

POWER SUPPLY PARTS LIST

R1—330 ohms
IC1—7808 8-volt regulator
IC2—7805 5-volt regulator
C1—2200 µF, 25 volts, electrolytic
C2, C3—1 µF, 15 volts, tantalum
F1—fuse, 0.5 amp, 125 volts
LED1—light-emitting diode
Note: An etched and drilled PC board is available for $15.95 from David A. Ward, 2261 W. Skyview, Cedar City, UT 84720-2233. All orders add $2.00 shipping and handling; Utah residents add 6% sales tax. Digitalker IC's are available from Jameco Electronics, 1355 Shoreway Road, Belmont, CA 94002 (415-592-8097).

LISTING 1

```
10 REM This program will make the
20 REM Digitalker pronounce all words
30 REM in SSR1 and SSR2 (CS1 is low)
40 FOR X = 0 to 143
50 LPRINT CHR$(X);
60 NEXT X
70 END
```

LISTING 2

```
10 REM This program will make the
20 REM Digitalker pronounce all words
30 REM in SSR5 and SSR6 (CS1 is high)
40 FOR X=0 to 130
50 LPRINT CHR$(X);
60 NEXT X
70 END
```

LISTING 3

```
10 REM REAL TIME CLOCK PROGRAM
20 CLS
30 PRINT"HOW OFTEN DO YOU WANT THE TIME ANNOUNCED?"
40 PRINT:PRINT
50 PRINT"ENTER 1 FOR 1 MINUTE INTERVALS..."
60 PRINT"ENTER 5 FOR 5 MINUTE INTERVALS..."
70 PRINT"ENTER 30 FOR 30 MINUTE INTERVALS..."
80 INPUT"",I
90 TIME$=TIME$
100 T$=LEFT$(TIME$,2)
110 T1$=MID$(TIME$,4,2)
120 H$=LEFT$(T$,1)
130 H1$=RIGHT$(T$,1)
140 H=ASC(H$)
150 H1=ASC(H1$)
160 H=H-48
170 H1=H1-48
180 H=H*10
190 HT=H+H1
200 IF HT>12 THEN HT=HT-12:P=47:GOTO 220
210 P=32
220 IF HT=12 THEN P=47
230 IF HT=0 THEN HT=12:P=32
240 M$=LEFT$(T1$,1)
250 M1$=RIGHT$(T1$,1)
260 M=ASC(M$)
270 M1=ASC(M1$)
280 M=M-48
290 M1=M1-48
300 IF M=0 AND M1=0 THEN M=68:M1=68
310 IF M=0 AND M1>0 THEN M=46
320 IF M=1 AND M1=0 THEN M=10:M1=68
330 IF M=1 AND M1=1 THEN M=11:M1=68
340 IF M=1 AND M1=2 THEN M=12:M1=68
350 IF M=1 AND M1=3 THEN M=13:M1=68
360 IF M=1 AND M1=4 THEN M=14:M1=68
370 IF M=1 AND M1=5 THEN M=15:M1=68
380 IF M=1 AND M1=6 THEN M=16:M1=68
390 IF M=1 AND M1=7 THEN M=17:M1=68
400 IF M=1 AND M1=8 THEN M=18:M1=68
410 IF M=1 AND M1=9 THEN M=19:M1=68
420 IF M=2 THEN M=20
430 IF M=3 THEN M=21
440 IF M=4 THEN M=22
450 IF M=5 THEN M=23
460 IF M1=0 THEN M1=68
470LPRINT CHR$(0);CHR$(138);CHR$(67);CHR$(139);CHR$(67);
CHR$(96);CHR$(71);CHR$(HT);CHR$(69);CHR$(M);CHR$(M1);
CHR$(71);CHR$(P);CHR$(44);CHR$(71);CHR$(71);
480 PRINT TIME$
490 GOSUB 510
500 GOTO 90
510 IF I=1 THEN I=60
520 IF I=5 THEN I=300
530 IF I=10 THEN I=600
540 IF I=30 THEN I=1800
550 Z=TIMER
560 Y=TIMER
570 IF Y-Z<I THEN 560
580 RETURN
```

Making the connection

Connecting the Digitalker to your computer is as simple as plugging it into your computer's parallel printer port. For testing purposes, wire a ROM-select switch as shown in Fig. 3-*a*.

It's easy to program the Digitalker. For example, simply by typing

```
LPRINT CHR$(0);
```

the Digitalker will say the phrase "This is Digitalker" if $\overline{\text{CSI}}$ is low, or "abort" if $\overline{\text{CSI}}$ is high.

Listing 1 and Listing 2 are test programs that sequentially pronounces all words contained in the selected ROM set. Both programs were written in GW-BASIC; they were tested on a Kaypro PC.

More sophisticated applications are not difficult. For example, the author has written BASIC programs that do the following; announce the time from the computer's real-time clock, pronounce the corresponding letter of the alphabet as a key is typed (great for a small child learning his ABC's), pronounce phone numbers as names are typed in, and prompt the user for input in various programs. The talking clock program is shown in Listing 3.

There are a couple of things to be aware of when programming the Digitalker. First, addressing a word with a number higher than that listed in the word lists will produce unintelligible speech, but will not damage the SPC or ROM chips. Second, the semicolons following the LPRINT statements are essential. If they are not present the Digitalker will pronounce *thirteen* and then *ten* after each word is spoken. That occurs because an ASCII 13 is a carriage return, and an ASCII 10 is a linefeed. The semicolon (;) eliminates the carriage return and linefeed.

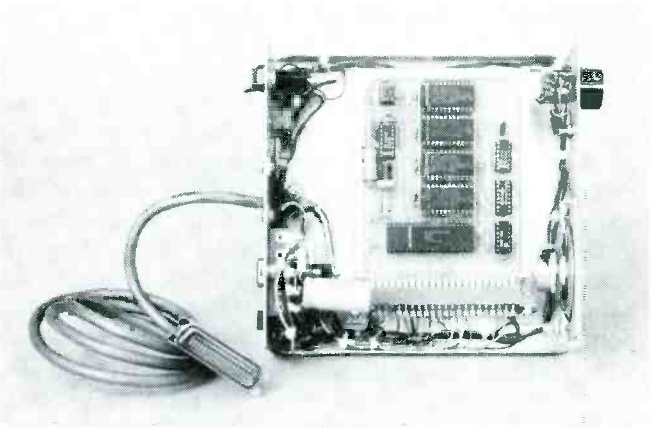
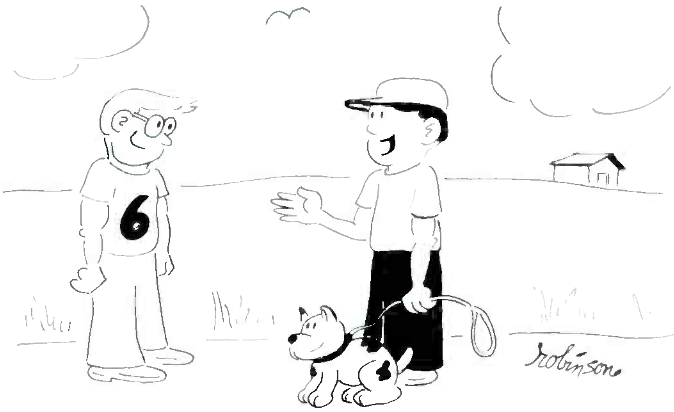


FIG. 6—THE ASSEMBLED SYNTHESIZER with its cover removed.

Applications ideas

Computer voice synthesis can be a very natural way for computers to communicate with people. For example, a synthesizer could be used to warn a pilot that the plane's altitude is critically low, or that the fuel level is low. A visually impaired person could compose documents with a word processor, or compute math problems with a calculator.

Undoubtedly, there are many other uses for computerized voice synthesis in cash registers, automatic teller machines, emergency warning systems, automobiles, telephone systems, etc. Have fun finding them! **R-E**



"The man at the pet shop said he can store up to 20 separate commands."

BUILD THIS

ACTIVE ANTENNA

When fate or nasty neighbors prevent you from stringing a long-wire receiving antenna, you'll find that this pocket-size active antenna will give the same, or even better, reception.

RODNEY A. KREUTER

FOR CONVENTIONAL ALL-FREQUENCY SHORT-WAVE RECEPtion, the general rule is "the longer the antenna the stronger the received signal." Unfortunately, between nasty neighbors, restrictive housing rules, and real-estate plots not much larger than a postage stamp, a short-wave antenna often turns out to be a few feet of wire thrown out the window—rather than the 130 feet of long-wire antenna we would really like to string between two 50-foot towers.

Fortunately, there's a convenient alternative to the long-wire antenna, and that's an *active antenna*; which basically consists of a very short antenna and a high-gain amplifier.

The concept of an active antenna is fairly simple. Since the antenna is physically small, it doesn't intercept as much energy as a larger antenna, so we simply use a built-in RF amplifier to make up for the apparent signal "loss." Also, the amplifier provides impedance matching, because most receivers are designed to work with a 50-ohm antenna.

Active antennas can be built for any frequency range, but they are more commonly used from VLF (10 kHz or so) to about 30 MHz. The reason for that is because full-size antennas for those frequencies are often much too long for the available space. At higher frequencies, it is quite easy to design a relatively small high-gain antenna.

The active antenna shown in Fig. 1 provides 14–20 dB gain at the popular short-wave and radio-amateur frequencies of 1–30 MHz. As you would expect, the lower the frequency the greater the gain. A gain of 20 dB is typical from 1–18 MHz, decreasing to 14 dB at 30 MHz.

Circuit design

Because antennas that are much shorter than ¼ wavelength present a very small and highly reactive impedance that is dependent on the received frequency, no attempt was made to match the antenna's impedance—it would prove too difficult and frustrating to match impedances over a decade of frequency coverage. Instead, the input stage (Q1) is an FET source-follower, whose high-impedance input successfully bridges the antenna's characteristics at any frequency. Although many different types of FET's may be used—such as the MPF102, 2N3819, or the 2N4416—bear in mind that the overall high-frequency response is set by the characteristics of the FET amplifier.

Transistor Q2 is used as an emitter-follower to provide a high-impedance load for Q1, but more importantly, it provides a low drive impedance for common-emitter amplifier Q3, which provides *all* of the amplifier's voltage gain. The most important parameter of Q3 is f_T, the high-frequency cut-off, which should be in the range of 200–400 MHz. A 2N3904, or a 2N2222 works well for Q3.

The most important of Q3's circuit parameters is the voltage drop across R8: The greater the drop, the greater the gain. However, the passband decreases as Q3's gain is increased.

Transistor Q4 transforms Q3's relatively moderate output impedance into a low impedance, thereby providing sufficient drive for a receiver's 50-ohm antenna-input impedance.

The antenna can be almost anything; a long piece of wire, a brass welding rod, or a telescopic antenna that was salvaged from an old radio. Telescopic replacement antennas for transistor radios are also available from most retail electronic-parts distributors.

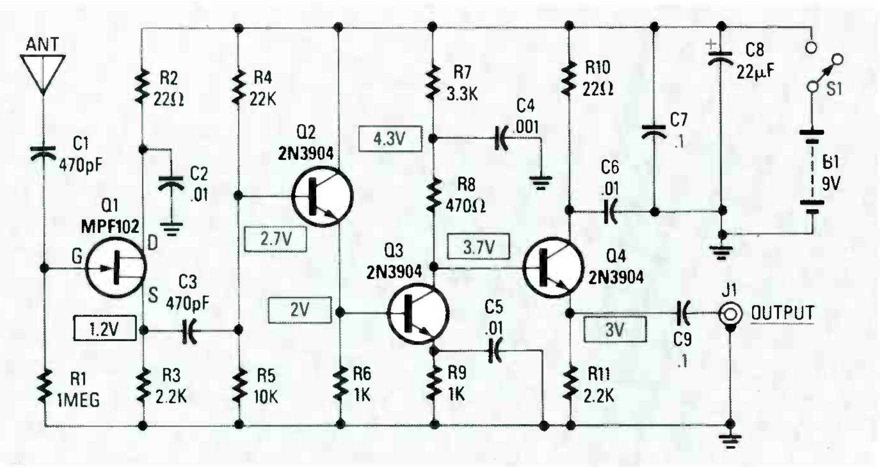


FIG. 1—THIS ACTIVE ANTENNA provides between 14- and 20-dB gain over the range of 1–30 MHz.

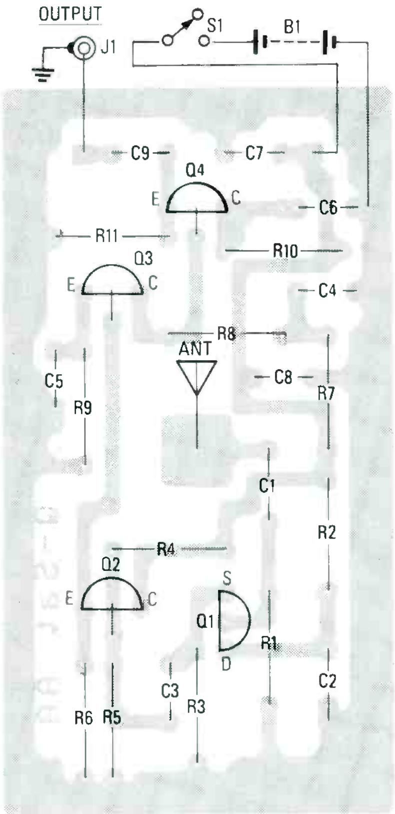


FIG. 2—THE GROUND CONNECTION for J1 is the metal cabinet. The cabinet is connected to the PC board's ground by the metal spacers at each mounting screw.

Construction

The amplifier for the prototype unit uses a printed-circuit board, for which a template is provided in "PC Service." The amplifier can be assembled on a perforated wiring board, but because there is *some* sensitivity to the parts layout, we strongly suggest that you use a PC board for best results.

The parts-placement diagram is shown in Fig. 2. Take note that although the battery's negative (ground) lead is returned to the PC board, output-jack J1 has a connection to the cabinet ground. The ground connection between the PC board and the cabinet is made through the metal standoffs or spacers that are used to mount the PC board in the cabinet. Do not substitute plastic standoffs or spacers because they won't provide a ground connection between the PC board, the cabinet, and J1. If you decide to use a plastic cabinet to house the amplifier, make certain that J1's ground connection is returned to the ground foil running around the edge of the PC-board.

A telescopic antenna mounts in the center of the PC board. From the foil side of the board, pass its mounting screw through the hole in the PC board and then solder the head of the screw to its foil pad. For both insulation and support, use a plastic or rubber grommet between the antenna and the hole in the cabinet's cover through which the antenna passes. In a pinch, several turns of a good-quality plastic tape wrapped around the antenna's shaft can be substituted for the rubber grommet.

If you decide to make provision for a wire antenna, install a 5-way binding post on the cabinet. Then, be sure to connect a short length of wire between the antenna's foil pad and the binding post.

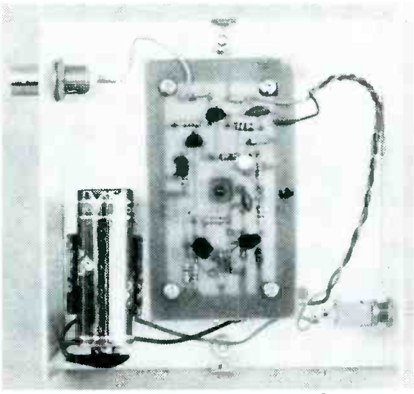


FIG. 3—THE AMPLIFIER IS SO SMALL that it almost gets lost in a 4-inch × 4-inch metal cabinet. The battery is held in place with a U-clamp. The output jack is anything that matches the receiver's antenna connection.

PARTS LIST

Resistors ¼-watt, 10%
R1—1 megohm
R2, R10—22 ohms
R3, R11—2200 ohms
R4—22,000 ohms
R5—10,000 ohms
R6, R9—1000 ohms
R7—3300 ohms
R8—470 ohms
Capacitors rated at least 16-WVDC
C1, C3—470 pF
C2, C5, C6—0.01 μF
C4—0.001 μF
C7, C9—0.1 μF
C8—22 μF, electrolytic
Semiconductors
Q1—FET, MPF102 or 2N3918 (see text)
Q2, Q3, Q4—NPN transistor, 2N3904, or equivalent
Other components
B1—9-volt battery
J1—Jack to match receiver cable
S1—SPST switch
ANT—Telescopic antenna or wire
Miscellaneous: Cabinet, printed-circuit materials, solder, etc.
Note: The following can be ordered from Q-Sat, P.O Box 110, Boalsburg, PA 16827: A printed-circuit board, $6 plus $1 shipping and handling; a complete kit (less case, switch, battery, and connectors), $15 plus $2 shipping and handling. Pennsylvania residents must add appropriate sales tax.

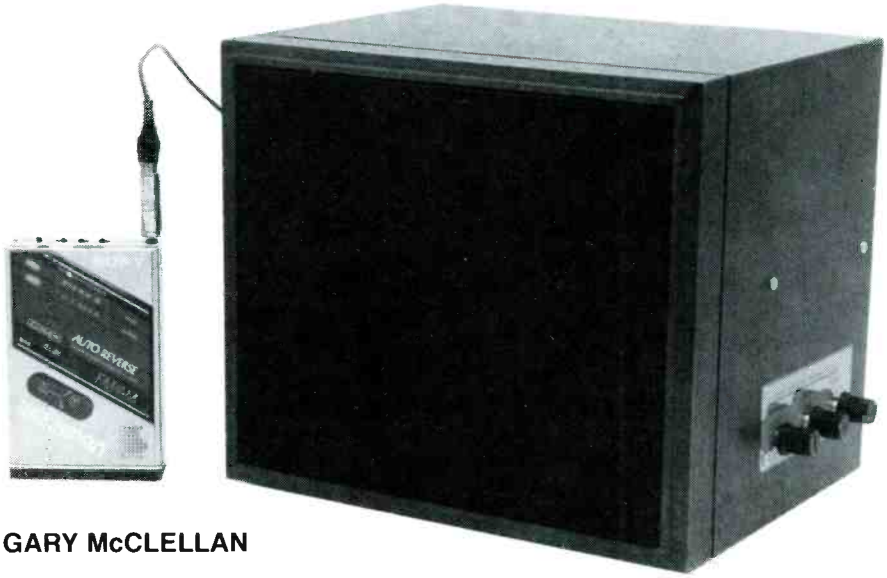
Modifications

If you are interested in a smaller frequency range than 1–30 MHz, resistor R1 can be replaced with an LC circuit tuned to the center of the desired range. The LC circuit will also improve the rejection of signals outside your range of interest, but remember that it won't improve the gain of the amplifier.

If your particular interest is the very-low frequencies (VLF), the am-

continued on page 130

AMPLIFIED SPEAKER



GARY McCLELLAN

You can build this low-cost amplified speaker system that is useful for testing audio components, or to amplify a walkman-type stereo for "ears-free" listening pleasure.

IF YOU WORK WITH AUDIO, THERE MUST BE times when you wish you had an amplifier and speaker system handy. If so, the amplified speaker described in this article is the answer to your needs. It is a low-cost, wide-range amplified-sound system complete with loudness, bass, and treble controls. Just connect power, and a line-level audio source and you're in business! Here are some common uses for the project:

If you would like to share the sound of your headphone stereo with your friends, all you have to do is connect the amplified speaker system. The project provides over 5 watts into an internal speaker, and the sound quality is great.

The amplified speaker system is also a great addition to your workshop because you'll no longer have to drag out your stereo and speakers just to check a tuner, tape deck, or other audio component. You'll be able to troubleshoot an audio component on your workbench rather than where your stereo is located.

Another possible use for the amplified speaker system is as an amplifier for an electric guitar or other musical instrument. And, because the project can be powered from a 12-volt car battery (we'll explain how later), you can even use it outdoors.

You should enjoy building the project almost as much as you'll enjoy using it. And, perhaps best of all, it's not going to break your bank account; ours only cost $17.00 to build. Of course, your cost will be determined by the state of your junkbox, and your ability to track down bargains.

How it works

The amplifier is based on a high-quality audio-amplifier IC made by Sanyo. That particular part was chosen because of its low distortion, high power output, and relatively low noise. Additional circuitry is included for loudness, bass, and treble controls, which are always included in a high-quality audio amplifier.

The schematic of the amplified-speaker project is shown in Fig. 1. Input signals to the audio-input terminals drive volume-control R2. Capacitor C2, resistor R1, and a tap on R2 are a loudness-compensation network, which boosts bass tones at low-volume levels. That circuitry corrects for human hearing deficiencies at low volume.

From R2, the audio signal is amplified by transistor Q1, which is a high-gain, low-noise device. That stage compensates for losses in the tone-control circuitry. Bias-resistor R3 further reduces noise by providing negative feedback. Capacitor C4 is included to prevent RF pickup and to roll off high-frequency noise.

Basically, the circuit connected between capacitor C6 and resistor R12 is a 20-dB resistive attenuator network combined with adjustable low-pass (bass) and high-pass (treble) filters. The potentiometers increase or decrease the capacitive reactance across various resistors, boosting or cutting bass and treble tones. Bass-control R7 is part of a voltage divider consisting of R6 and R8. Turning the potentiometer clockwise puts more of the reactance of capacitor C8 across the potentiometer and R8, shunting most of the high frequencies to ground, and boosting the lows. Turning the potentiometer counterclockwise puts more reactance of C7 across the potentiometer and R6, boosting most of the high frequencies and cutting the lows.

The output from the bass potentiometer (R7) goes to resistor R10, which reduces control interaction, and then it goes to treble-control R11. That potentiometer is in a series voltage divider with capacitors C9 and C10. Turning R11 clockwise puts more of the reactance of C9 in the circuit, shunting high frequencies around the bass control, boosting tre-

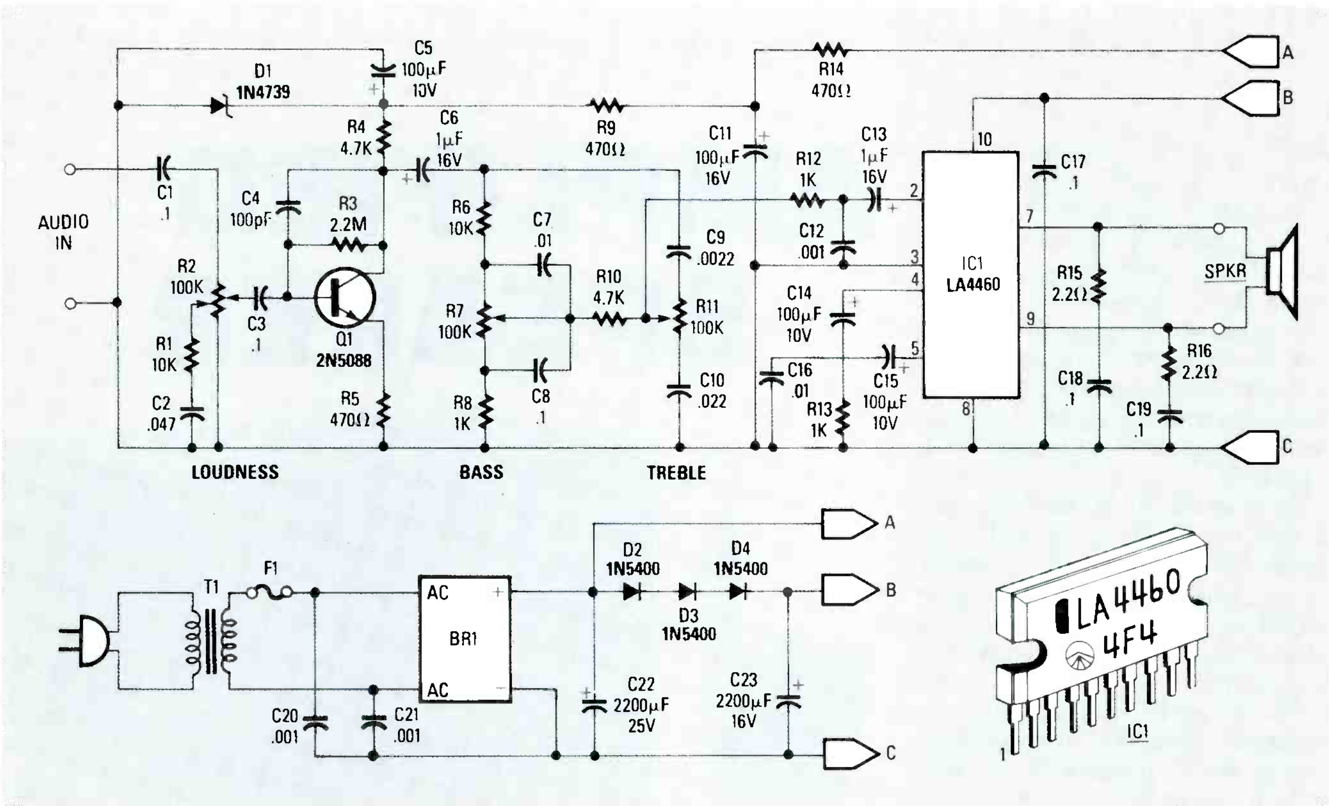


FIG. 1—SCHEMATIC DIAGRAM of the amplifier board and its power supply.

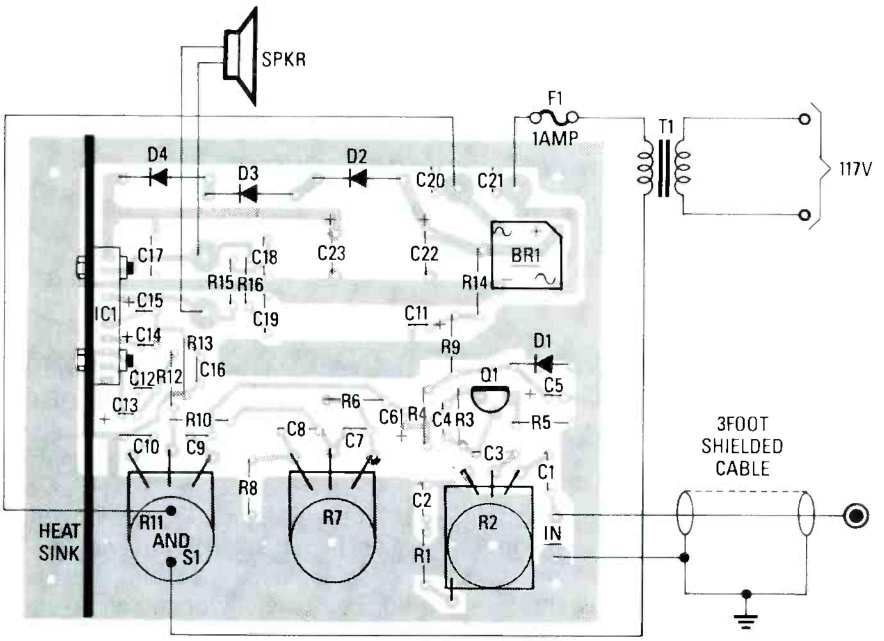


FIG. 2—PARTS PLACEMENT DIAGRAM for the PC board. Close attention should be paid to the polarities of the electrolytic capacitors.

ble. Likewise, turning R11 counterclockwise shunts high frequencies away from the bass control to ground, cutting treble tones. The tone-control output drives resistor R12 and capacitor C12, which serve as a low-pass filter. That circuitry is included to prevent oscillation in power-amplifier IC1.

Power-amplifier IC1 is a bridging-type amplifier. That means that there are two power amplifiers inside the package that drive the speaker in a push-pull configuration for double the power output. The input signal to pin 2 is amplified and then drives the speaker from the pin-7 output. A phase-inverted output appears at pin 4 and is coupled through capacitors C14 and C13 to the second amplifier in IC1. After being amplified, the phase-inverted output drives the speaker from pin 9. Resistors R15 and R16, and capacitors C18 and C19, are included at the output of IC1 to prevent high-frequency oscillation. Note that if you can't find the 2.2-ohm resistors specified for R15 and R16, 10-ohm units may be substituted. The exact value isn't critical, although 2.2 ohms is preferred.

Rounding out the circuitry is a fairly conventional power supply, consisting of bridge rectifier BR1; capacitors C22 and C23; and diodes D2, D3, and D4. Since the supply voltage, after being rectified, is at about 17 volts, D2, D3, and D4 are required in order to drop it down to about 15 volts. Note that power is also tapped off capacitor C22 for Q1. That extra

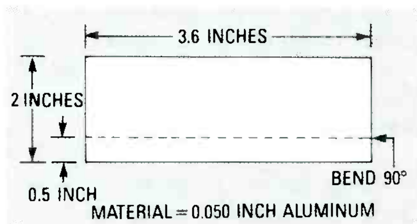


FIG. 3—YOU CAN MAKE A HEAT SINK for IC1 from a piece of scrap aluminum.

All resistors are ¼-watt, 5% unless noted
R1, R6—10,000 ohms
R2—100,000 ohms, potentiometer, 40% loudness contour tap (Radio Shack 271-1732)
R3—2.2 megohms
R4, R10—4700 ohms
R5, R9, R14—470 ohms
R7, R11—100,000 ohms, potentiometer, audio taper (Radio Shack 271-1722)
R8, R12, R13—1000 ohms
R15, R16—2.2 ohms
Capacitors
C1, C3, C8, C17, C18, C19—0.1 μF, 50 volts, radial-lead polyester
C2—0.047 μF, 50 volts, radial-lead polyester
C4—100-pF, 500 volts, ceramic disc
C5, C14, C15—100 μF, 10 volts, radial-electrolytic
C6, C13—1 μF, 16 volts, radial-electrolytic
C7, C16—0.01 μF, 50 volts, radial-lead polyester
C9—0.0022 μF, 50 volts, radial-lead polyester
C10—0.022 μF, 50 volts, radial-lead polyester
C11—100 μF, 16 volts, radial-electrolytic
C12, C20, C21—0.001 μF, 50 volts, ceramic disc
C22—2200 μF, 25 volts, radial-electrolytic
C23—2200 μF, 16 volts, radial-electrolytic
Semiconductors
IC1—LA4460 linear power amplifier (Sanyo)
Q1—2N5088 NPN transistor
D1—1N4739 9.1-volt, 1-watt, Zener diode
D2-D4—1N5400 3 amp, 50 PIV, silicon diode
BR1—6 amp, 50 PIV, bridge rectifier
Other components
S1—SPST potentiometer switch for R11 (Radio Shack 271-1740)
T1—Plug in transformer, 12 volts AC, 1 amp (Jamenco AC1000 or equivalent)
PL1—RCA plug
F1-1 amp, slow-blow, 3AG fuse and holder
Miscellaneous—speaker, PC board, 3 knobs, 3 feet of shielded wire, scrap aluminum for heatsink, hardware. **Note: A PC board is available from E²VSI, P.O. Box 72100, Roselle, IL 60172, for $9.95 plus $0.50 shipping.**

power-supply circuitry is required to ensure amplifier stability, as it would otherwise *motorboat* (low-frequency self-oscillation). Resistors R14 and R9 provide current limiting, while capacitors C11 and C5 provide extra filtering. Zener diode D1 ensures that the supply voltage is stabilized at 9.1 volts, as required by transistor Q1.

Part selection

Now that we have covered the circuit details, let's discuss the parts.

The speaker system may be any decent-sounding unit you can find. Chances are you will want to build two amplified-speaker systems, so it would be wise to get two identical units for balanced sound. The Panasonic two-way unit used for our prototype was purchased at a flea market for $1.50; perhaps you can do better. If possible, test out the speaker system you are considering, as you don't want to waste time on a unit that is defective, or has poor sound quality.

You may have some trouble finding a tapped potentiometer that is required for R2. One alternative is the ganged unit mentioned in the Parts List. That unit consists of two ganged potentiometers, but only one of them is used. Of course, if you can find a single-unit substitute with same specifications, you should use that.

The semiconductors are available from a wide variety of sources. Many Japanese TV/stereo replacement-parts suppliers carry the Sanyo LA4460 for IC1. And any 3-amp diodes can be used for D2, D3, and D4. The bridge rectifier specified is a standard 6-amp, 0.6-inch square-cube unit. You can also cross-reference those semiconductors with the Phillips-ECG replacement line, as well as many others.

Finally, transformer T1 is a plug-in 12-volt AC 1-amp unit. It is available from several sources. If you prefer, a standard 12.6-volt AC, 1-amp or better, filament transformer may be used. If you go with a standard filament transformer, remember to pick up a line cord and a ¼-amp fuse for F1.

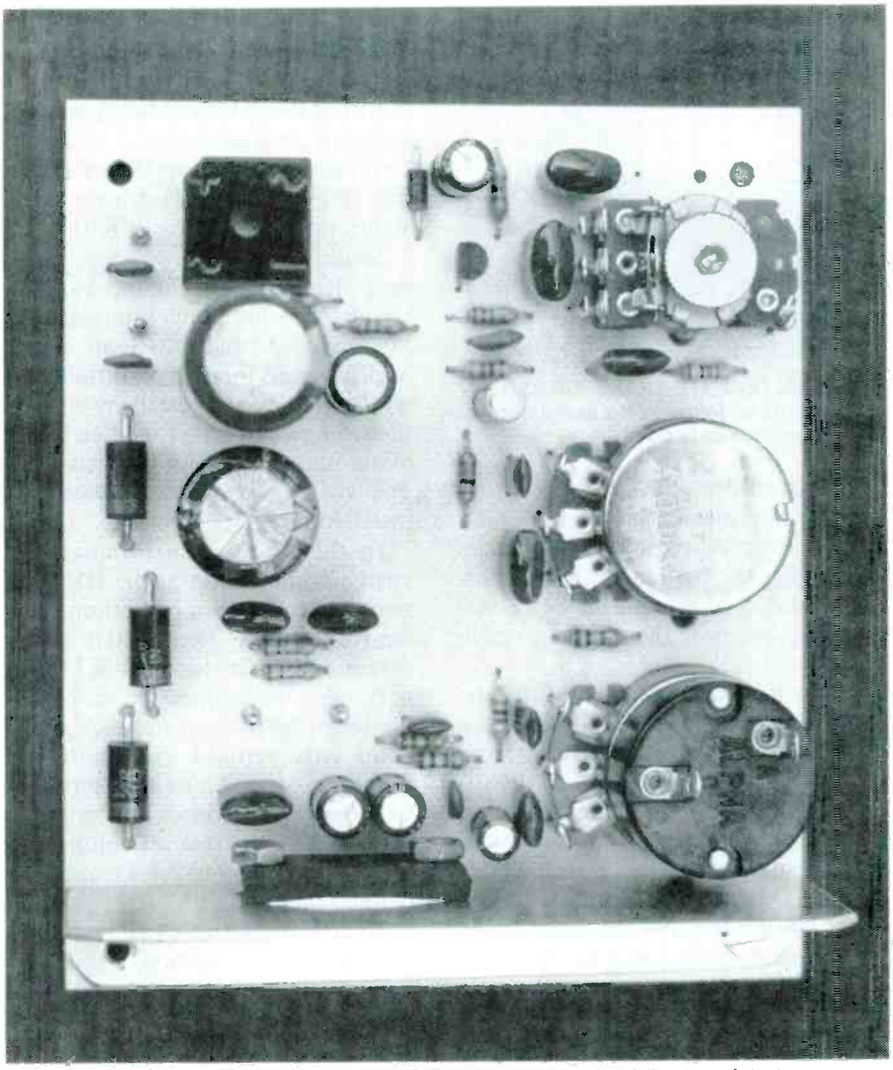


FIG. 4—YOUR BOARD SHOULD look similar to this one when it is completed.

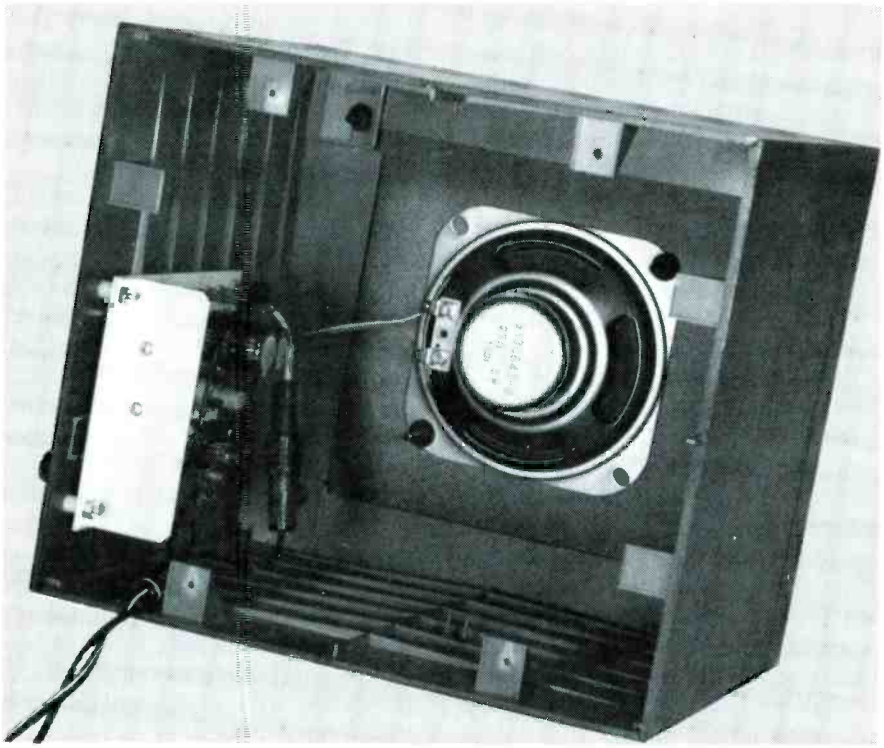


FIG. 5—A GOOD PLACE TO MOUNT the board is on the side of the cabinet, near the rear. Note the spacers that are used between the board and the cabinet

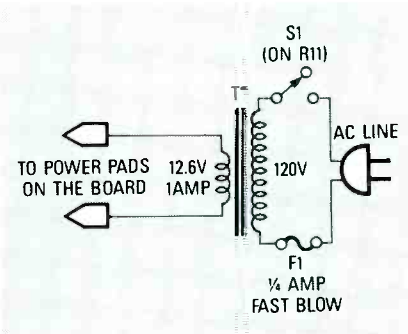


FIG. 6—ALTERNATE TRANSFORMER details should be followed if a standard filament transformer is used.

Construction

The amplifier should be built on a PC board for best results. Either make one using the pattern in the PC Service section of this magazine or you can buy one from the source given in the Parts List.

Start the assembly by stuffing the amplifier PC board. Refer to Fig. 2 for component locations and the Parts List for values. Starting with the diodes, install bridge-rectifier BR1 with the case, notch, or positive terminal as shown. Then install 3-amp diodes at D2, D3, and D4 as indicated. Finally, install the 1N4739 Zener diode at D1 near BR1. Double-check all parts before continuing.

Next comes the resistors. Install 470-ohm resistors at R14, R9, and R5 as indicated. Then install a 2.2-megohm resistor at R3 and a 4.7K resistor at R4. Next, install 10K resistors at R1 and R6. After that install 2.2-ohm resistors at R15 and R16. Continue by installing 1K resistors at R12, R13, and R8. Finish up by installing a 4.7K resistor at R10.

Modify the three potentiometers next. If necessary cut the shafts to length. Measure 1 inch from the bushing, mark it, and cut it off with a hacksaw, and then smooth the edges with a file. We suggest using a potentiometer switch for S1, and an appropriate unit is listed in the Parts List. The switch, by the way, should be installed on R11.

Install the potentiometer and switch combination at the R11 location, and the tapped potentiometer in the R2 location. Then install the last potentiometer in location R7. Connect the potentiometer terminals to the board by passing short lengths of solid wire through the board and through each potentiometer terminal. Leftover resistor leads are good for that. Make sure that all connections are soldered, and check for mistakes before continuing.

Next comes the capacitors. Remember to pay attention to the polarities of the electrolytics as you install them. Start by installing the 2200-μF, 25-volt capacitor at C22. Then install the 2200-μF, 16-volt capacitor at C23. Continue by installing 0.1-μF capacitors at C17, C18 and C19. Now move over to the righthand side of the board and install 0.1-μF capacitors at C1 and C3. Next, install a 0.047-μF capacitor at C2 and install a 100-pF disc at C4. Now install 1-μF capacitors at C6 and C13, and a 0.01-μF capacitor at C7. Next to that, install a 0.1-μF capacitor at C8. Now install a 0.0022-μF capacitor at C9, and install a 0.022-μF capacitor next to it at C10. Finish up by installing 100μF capacitors at C14 and C15, and check everything before continuing.

Next, Q1 and IC1 are installed. Place the 2N5088 as shown at Q1, and then install the LA4460 at IC1. Insert the part with the metal side to your left. Also, note that the pin-1 marking on the board matches the pin-1 stripe on the IC package. Double check before soldering the connections.

Continue by fabricating a heat sink for IC1. Details are shown in Fig. 3. We used a piece of aluminum salvaged from an old chassis for the heat sink, as it conveniently already had a ½-inch lip on it.

Install the heat sink. Place it against IC1 with the lip over the board's mounting holes. Then mark and drill the two mounting holes for IC1. Also, mark and drill the board's mounting holes. Put a dab of silicon grease on the metal surface of IC1 and secure the heat sink to IC1 with 4-40 × ½-inch screws. Tighten the screws just enough to hold IC1 in place, as overtightening may damage it. The board is now complete, and it should look like the one shown in Fig. 4.

Set the assembled board aside for a moment and work on the speaker cabinet. Determine a suitable location to mount the board. A good location is on the side of the cabinet, toward the rear, as shown in Fig. 5. Using the board as a guide, measure, and mark the holes for the four mounting screws, and the three knob shafts. Do that carefully, as mistakes will be hard to fix later on. Note that the holes for the screws must be smaller than the holes for the knob shafts. Drill all holes and make sure the board fits. You can, if you like, use rub-on lettering to label the controls for a professional appearance.

Return to the assembled board and refer back to Fig. 2 for final assembly details. Start by wiring a shielded cable to the IN pads on the board as

continued on page 130

BUILD A SERIAL PRINTER MULTIPLEXER

Build a serial printer multiplexer for a fraction of what commercial units cost.

PAUL RENTON

Many a small business has more computers than printers. The reason why purchasing a separate printer for each user is unjustified is because few users actually print all day long. Besides, buying separate printers can be expensive.

The biggest problem of printer sharing is how to hook things up. Many people simply switch cables, but that's inconvenient, and wastes time. Others use some sort of mechanical switch, but that's also inconvenient, because the user must get up and physically push a button or turn a knob.

Another approach is to use a device called a printer multiplexer. The device connects the computer to the printer automatically, eliminating the need to switch cables or press buttons.

The multiplexer presented here allows you to connect as many as four computers to the same serial (RS-232) printer. The multiplexer works by scanning each computer's output port sequentially. As soon as one computer begins a print job, the multiplexer locks onto that computer and allows data to flow from computer to printer. Meanwhile, the busy lines to the other computers' output ports are asserted. When the print job is done, the multiplexer releases the busy lines, and resumes scanning.

One special feature of our printer multiplexer is the PAUSE button, which can be used to halt data flow from the computer to the printer. As long as that button on the unit is pressed, no computer will be able to send data to the printer.

How it works

To accomplish multiplexing the printer multiplexer uses hardware handshaking. Handshaking is the term used to describe what prevents the computer from sending data to the printer when the printer is not ready for it. Generally speaking, there are two types of handshaking: software and hardware. There are several varieties of each type of handshaking, but XON/XOFF and busy line, respectively, are the most common.

In the XON/XOFF method, the printer sends control characters to the computer to indicate when it is able to accept data, and when it is not. To use that type of handshaking, the printer multiplexer would have to be microprocessor controlled. We wanted a simple and inexpensive method of printer sharing, so software handshaking is not used.

In the busy-line method, the printer controls the state of its Data Terminal Ready line (which is usually pin 20 of a 25-pin D connector). In general, if DTR is high (+12 volts), then the printer can accept data. If DTR is low (−12 volts), then the printer cannot accept data. Unfortunately, some printers interchange the meanings of high and low. Our design does not allow for busy-line polarity selection, however, modifying the multiplexer to do so is a relatively simple task.

In the multiplexer, if the printer holds its own DTR line low (indicating that it's busy), then all DTR lines going to the computers are also held low. When the printer is ready to accept data, the DTR line of the currently selected

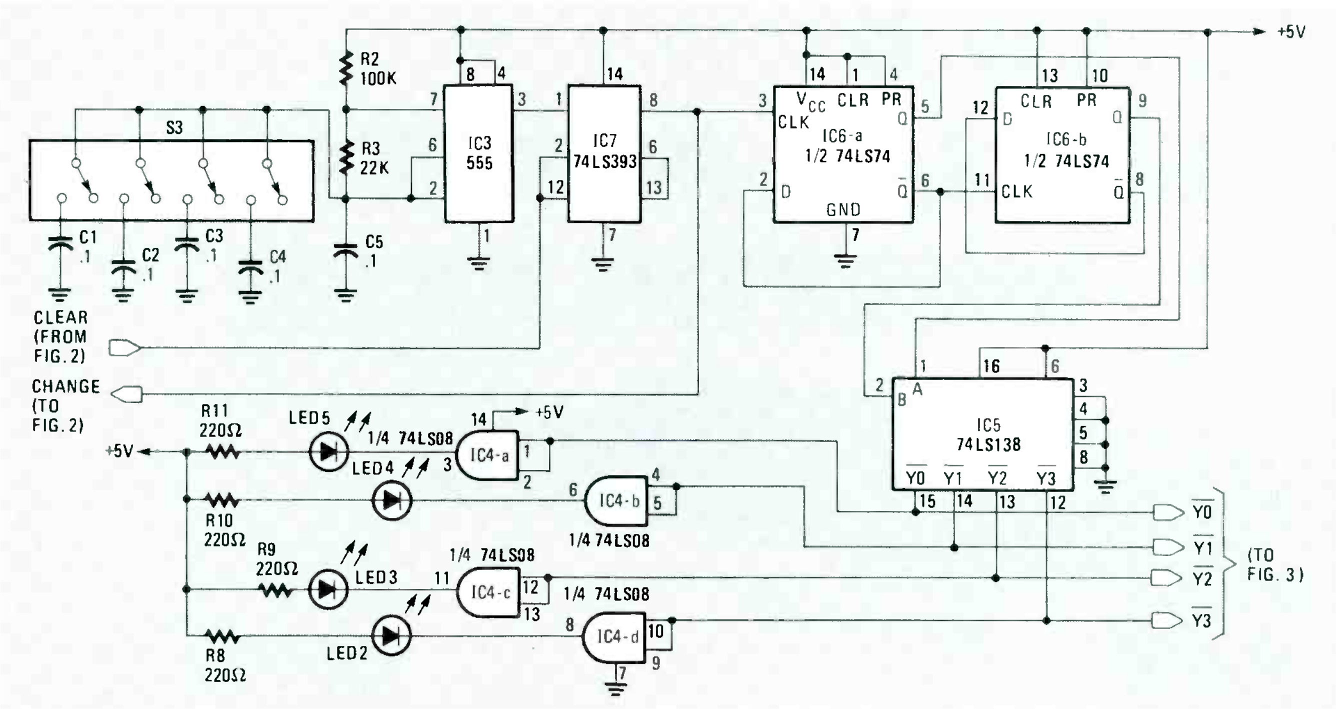


FIG. 1—SEQUENTIAL SCANNING CIRCUIT: As long as no signal is present at the CLEAR input, the outputs of IC5 are asserted one after the other.

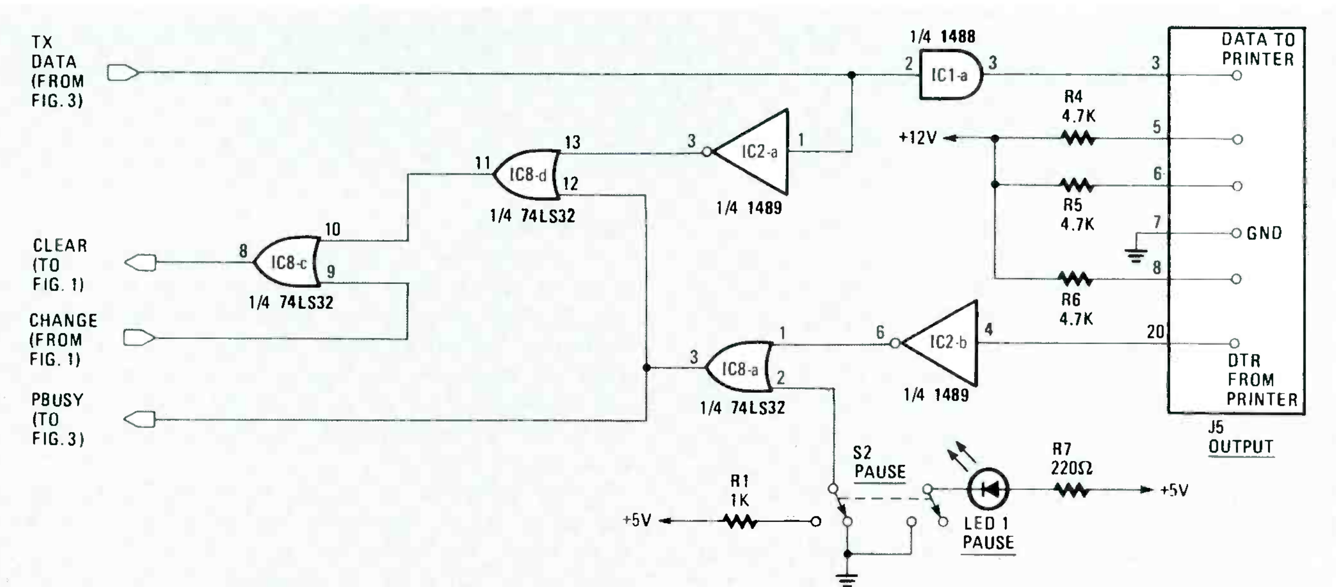


FIG. 2—PAUSE GENERATOR: This circuit causes scanning to stop whenever data is received at TX DATA, when the printer is busy (i.e., pin 20 of J5 is low), when the PAUSE switch is pressed, or when IC8 (shown in Fig. 1) changes state.

computer is released, and the DTR lines of the unselected ports remain low.

Computer-port selection is done with a 555 timer and three other IC's, as shown in Fig. 1. The 555 (IC3) runs in the astable mode; its rate determines how often the multiplexer switches ports. The values shown for R2, R3, and C5 cause a pulse to be generated about once every second. One second should be enough time for most applications, but the DIP switch (S3) allows additional capacitance to be added to the timing circuit; doing so increases the delay to two, three, four, and five seconds, as each section of the switch is closed. Variable time delay was provided to ensure that a computer was not cut off in the middle of a print job. If five seconds does not allow enough time, resistor values could be increased to further increase the time delay.

Whatever the delay, the timer clocks IC7, a 74LS393 8-bit counter. After 128 counts, pin 8 of IC7 goes high, and that clocks IC6-a, half of a 74LS74, and it in turn drives IC6-b, the other half. The Q outputs of both flip flops are decoded by IC5, a 74LS138 3-to-8 line decoder. The active output of that IC selects the current computer. The outputs labeled $\overline{Y0}$ through $\overline{Y3}$ are used to generate the DTR signals and thereby to determine the active port.

The selected computer port is indicated on the front panel via LED2–LED5. The 74LS138 outputs are simply buffered by IC4, a 74LS08. As scanning continues, each LED lights up in turn.

The preceding description shows how the multiplexer cycles through the four ports. But how does it select one and stop the counting?

An input port is selected by way of the clear inputs (pins 2 and 12) of the 74LS393, which are used to inject a time delay in the switching sequence. If those inputs are brought high, then the counter resets and starts counting from zero again. So if it's continually cleared, it will never count 128 pulses, the flip-flops in IC6 will not change state, and neither will IC5.

Actually there are three reasons why IC7 might be prevented from counting: when data is being sent from a computer, when the printer is busy, or when the pause function is engaged. As shown in Fig. 2, that is accomplished by using several OR gates (and some inverters).

As the computer sends data, the first bit of that data, which appears after buffering (by circuits discussed below) at the TX Data input of Fig. 2, will cause the clear lines to go high, resetting the counter. That signal is ORed with the DTR signal and with the output of the PAUSE button. Thus, the counter will also be reset whenever the printer's DTR line goes low (indicating printer is busy); or the pause line goes high (indicating pause button is pressed).

In Fig. 3, IC9-a, IC9-c, and IC9-d combine the data inputs from each port into the single signal that drives TX Data (shown in Fig. 3). The buffers in IC11 convert the incoming RS-232 signals to TTL levels; the buffers in IC10 convert the outgoing TTL signals to RS-232 levels.

The power supply, shown in Fig. 4, supplies ±12 volts to power the 1488 line drivers. The power supply also provides +5 volts for the remaining circuits.

Construction details

It's easiest to build the multiplexer on a small double-sided PC board, patterns for which are shown in PC Service. You can also purchase your own from the source mentioned in the Parts List.

If you make your own board, before mounting any components install and solder jumpers in all feedthroughs. Then, for ease of assembly, mount all discrete components, except the power-supply capacitors, the voltage regulator, and the switches. Solder each on both sides of the board. Then install the IC's, either soldering them directly to the board or with wirewrap sockets. If you use sockets, mount them about ¼ inch above the board, to

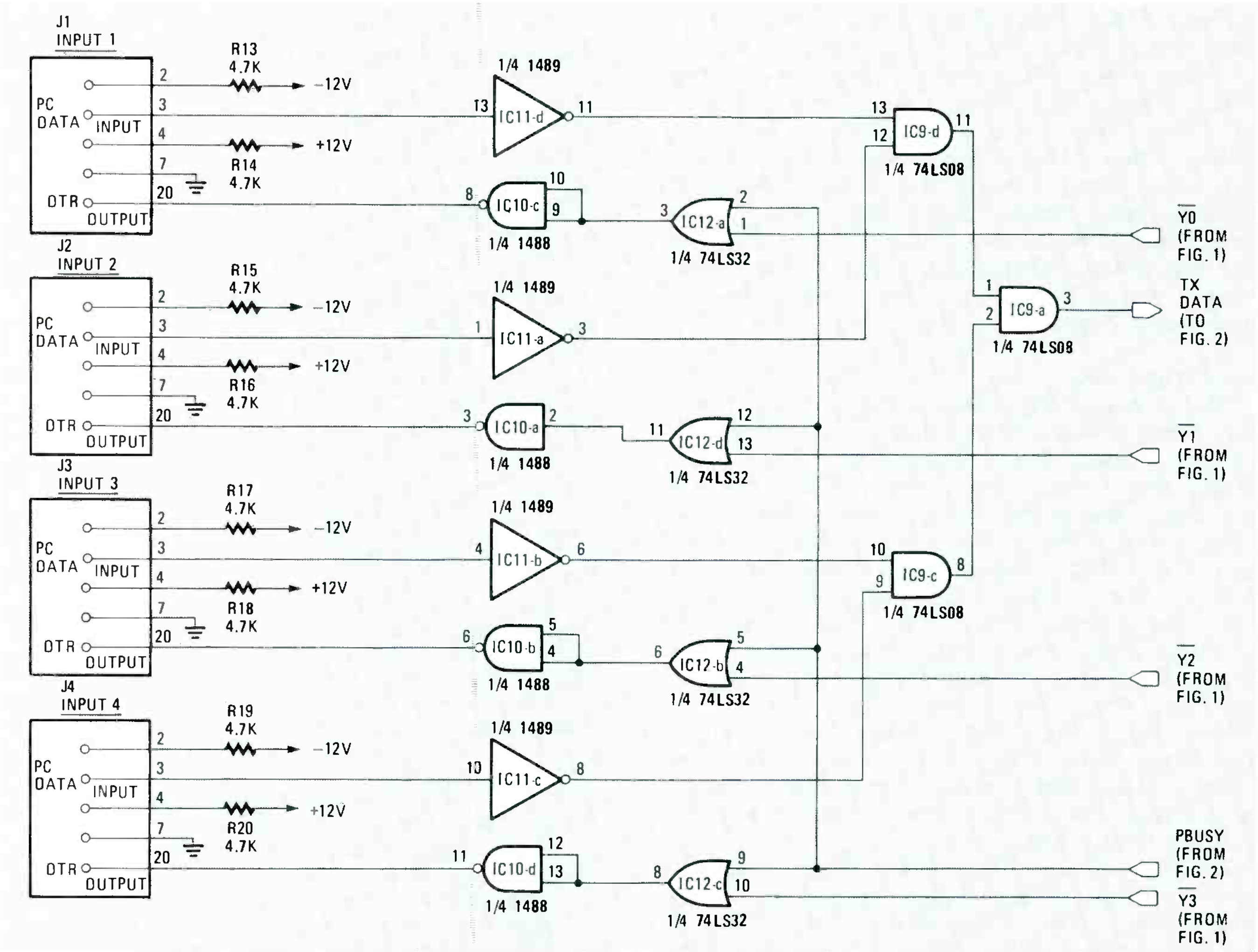


FIG. 3—THE DATA INPUTS of the four channels are ANDed together by IC9-a, IC9-c, and IC9-d to drive the pause generator that is shown in Fig. 2.

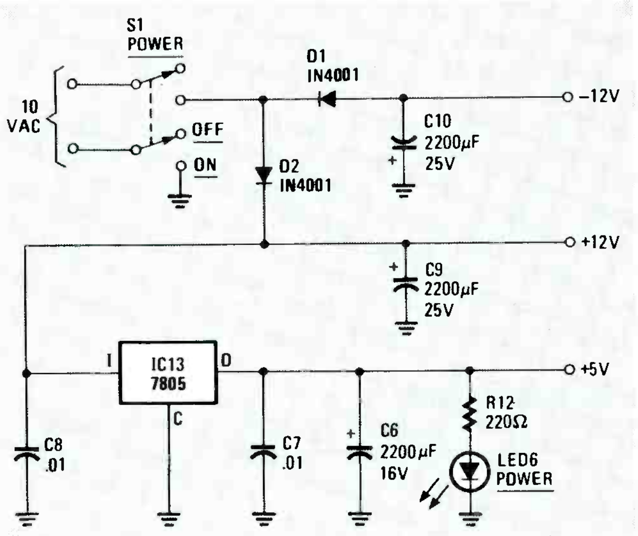


FIG. 4—THE MULTIPLEXER'S POWER SUPPLY: Mount IC13 on a small heatsink.

provide clearance for soldering. Now install the remaining components, and then make sure that all polarized components are installed correctly.

The next step is to prepare the case. You'll need to provide holes on the front panel for S1, S2, and the LED's, and holes on the back for the five RS-232 connectors and the power jack. Label the case with dry-transfer lettering.

Connect (but don't mount) the power jack and the RS-232 connectors. Input jacks J1–J4 are wired identically; output jack J5 is wired differently, so be careful! Solder all wires to both sides of the board. Then, after the jacks are connected, mount them to the case, making sure the output jack is mounted in the correct location. Now wire and mount the switches and LED's. With all components installed, the PC board can be mounted. Secure it to the bottom of the case using ⅜-inch standoffs. The complete assembly appears as in Fig. 6.

Testing and use

The first test is done before connecting the multiplexer to a printer. Make sure the PAUSE button is disengaged, and then apply power. The POWER LED should light up, as should one of the four port-indicator LED's. If that does not happen immediately, remove power and make sure all parts were installed in the correct locations, with the correct orientation, and that all solder joints are good. When the board is debugged, resume testing.

With no printer connected, the first port-indicator LED should remain lit, indicating that the scanning circuitry is in the pause state, because the multiplexer's ready input (pin 20 of J5) is simply floating.

Now connect a printer and one or more computers to the multiplexer. Be sure that the printer is on, has paper loaded, and is on line. The computer should be configured for the printer's baud rate, number of start and stop bits, and DTR handshaking.

The port-indicator LED's should light up sequentially now, indicating that the multiplexer is checking the input ports for data to print. Engage the PAUSE button. The LED that is currently lit should remain so. Now release the PAUSE button; scanning should resume.

Now try printing something from a computer. As the sequencer reaches the port that the computer is connected to, it should lock onto that port, and the printer should begin to print. Printing can be suspended at any time by simply pressing the pause button. Of course, if your printer has any memory of its own, printing may continue for some time until the contents of that memory are exhausted. When the PAUSE button is released printing should resume.

Start a print job from the second computer before the first is finished. When the first computer is done the multiplexer will resume scanning. As it reaches the second computer's port, it should lock onto it and the printer should begin printing.

Cable notes

The multiplexer should be located with respect to the printer and the computers so that overall cable length is minimized. If a print buffer is being used, for all computers to benefit from it, it should be connected between the multiplexer and the printer.

Each of the multiplexer's input ports is configured so that it appears as a printer port. Data is received on pin 3, and pin 2 (which would be used to transmit data back from the printer to the computer) is simply held at a low RS-232

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
R1—1000 ohms
R2—100,000 ohms
R3—22,000 ohms
R4–R6, R13–R20—4700 ohms
R7–R12—220 ohms
Capacitors
C1–C5—0.1 µF, disk ceramic
C6—220 µF, 16 volts, electrolytic
C7, C8—0.01 µF, disk ceramic
C9, C10—2200 µF, 16 volts, electrolytic
Semiconductors
IC1, IC10—1488, quad RS-232 line driver
IC2, IC11—1489, quad RS-232 line receiver
IC3—555, timer
IC4, IC9—74LS08, quad AND gate
IC5—74LS138, 3-to-8 line decoder
IC6—74LS74, dual RS flip-flop
IC7—74LS393, 8-bit binary counter
IC8, IC12—74LS32, quad OR gate
IC13—7805, 5-volt regulator
D1, D2—1N4001 rectifier
LED1–LED6, standard
Other components
S1, S2—DPDT switch (Thorsen 35-491 or equivalent).
S3—four pole DIP switch
J1–J5—25-pin D connector
Miscellaneous
10-volt AC wall-mount power transformer, matching jack, case, hardware, etc.
Note: The following are available from Renton Products, P.O. Box 16271, Seattle, WA 98116: etched and drilled PC board, $19; complete kit of parts (including PC board, power supply, all components, and hardware except for the case), $89. Washington residents add appropriate sales tax. All orders add $3 shipping and handling.

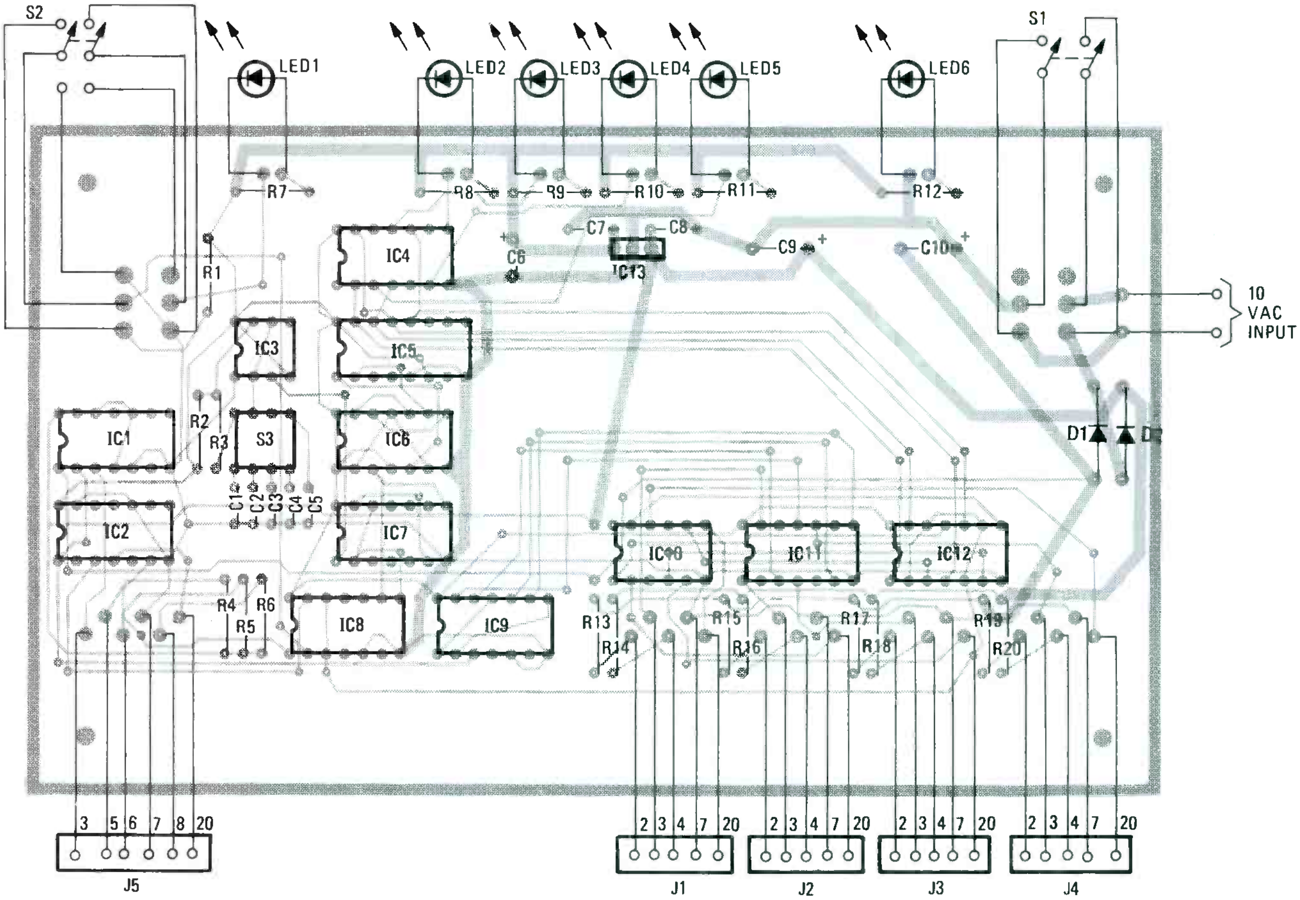


FIG. 5—MOUNT ALL COMPONENTS as shown here.

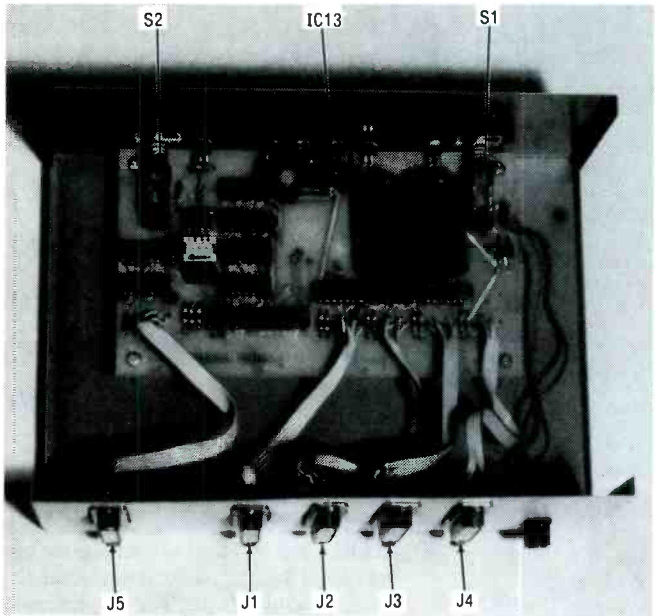


FIG. 6—THE FINAL ASSEMBLY looks like this.

level. Pin 4 is the Data Set Ready signal; it is pulled high to 12–15 volts through a 4.7K resistor. Many computers require that pin to be high before they will transmit data.

The serial port of the IBM PC (and compatibles) is configured so that a cable with pin-for-pin connections (pin two to pin two, pin three to pin three, etc.) would be used with a modem. To connect a printer to a PC, a "null modem" cable must be built. The wiring is shown in Fig. 7. Or you could rewire the multiplexer's input ports so that a "straight" cable could be used.

The port from the multiplexer to the printer should be wired up with a straight cable. However, check your printer's documentation just to be sure.

Problems and solutions

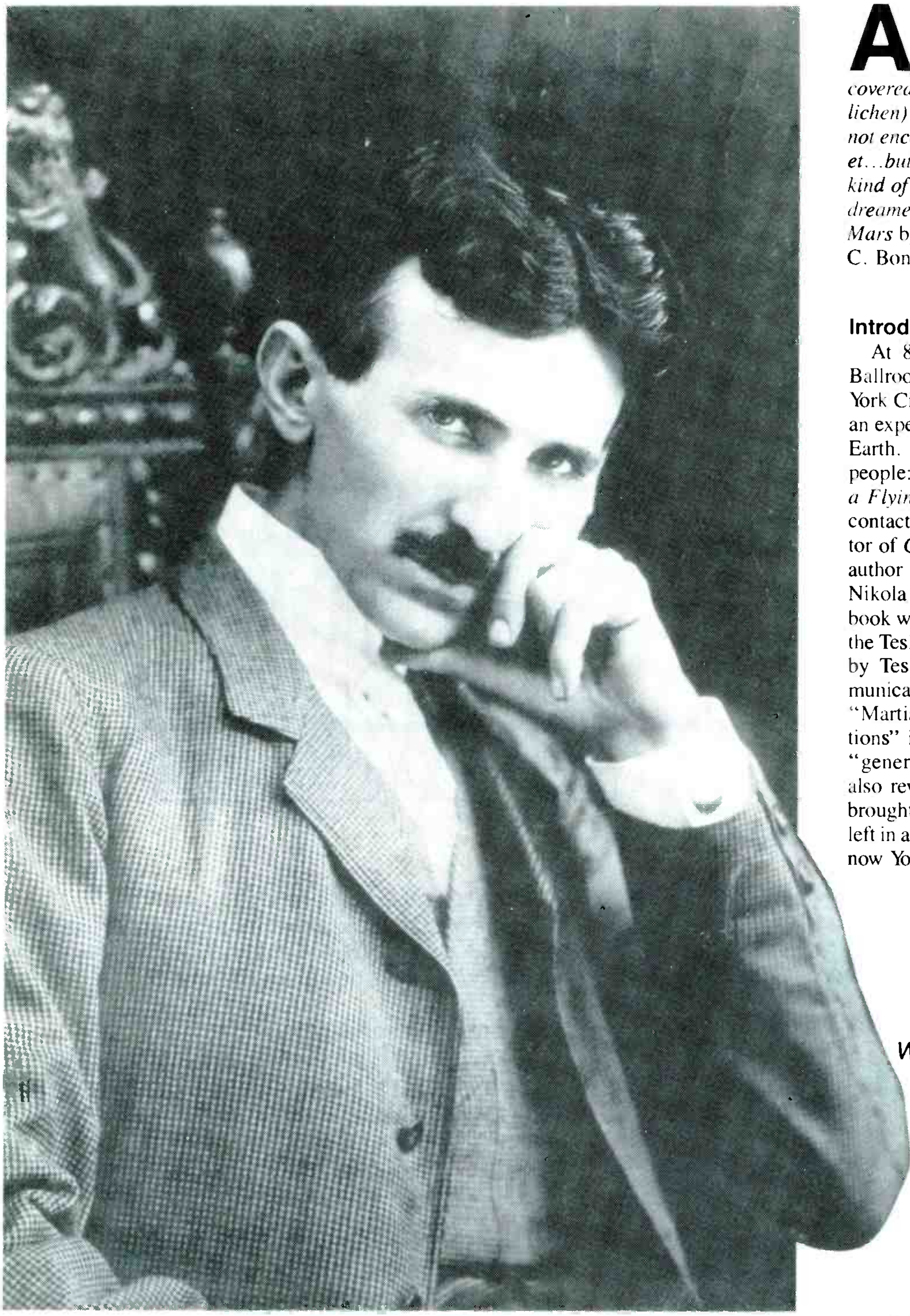
You may have problems using the multiplexer with some software packages. For example, a CAD program might output some data, do some calculations, and then output some more data. During the calculations, the multiplexer's timer may time out, in which case the multiplexer would resume scanning. It might then lock onto another port and mix up print jobs.

Another problem might be using a word-processor in a single-sheet mode, wherein the software pauses after printing each page and then allows you to insert a new sheet of paper. Again, during the pause, the multiplexer could resume scanning.

The solution in both cases would be to increase the timeout period. First try closing the sections of the DIP switch; if that doesn't help, you can increase resistor values, capacitor values, or both, in the 555 circuit.

Another less-desirable approach is to press the multiplexer's PAUSE button when you need to change sheets of paper. You could also take the printer off line.

Some programs may tell you that the printer is not ready if the DTR line is low. That could happen if a second print job were started before a first ended. In that case you may find that it is necessary to instruct your program to print several times until the multiplexer gets around to checking your port.



NIKOLA TESLA: Interplanetary Communicator?

BY MARC J. SEIFER

And this is the picture of Mars at mid century: a small planet which three-fourths is cold desert, with the rest covered with a sort of plant life (most likely lichen) that our biological knowledge cannot encompass...Mars is not the dead planet...but neither can it be inhabited by the kind of intelligent beings that many people dreamed of in 1900" (*The Exploration of Mars* by Werner von Braun, Willy Ley and C. Bonestell, 1956).

Introduction

At 8 p.m. on June 20th, 1957, in the Ballroom of the Hotel Diplomat in New York City, a meeting was held to coordinate an expected visit by "the Space People" to Earth. The meeting was planned by three people: George Van Tassel, author of *I Rode a Flying Saucer*; George King, telepathic contactee with the extraterrestrials and editor of *Cosmic Force*; and Margaret Storm, author of an occult-oriented biography of Nikola Tesla entitled *Return of the Dove*, a book whose "transcripts (were) received on the Tesla set, a radio-type machine invented by Tesla in 1938 for interplanetary communication." By July 1, it was assured, the "Martians" would have "full scale operations" in Washington D.C., New York and "general North American areas." It was also revealed that "Tesla was a Venusian, brought to this planet as a baby in 1856, and left in a remote mountain province in what is now Yogoslavia [sic]."

Througout his life, inventor Nikola Tesla was convinced that he had received a message from beyond the Earth. Was he right?

In attendance at that meeting was a man who preferred to remain unnoticed. He was an FBI agent assigned to continue the growing file on the enigmatic Serbo/Croatian inventor, Nikola Tesla. *The Interplanetary Sessions Newsletter* from which the preceding information was taken came from the Tesla FBI file released to me through the Freedom of Information Act.

From this same dossier it is clear that Tesla had been watched in his waning years by J. Edgar Hoover, who wrote, on January 21, 1943, during the height of World War II, "A review of the Bureau files reveals considerable information concerning Nikola Tesla and his inventions." It was just two weeks after the inventor's death, and Hoover feared that Tesla's creations, including his well publicized "death ray," could get into the hands of "the Axis Powers" or the Soviet Union as Tesla's nephew, Sava Kosanovich, ambassador to the newly created Communist country of Yugoslavia was demanding that his uncle's estate be shipped to a museum that was being erected there in his honor. Hoover wrote that "Kosanovich might possibly make certain material available to the enemy."

The Teslascope

Margaret Storm's supposition that Tesla was born from another planet to give our world such devices as the induction motor, fluorescent and neon lights, remote control, robots, the radio, and also our entire electric-power distribution system, stemmed from a colorful history of the inventor's ties to the group-fantasy that life on Mars was a virtual certainty. Storm was also influenced by the times (e.g., the mid-1950's interest in UFO's; the general state of paranoia fueled by the fear of communist infiltration, *i.e.*, the McCarthy period), her readings in Theosophical literature which linked Tesla to the so-called sixth-root race, (the new species of human that was evolving on the planet), and also to her friendship with Arthur Matthews, a bizarre electrician, who as far as I know is still alive and still contends that he and his employer, Tesla, had traveled many times to nearby planets aboard a Venusian spacecraft.

Storm's choice of 1938 as the date for the invention of the interplanetary communicator appears to be a year off. On Tesla's 81st birthday, he announced the invention of what has come to be called the "teslascope."

An article in the July 11, 1937 *New York Times* quoted Tesla: "I have devoted much of my time during the last year to the perfecting of a new small and compact apparatus by which energy in considerable amounts can now be flashed through interstellar space to any distance without the slightest dispersion."

The article went on to describe "a new form of tube" able to produce potentials in excess of 18 million volts. "It is of ideal simplicity...It will carry heavy currents, transform any amount of energy within practical limits, and permits easy control and regulation of the same."

Schemes and apparatus for an interplanetary communicator for the octogenarian, however, were anything but new. For instance, in a 1907 *New York Times* editorial, Tesla said, "My magnifying transmitter...can easily bridge the gulf which separates us from Mars." Many years later (1921), Tesla published a short article in the *Electrical World* entitled "Interplanetary Communication." There, he restated that he had received impulses stemming from Mars in 1899 and that since that time had developed "numerous designs...(for) thoroughly practical apparatus."

Tesla: Cosmic Star of the Gilded Age

Kings of Belgium and Serbia, and upper echelons in England, France, Germany, Austro-Hungary, Italy, and Russia knew the electrical genius intimately. Tesla was an international figure who moved among the very pinnacle of social circles. At the turn of the century, his American friends, enemies, and associates included: Col. John Jacob Astor, perhaps the greatest landowner in New York City and builder of the Waldorf Astoria, Tesla's lodging for over a decade; industrialists George Westinghouse and John Hays Hammond; financiers Henry Clay Frick, builder of the Frick Museum, Equitable Insurance director Thomas Fortune Ryan, J. Pierpont Morgan, investor in many Tesla products and schemes and most powerful economic force on the planet, and banker Jacob Schiff; editors Robert Underwood Johnson of *The Century*, T.C. Martin of *Electrical World* who was the compiler of the first Tesla collected works and a biography of Edison, and Joseph Collier of *Collier's Magazine*; artists such as composer Dvorak and writers Rudyard Kipling and Mark Twain; and, of course, inventors such as Oliver Lodge, Guglielmo Marconi, Elihu Thomson, and Thomas Edison— Tesla's employer from 1884–85 and arch-enemy/competitor for the next 35 years.

Tesla's invention of the induction motor and alternating-current polyphase system, sold to Westinghouse as a 40-patent package for $85,000, plus royalties, in 1888, changed the course of history in a dramatic and intimate way. The electrical genius had conceived a means of sending electricity more than one mile.

Before Tesla, that was about the extent of the budding electric-utility industry's ability to transport energy, and then only to illuminate lightbulbs. After Tesla, power to run factories could be transported hundreds of miles—for example, from Niagara Falls to New York City. Tesla made impossible dreams industrial realities and he was heralded at the time for his brilliance. Remember that when you see a jewel-lit city and surrounding network of illumed surburbia some night, it is a monument to the Serbian Aladdin who believed in interplanetary communication.

After changing the course of history from a future envisioned by Edison backers, which would have required a power station every square mile across the civilized continents, to one containing just a small number of mighty transmitting sources, Tesla decided to go one better. In 1893 he pieced the wireless puzzle together from his own experiments in cordless vacuum lamps and from research by Sir William Crookes, Sir Oliver Lodge, Heinreich Hertz, and Sir William Preece. Tesla discovered that the Earth itself could be used to transmit energy. Thus, the need for constructing hundreds of thousands of miles of transmission lines was unnecessary, for proper apparatus could transport huge amounts of energy from one point on the globe to another without any wires.

The inventor's scheme was actually quite simple. Tesla realized that this giant electromagnet called Earth has resonant frequencies (which today are known as telluric currents). By building giant broadcasting towers to pump large voltages into the earth and ambient medium, and by building identically designed receiving stations, both in exact mathematical relationships to the size of the Earth and its period of frequency, terrestrial carrier waves would abolish the need for transmission lines. Once power was "jumped" that way from, say, a waterfall to a distant city (i.e., from tower to tower) and converted to more useable frequencies, energy could be transported locally by means of conventional wire transmission lines or via resonant receiving devices such as remote controlled clocks, telephones, teletype, and lighting fixtures. At the same time, Tesla reasoned, even greater charges set up in such a way as to amplify the naturally flowing Earth current could transmit a significant impulse from this planet to another.

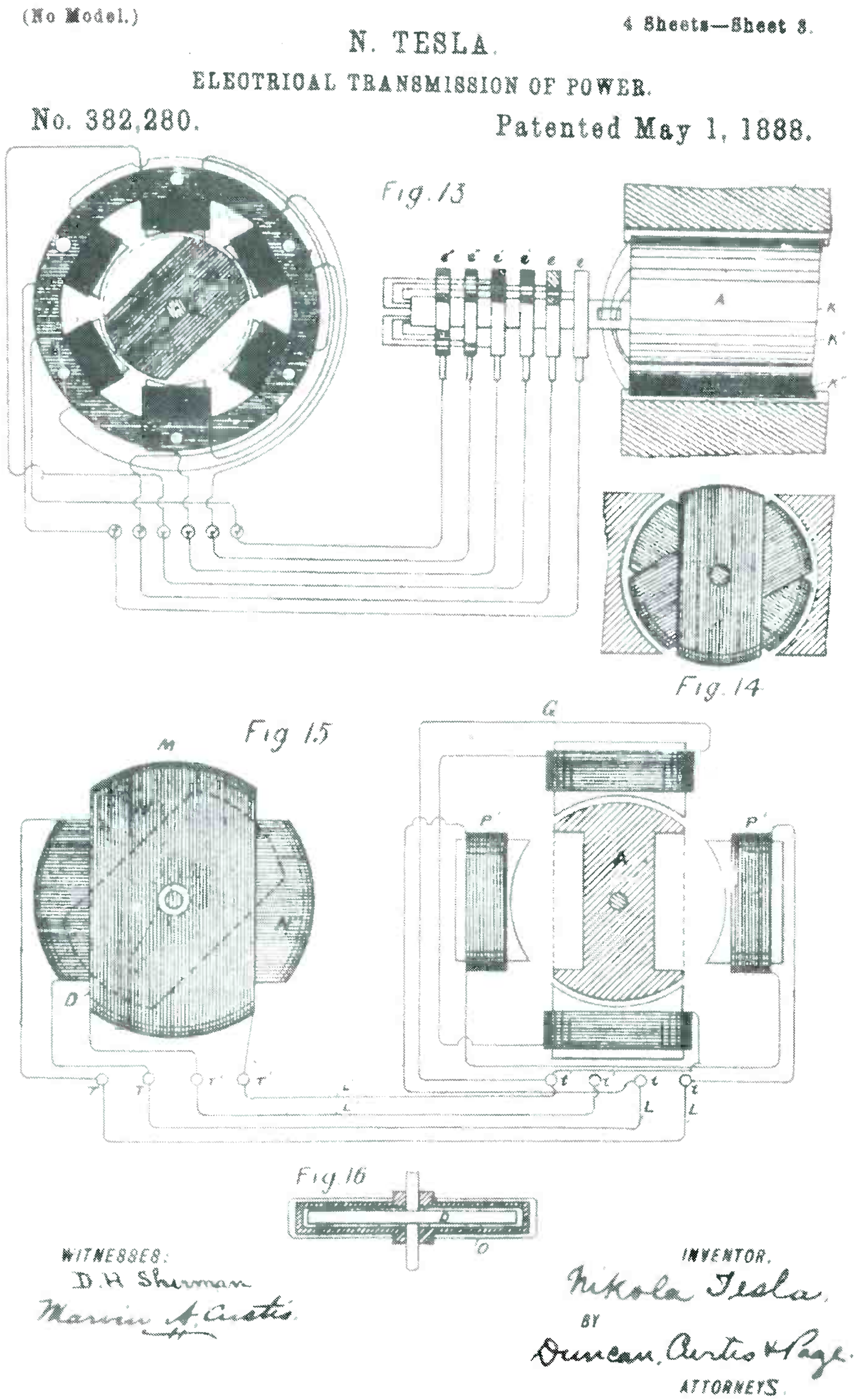
Interplanetary Communication

To prove his wireless scheme and begin plans for inauguration of his World Telegraphy System, in 1899, Tesla moved his operations to Colorado Springs where he constructed a laboratory and 200 foot transmission tower with plans of circumscribing the globe with electrical impulses. One summer night, while in his wireless laboratory high in the Rockies, Tesla was engaged in tracking thunderstorms within a radius of 1200 miles with sensitive electrical devices. During that time he received "three fairy taps" on that radar-like apparatus. He speculated in a series of articles, one in 1901 in *Colliers Magazine*, that those impulses probably originated from intelligent sources exterior to the Earth such as from Venus or Mars.

In the *Colliers* article, Tesla said "I can never forget the first sensations I experienced when it dawned upon me that I had observed something possibly of incalculable consequences to mankind...the feeling is constantly growing in me that I had been the first to hear the greeting of one planet to another."

Stating in the same article that he "could feel the pulse of the globe as it were," the electric sorcerer rejected the idea that he may have intercepted a mere earthly message from such wireless colleagues as Professor Marble in Connecticut, Dr. Riccia in France, Professor D'Azar in Rome, or rival Guglielmo Marconi who two years later sent "3 fairy taps" across the Atlantic Ocean to capture the imagination of the world with the first transatlantic wireless message.

During the very months Tesla was perfecting long-range wireless transmission



Tesla's invention of the induction motor and the AC polyphase system changed the course of world history. His inventions made it possible to transmit electrical power over wires for long distances. Previously, the maximum distance possible was limited to about one mile.

and radar tracking devices, Marconi was experimenting with pirated Tesla oscillators in broadcasting the Morse code for the letter S (*i.e.*, dot-dot-dot) over hundreds of miles in Europe and across the English Channel. Modifying the extraterrestrial encounter, recent biographers such as Hunt and Draper, and Cheney, have suggested that Tesla may have picked up the vibrations from a stellar quasar. In either case, however, Tesla was perceived as returning to New York City and his home at the Waldorf, having received messages from outer space.

A few years later, the awful truth dawned upon Tesla: he had received the electromagnetic echo of Marconi's experiments; however, that realization was too painful and Tesla defended vehemently against it in a classic psychoanalytic way: he rationalized by seeking alternative hypotheses and regressing to a more-primitive belief structure. In a 1921 article, Tesla admitted as much but disguises it as a denial:

"I was naturally very much interested in reports given out about two years ago that...these supposed planetary signals were nothing else than interfering undertones of wireless transmitters, and since I announced that fact other experts have apparently taken the same view. These disturbances I observed for the first time from 1906 to 1907. At that time they occurred rarely, but subsequently they increased in frequency. Every transmitter emits undertones, and these give by interference long beats, the wavelength being anything from 50 miles to 300 or 400 miles."

To further support the claim that Tesla's reception of so-called Martian signals was based upon self-delusion, it is clear that for at least seven years prior to 1899, Tesla desired to transmit and receive impulses with nearby planets. For instance, in 1896, fully three years before Tesla's alleged ET encounter, the *New York Sun* published a Tesla interview under the spectacular title "Tesla May Signal to Mars." The inventor said: "If there are intelligent inhabitants of Mars or any other planet, it seems to me that we can do something to attract their attention."

Three years later when he arrived in Colorado, after announcing to the reporters once again that he could signal Mars, Tesla fulfilled his own oft-stated boast by being the first human to hear from the space people. Rather than accept the more likely hypothesis, that deep within himself he probably/possibly knew was the correct one (*i.e.*, undertone receptions from Marconi), Tesla opted for the more exotic scenario of space communications. With each succeeding year, the event became slightly more exaggerated as it took on more and more symbolic importance.

The reclusive Balkan inventor clung to the extraterrestrial motif throughout his life, repeating the speculation publicly on many occasions such as in 1931 for a Time Magazine cover story celebrating his 75 birthday:

"Nothing can be more important than interplanetary communication. It will certainly come some day, and the certitude that there are other human beings in the universe working, suffering like ourselves will produce a magic effect on mankind and will form the foundation of a universal brotherhood that will last as long as humanity itself."

In no way was Tesla alone in his belief in the existence of extraterrestrial intelligence. The theme of space beings wishing to communicate with Earthlings can be traced to biblical tales of burning bushes, aerial wheels of electrum, cosmic commandments, and bright stars traversing the sky to point out the birth of Christ; or to the mythological gods of ancient Rome or Greece such as Zeus, Thor, Hermes, Venus, and Apollo. However, it was modern "scientific" and literary fiction that inspired the more apparent basis for Tesla's suppositions.

The Plurality of Worlds

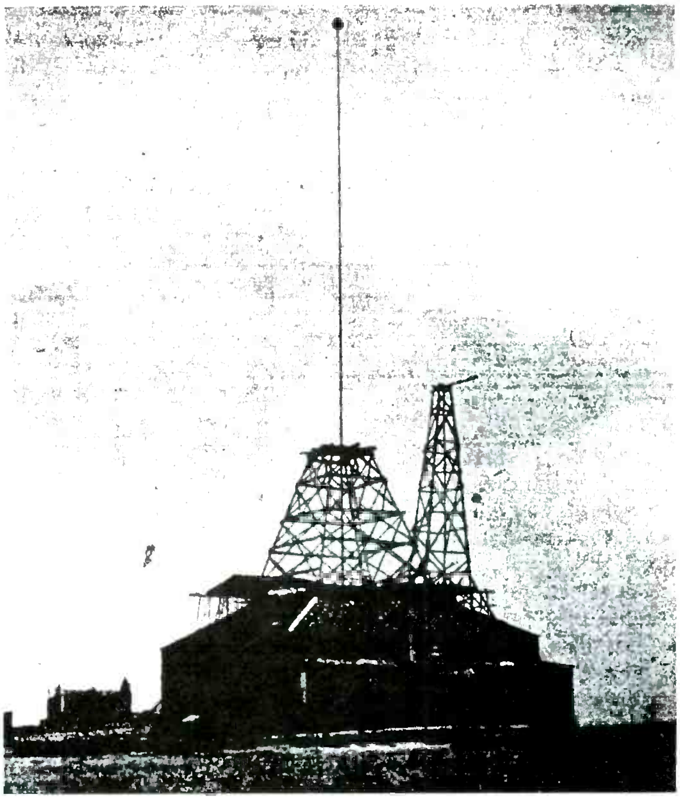
As anyone who has stared at the star-lit night sky knows, the belief that we are not alone is a very plausible hypothesis. With millions of galaxies each containing billions of stars, there are virtually an infinite number of potential star systems with satellites similar to our own probably capable of sustaining life. This idea, called the plurality-of-worlds hypothesis, is a concept that through the ages has counted numerous scientists among its ranks. Early astronomers such as Bruno, Kepler, Newton, Laplace, and Herschel took that position, along with such modern-day astrophysicists as Willy Ley, Werner von Braun and Carl Sagan.

Naturally, at the same time, numerous artists and authors also have seized that notion and fashioned tales of extraterrestrial travel and intrigue. Two thousand years before Steven Speilberg's movie "ET" earned over $300,000,000, and the phrase "ET phone home" became embraced by the public, Lucian of Samoa, a contemporary of the Greek philosopher Plutarch, wrote *The True History*, a fable about a sailing ship that was hurled to the moon by a whirlwind. That theme of planetary travel was also echoed by Bishop Goodwin in 1638 when he authored a story about a man who was towed on a sleigh to the same heavenly body, and by Cyrano deBergerac 20 years later in his books *Empires of the Sun* and *Voyage to the Moon*.

In 1835, Richard Adams Locke, of the *New York Sun* created a series of front page articles on astronomer Sir John Hershel and his alleged discovery of advanced life forms on the moon. Locke's hoax, which spread around the world before it was exposed, was predicated on the fact that Herschel was in South Africa at the time, and therefore out of contact with the press. Hershel's supposed discoveries of unicorn-like animals and winged humanoids were made via a marvelous (and fictitious) telescope that weighed 15,000 pounds, was 150 feet long, and could magnify the heavens 42,000 times.

In 1865, Jules Verne reawakened the idea of journeying to the moon, but by the late 1870's, focus shifted to Mars. That planet became the most likely candidate for the home of higher beings for fiction writers and astronomers alike, not only because of its similarity to the Earth in size and position, but also because of the dynamic and changeable nature of its surface as seen by the astronomers. For instance, Mars has ice caps that grow and diminish with the seasons.

The first attempts to create a map of Mars and delineate those lines can be traced back to Bernard de Fontana, Christain Huyghens, and Mr. Cassini in the mid-1600's. More detailed drawings were done by the discoverer of Uranus, the well-known astronomer Sir John Herschel in 1830 and by numerous other scientists such as Mr. Schmidt (1862), R.A. Proctor (1867) and Camille Flammarion (1873).



Tesla's experimental laboratory in Colorado Springs, Colorado. Here, while working on his theory of worldwide power transmission, he received "three fairy taps" he felt were sent by intelligent life on Mars or Venus.

The year 1877 was a watershed for Martian influence on Earthlings. During a particularly close pass to our planet that year, two fabulous discoveries were made: Mars had its own moons and its surface was adorned with a matrix of symmetrical furrows.

The first discovery by Professor Asaph Hall confirmed Kepler's supposition of 1610 that two small satellites circled the "Planet of War." That find was of particular importance because it also supported claims for two Martian moons put forward by novelists Voltaire and Johnathan Swift, the former in a philosophical treatise on the Solar System and the latter in his classic tale *Gulliver's Travels*. In the December 1887 issue of *Cornhill Magazine*, Astronomer Hall wrote dramatically that the path of one of the moons across the zodiac: "passes...the feet of the Herdsman, the body of the Serpent...over the Bow of the Archer...the head of the Crane, and along the Southern fish...Thence the Martian moon passes athwart the Sea Monster and the River Eridanus...(and) very near the celestial equator of the Martian heavens."

The widely read monthly concluded that "Martian moonlight is but small in amount, and certainly can not go far to compensate the Martians—as compared with us terrestrials." However, no real evidence regarding the prevailing theory of the plurality of worlds was obtained.

That theory was championed by the flamboyant French astronomer and psychical researcher Camille Flammarion in his classic works *The Plurality of Worlds* and *Mars and Its Inhabitants*. Both "scientific treatises" were written after his more mystical tale, entitled *Stories of Infinity*, about a conversation the author had with a comet named Lumen was published.

Flammarion's belief that Mars housed life stemmed not only from his daily studies with his own telescope of the mountains and craters of the planet, but also from the more detailed observation supplied by Italian stargazer Giovanni Schiaparelli, who announced to the world that the Red Planet was etched with geometrical and parallel trails which he named "canali." Renamed "canals," instead of the more literal translation of "channel," Flammarion boldly suggested that: "these canals may be natural...or they may be grooves excavated by the inhabitants for the distribution of water..."

After discussing the size of the oceans, (which were no larger than the Mediterranean), the changing climates, and a snowfall photographed by Professor Pickering of Harvard in 1890, Flammarion concluded "it is obvious...that the world of Mars is...vigorously alive." He also suggested that due to the lightness of the atmosphere: "the inhabitants of this planet may have received the privilege of flight... May they not rather be like dragon-flies fluttering in the air above the lakes and the canals?"

Influenced rather dramatically by those bold words and scientific observations, which appeared in *Review of Reviews* and *North American Review*, the *Time Magazine* and *Saturday Evening Posts* of the Gay Nineties, the hypothesis that Mars was inhabited by an advanced civilization was given further observational corroboration by Percival Lowell, discoverer (30 years later) of the planet Pluto, and builder of a magnificent telescope in Flagstaff, Arizona.

A descendant of the prestigious Bostonian Lowell family and brother of the president of Harvard University, Percival captured the front page of the *New York Times* with "Mars Inhabitated" headlines on a number of occasions as he published the results based upon his detailed Martian maps in the prestigious science journals such as *Nature*, and in a magnificent text published by Macmillian entitled *The Canals of Mars*: "Suggestive of a spider's web seen against the grass of a spring morning, a mesh of fine reticulated lines overspreads...the globe from one pole to another...That Mars is inhabited by beings of some sort or other we may consider as certain as it is uncertain what those beings may be...Girdling their globe and stretching from pole to pole, the Martian canal system not only embraces their whole world, but it is an organized entity...the first thing that is forced on us in conclusion is the necessarily intelligent and non-bellicose character of the community which could act as a unit throughout its globe."

Not to be undone, novelists and newspaper columnists embraced this group fantasy with ardor, In 1896, George duMaurier, grandfather of Daphne, wrote the novel *The Martian* in which he described the telepathic winged beings "that descends from no monkey," but are able to excavate, adorn with marble statues, and irrigate the entire planet. H.G. Wells went one better with in his serialized 1897 horror story *War of the Worlds*, when he had terrible extraterrestrials invade and destroy the Earth. George Lathrop, son-in-law of gothic writer Nathaniel Hawthorne, combatted the Red Planet's warriors on the pages of *The New York Journal* in 1895 with disintegrating death rays invented by the Wizard of Menlo Park, Tom Edison.

Other scientists such as Lord Kelvin suggested that the light from New York City created a clear signal of progress to the Martians; Elihu Thomson of General Electric brought his telescope to his factories in order to show his workers the canals of Mars with their own eyes!

Tesla and the extraterrestrials

Quite naturally, Tesla, who like the others, had followed the interplanetary developments for decades, did not want to be eclipsed by such competitors as Thomson or Edison. Therefore, he proclaimed boldly that the time finally arrived: communication with our extraterrestrial neighbors had (probably) begun.

Perhaps due in part to a friendly sparring match of spectacular articles, the brother-in-law of George Lathrop, *Philadelphia North American* columnist Julian Hawthorne came to Tesla's aid and authored a series of rather detailed treatises on the inventor's philosophy, laboratory, and fabulous electronic experiments...and also his work in interplanetary communication.

In an article entitled, "And How Will Tesla Reply To Those Signals From Mars?" Hawthorne wrote: "Mars, for example, is several millions years older than this little dot of an Earth of ours...How we stare at the Neanderthal skull and try in vain to reconstruct for ourselves a mode of existence the date of which in contrast with the superiority in age of Mars over us, is but as yesterday...Think what prophecies we are hazarding as to the miracles we will achieve before the year 2000...Measuring against that standard, then, to what height shall we have attained this day in a million years?...

"The other day, there happened to Mr. Tesla the most momentous experience that has ever visited a human being on this Earth. Three soft impulses travelling with the speed of light were received by Tesla in Colorado from some Tesla on the planet Mars!

"...No thoughtful man can have much doubt then, that little as we are aware of it, we must for many ages have been subjected to the direct inspection and familiar approach of the men of Mars and of the other older planets. They visit us and look us over...year after year; and report at home: They're not ready yet! But at length a Tesla is born, and the starry men are on the watch for developments. Possibly they guide his development; who can tell?"

Thus, when Margaret Storm suggested that Tesla was a space being, it is clear that her hypothesis was deeply rooted into a well-ingrained belief that extraterrestrial life was a certainty. Her choice of the year 1938 was somewhat arbitrary in terms of pinpointing a specific date for over 40 years of Tesla dabbling with interplanetary devices. The year 1938 may actually have been chosen by Storm for quite another reason, as that was the year John Houseman and Orson Welles terrified America by broadcasting on the radio an updated version of H.G. Wells' classic tale, *War of the Worlds*.

Located in Shoreham, NY, this tower was built by Tesla for experiments in worldwide telegraphy and power transmission. The tower never became operational.

A Gallup poll taken just a few days after the authentic-sounding broadcast about a Martian invasion, estimated that upward of two million people were psychologically shaken by it. Perhaps fired up by the recent success of the Nazi invasion of Austria, numerous people huddled by their radios and waited for Armageddon.

"When the Martians started coming north from Trenton we really got scared," said one listener. Where another person assumed God was finally punishing humans for their evil deeds, a third radio buff said in resignation to her nephew, "Well, we might as well eat this chicken—we won't be here in the morning."

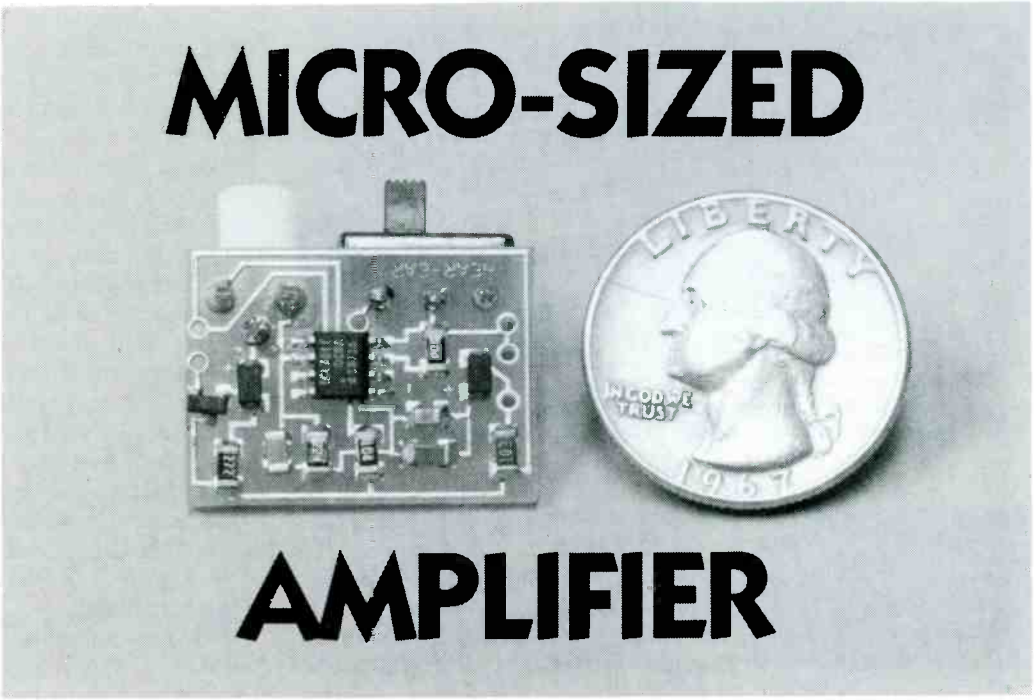
Tesla's attachment to the Martian hypothesis in the short run fueled controversy and notoriety from admirers and vehement anger from competitors and critics. However, in the long run, those spectacular claims only served to undermine the inventor's credibility and make it more difficult for him to raise the necessary capital for his quite serious inventions in the wireless telegraphy of light, voice, pictures, and power, a project which even to this date has yet to be realized. Eventually and steadily, Tesla's well deserved fame for his patented inventions disappeared from the public eye, as the name of Tesla became associated with the flying saucer crowd, which transformed the Serbian mystic into an extraterrestrial messiah whose secret inventions provided the key for direct communication with the "Great Beings" above.

Epilogue

On May 22, 1983, the batteries on the Viking probe that landed on the Red Planet in 1976 burned out. However, the satellite had served humanity well: Its robot arm, affectionately named Mr. Badger, which scraped up Martian turf and fed it Earth food, had recorded rather astonishing results. Expecting an effect which would have either increased or decreased the amount of organic material presented, the Martian soil reacted in such a way that both increases and decreases were achieved. As quoted in the December, 1976 issue of *Science*, that was called "extraordinary behavior" by NASA scientists Crofton Farmer and Hugh Kieffer.

Although no organic material was discovered and the scientists "warrent(ed) extreme caution in reaching a conclusion concerning the existence of life," Farmer and Kieffer were forced to conclude "despite all hypothesis to the contrary, the distinct possibility remains that biological activity has been observed on Mars." Was Tesla, as he usually had been in all his work, simply ahead of his time again? ■

MICRO-SIZED AMPLIFIER



Because it uses surface-mount technology, this micro-size amplifier is not much larger than your thumbnail; but it can make your ears super-sensitive.

FRANK POLIMENE

BECAUSE THEY'RE SO TINY THAT THEY CAN be tucked directly inside the ear, high-gain micro-amplifiers add greatly to the quality of life for the hearing-impaired. For others—those who can still hear the TV without cranking up the volume so high that it can be heard down the block—micro-amps can be lots of fun, because they make possible projects that couldn't be done using conventional-size, or even miniature amplifiers.

As a general rule, commercial super-gain micro-amps are usually a component part of a larger, relatively expensive device, such as a hearing aid, a long-range Big Ear-type microphone, or a surface-microphone super-snooper device that you can use to listen through walls or to monitor your own heartbeat. However, if you'd like to experiment with a micro-amp that's so small that it can almost hide behind a quarter, you can build an SMT (*S*urface-*M*ount *T*echnology) version of the amplifier shown in Fig. 1 for under $20.

If the amplifier was assembled using standard technology it would occupy a space of approximately four square inches; but, by using surface-mount technology we will build the amplifier, including through-hole devices S1 and R6, on a ¾ × 1-inch PC board. Then we'll show you how to use the micro-amp for both a home-brewed Big-Ear type microphone and a super-snooper.

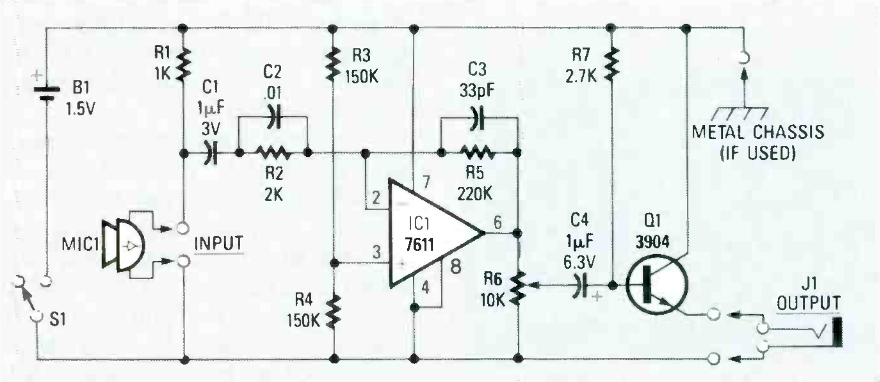


FIG. 1—THIS AMPLIFIER CAN BE BUILT using either SMD or conventional components. Even IC1 and Q1 are available in both SMD and conventional sizes.

Really small

The operational amplifier (IC1) and transistor (Q1) shown in Fig. 1, as well as all the capacitors and fixed-resistors, are available in both conventional and SMD (*S*urface-*M*ounted *D*evice) versions.

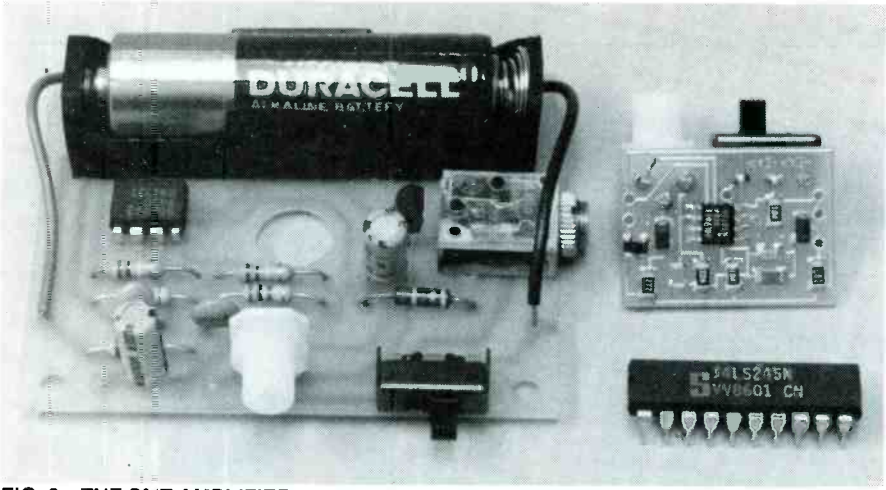


FIG. 2—THE SMT AMPLIFIER on the right and the conventional amplifier on the left have the same performance, although the conventional amp's PC board has room for a battery holder and an output jack. The 20-DIP IC also serves to illustrate the small size of the SMT amplifier.

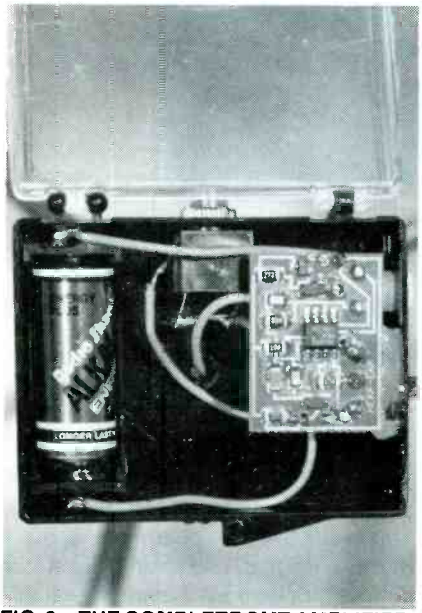


FIG. 3—THE COMPLETE SMT AMPLIFIER, including an N-battery and an earphone jack, can be assembled in a small plastic pill box.

SMD-type capacitors and resistors are called *chips*; hence, an SMD-type resistor is called a *chip resistor*.

Figure 2 shows the SMT amplifier on the right and the same circuit, made using conventional miniature components, on the left. Note that when using conventional parts, the PC board gets so large that's its easy to install the battery holder and an output jack for the headphones directly on the board. Obviously, for the SMT amplifier the battery (B1) used for the power supply and the microphone (MIC1) must be external to the amplifier. The 20-pin DIP IC, also seen in Fig. 2, shows the relationship in size between the entire SMT amplifier and a single conventional integrated circuit.

Why so small?

While most of us can understand the reasons for using surface-mount technology in commercial equipment, it's logical to ask what real value or purpose there is for the hobbyist to use SMT to build what is essentially a simple electronic circuit. First, it gives you a chance to build a practical device that could not be easily done using conventional-size components. Second, using SMT provides both acquaintance and experience with the latest manufacturing technology used in consumer and professional equipments.

The complete amplifier assembly (Fig. 3) that is used for for both the Big Ear-type microphone and the super-snooper is a good example of why a hobbyist would use SMT construction. The entire amplifier, including its battery and headphone jack, is so small it can be assembled in a plastic pill box that can be glued to the front of a Big Ear-type microphone, or carried in a shirt pocket.

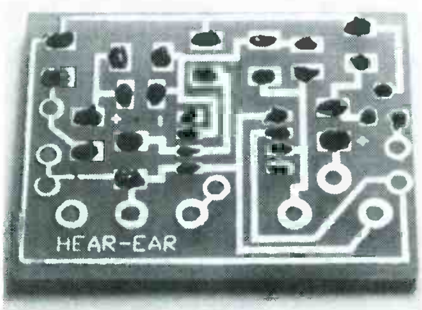


FIG. 4—DROPS OF SOLDERING PASTE are applied only to the components' soldering pads.

The amplifier

Sound detected by the electret microphone (MIC1) is fed to IC1's input through resistor R2, and capacitors C1 and C2. Resistors R2 and R5 determine the overall stage gain, while C2 partially determines the amplifier's frequency response. To ensure proper operation using a single-ended power supply, R3 and R4 simulate a null condition equal to half the power supply's voltage at IC1's non-inverting input.

The output of IC1 is transferred to emitter-follower amplifier Q1 via volume control R6. The high-Z-in/low-Z-out characteristic of the emitter-follower matches the moderately high-impedance output of IC1 to a low-impedance headphone load.

Stop and think

One note of caution on the SMT amplifier. There is a practical limit as to how small the battery can be. While N-size and larger batteries work fine, the small 1.5-volt button cells don't have sufficient ampacity (current-capacity) to provide a low-distortion output. So when figuring how you'll house the amplifier, keep in mind that the battery will be about the same size as the amplifier, or larger. Also, the battery's life depends on the type that you use. You can expect about 12–24 hours of continuous use from a small watch battery, and two months or more from a D-type Alkaline flashlight battery. Keep in mind that the distortion is a good indicator of the battery's condition: A dramatic increase in distortion means that the battery is pooped out.

Construction

The most important part of both the long-range Big Ear microphone and the super-snooper is the SMT micro-amplifier, so we'll cover the amplifier construction first.

It is almost impossible to create an SMT foil pattern "by hand," so we suggest that you use the double-size PC-board template shown in PC Service. Just make certain that you scale it down by a factor of 0.5. We suggest that a professional photographic positive or negative be used. Most copy houses and photographic dealers can use the PC Service template to prepare a negative or positive "stat."

PARTS LIST

Resistors are ⅛-watt chip-type unless otherwise noted.
R1—1000 ohms
R2—2000 ohms
R3, R4—150,000 ohms
R5—220,000 ohms
R6—10,000-ohm miniature control, Mouser ME322-9400 or equivalent
R7—2700 ohms
Capacitors are chip-type rated at least 6.3 volts.
C1, C4—1 µF
C2—0.01 µF
C3—33 pF
Semiconductors
IC1—ICL7611DCBA, operational amplifier (Intersil)
Q1—MMBC3904, PNP transistor
Other components
B1—1.5-volt battery, see text
J1—Miniature phone jack
MIC1—electret microphone, Mouser 25LM042 or equivalent
S1—SPDT, miniature switch, Mouser 10SP018 or equivalent
Miscellaneous: printed-circuit board materials, 1-oz. solder paste, 32-ohm stereo headphones, solder, etc.
Note. The following components are available from BCT Electronics, 8742 Belair Rd., Baltimore, MD 21236:
Etched and drilled printed-circuit board, $3.95; IC1, $3.95; complete kit including solder paste, $14.95. Add $1.50 postage and handling for each order. Maryland residents must add 5% sales tax. Visa, Am. Exp., MC, Discover, call 301-256-0344.

If you don't want to go through the hassle of making the board yourself, it can be ordered from the source given in the Parts List.

Although commercial SMT printed-circuit assemblies are made using a variety of methods, most use some kind of solder mask and/or automatic adhesive dispensing, and a pick-and-place machine to put the parts on the board. But you'll have to put the parts in place one at a time by hand, so you'll have to provide a way to position the component, hold it in place, and ready it for soldering.

The positioning, holding, and prefluxing is done with a special kind of solder paste that contains tiny balls of solder mixed with flux. (The mixture forms a paste that's similar in consistency to smooth peanut butter.) It is usually supplied in jars or cans, but is also available in syringe-type dispensers for precise paste delivery.

Most electronic supply stores now carry some variation of SMT solder paste as a stock item. But a note of caution: Solder paste has a relatively short shelf-life—6–12 months after it's been opened—so purchase the minimum amount possible and store it in the refrigerator when not in use.

Mix the solder paste thoroughly. Place a small amount on a piece of aluminum foil and allow it to reach room temperature. Stir the paste with a toothpick until it reaches a smooth consistency; then, as shown in Fig. 4, place small drops of the paste only on the soldering pads that will be used for the SMD's.

If in the process of applying the paste to the PC board you mess up, simply use a toothpick to move or remove the paste. If the mess is beyond control, use a tissue to mop up all the paste and start over.

Using tweezers, position an SMD over its pasted pad and gently press the SMD into the paste. The paste will hold the part in position until it's soldered. If positioning the components causes the solder paste to slop onto adjacent traces, use a toothpick to clean the area between the traces.

Soldering

Position the parts on the PC board as shown in Fig. 5. The SMD's don't have to be perfectly centered on the pads because the paste will pull them into position during the soldering process. After all the SMD's have been placed, prepare the soldering device—a hot plate that's topped with a shallow aluminum pan or a skillet—by preheating the pan or skillet with the hot plate's temperature control set to HIGH. (Solder melts at approximately 400°F.) Pick up the completed board with tweezers and place it on the pan or skillet with the board's flat side down (component side up).

It will take from 20 to 50 seconds for the solder to melt. Then remove the board quickly to prevent the components from overheating. Set the board aside to cool. Next, using a low-wattage soldering iron, install switch S1 and volume-control R6. Microphone MIC1, battery B1, and output-jack J1, are connected through wires that are hand-soldered to their respective PC-board terminals.

Finally, as shown in Fig. 3, install the amplifier, along with B1 and J1, in a small plastic pill box.

The reflector

Details for building the prototype Big Ear-type reflector are shown in Fig. 6. The reflector is an 11-inch aluminum bowl. Actually, unlike a parabolic reflector—which is really what's needed—the bowl-shaped reflector used for our prototype Big Ear-type microphone doesn't sharply focus the arriving sound into the microphone. But the back of the bowl *does* have the approximate shape of a small parabolic reflector, and the tube that supports the microphone and its amplifier housing can be positioned for optimum sound pickup—so the assembly really can function as a moderately sensitive Big Ear.

The amplifier's cabinet is cemented to the back of a 7-inch length of ½-

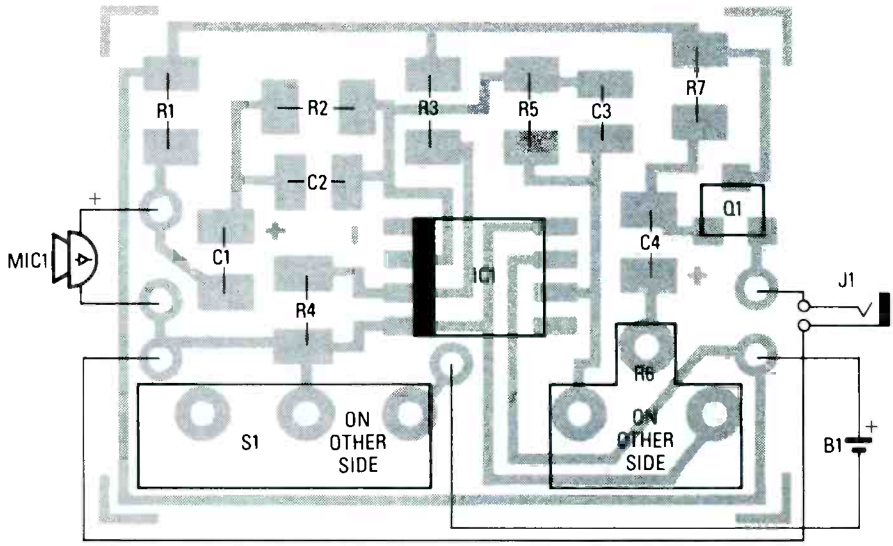


FIG. 5—THE SMT AMPLIFIER'S PARTS LAYOUT. Keep in mind that you're dealing with chip components that are all soldered in place at the same time.

inch copper tubing. Microphone element MIC1 is secured inside a ⅜-inch rubber grommet that's cemented inside the tubing with silicon rubber adhesive or hot-melt glue. The front of the microphone should be flush with the front of the grommet, which is set back about ¼-inch from the input end of the tubing. The details for the amplifier assembly and the microphone installation are illustrated in Fig. 7.

As shown in Fig. 6, the microphone assembly is supported by three bands formed from ¼-inch copper tubing. One end of each band is screwed to the bowl; the other end is soldered to a ½-inch solder-type copper coupling. The microphone's pickup is optimized by sliding the amplifier assembly back and forth in the coupling until the best sound pickup is attained. The actual Big Ear-type microphone prototype is shown in Fig. 8.

Snooping

A super-snooper's amplifier is built the same way as for the Big Ear, with the exception that the microphone is not installed in a pipe that's attached to the amplifier. Instead, using the same mounting arrangement shown in Fig. 7, install the microphone in a 1-inch length of ½-inch plastic tubing, PVC, or ABS pipe. Connect the microphone to the amplifier's input through approximately two feet of shielded cable. Since the amplifier is intended for listening to weak sounds, expect to hear considerable distortion if someone speaks directly into the microphone, or even nearby. As a general rule, use the super-snooper for monitoring weak sounds, such as your own heartbeat, and adjust volume-control R6 for the minimum usable gain.

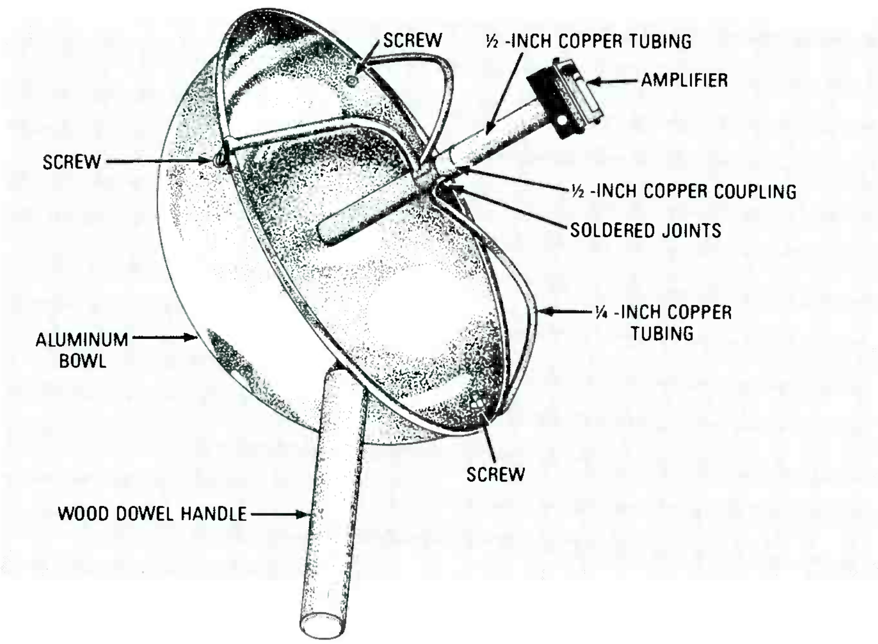


FIG. 6—THE BIG EAR-TYPE MICROPHONE'S REFLECTOR is actually an aluminum bowl, so it does not have the sensitivity of a parabolic-reflector long-range microphone.

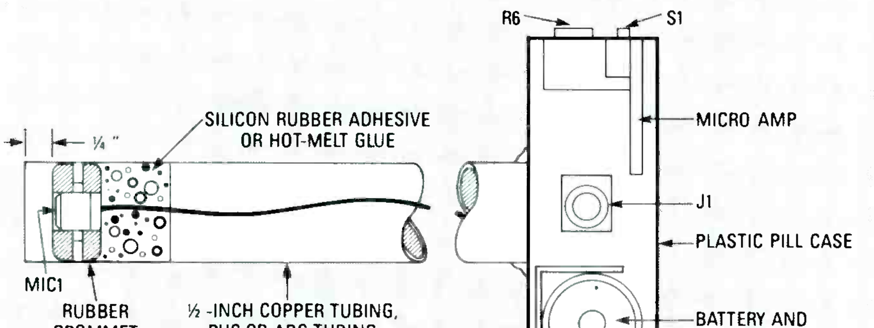


FIG. 7—THE SAME TYPE OF MICROPHONE ASSEMBLY is used for both the Big Ear-type microphone and the super-snooper. The only real difference is the length of the tubing used to hold the microphone element.

FIG. 8—THE PROTOTYPE BIG EAR-TYPE microphone. The tubing containing the microphone and the amplifier is positioned for optimum sound pickup.

Unusual snooper

Figure 9 shows an unusual kind of snooper; one that you can wear in a crowd and no one will be the wiser. A complete circuit, including the microphone, and a power source, is built into both "headphones" of a *radio headset*; one of those listen-while-you-jog radios. Simply strip out the guts from both earpieces—taking care not to damage the headphone unit itself—and install our micro-amp, a microphone, and a button-cell. **R-E**

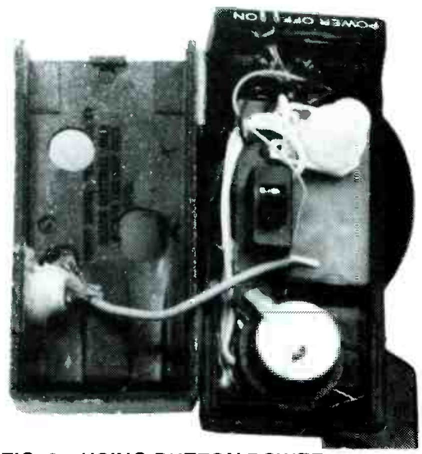
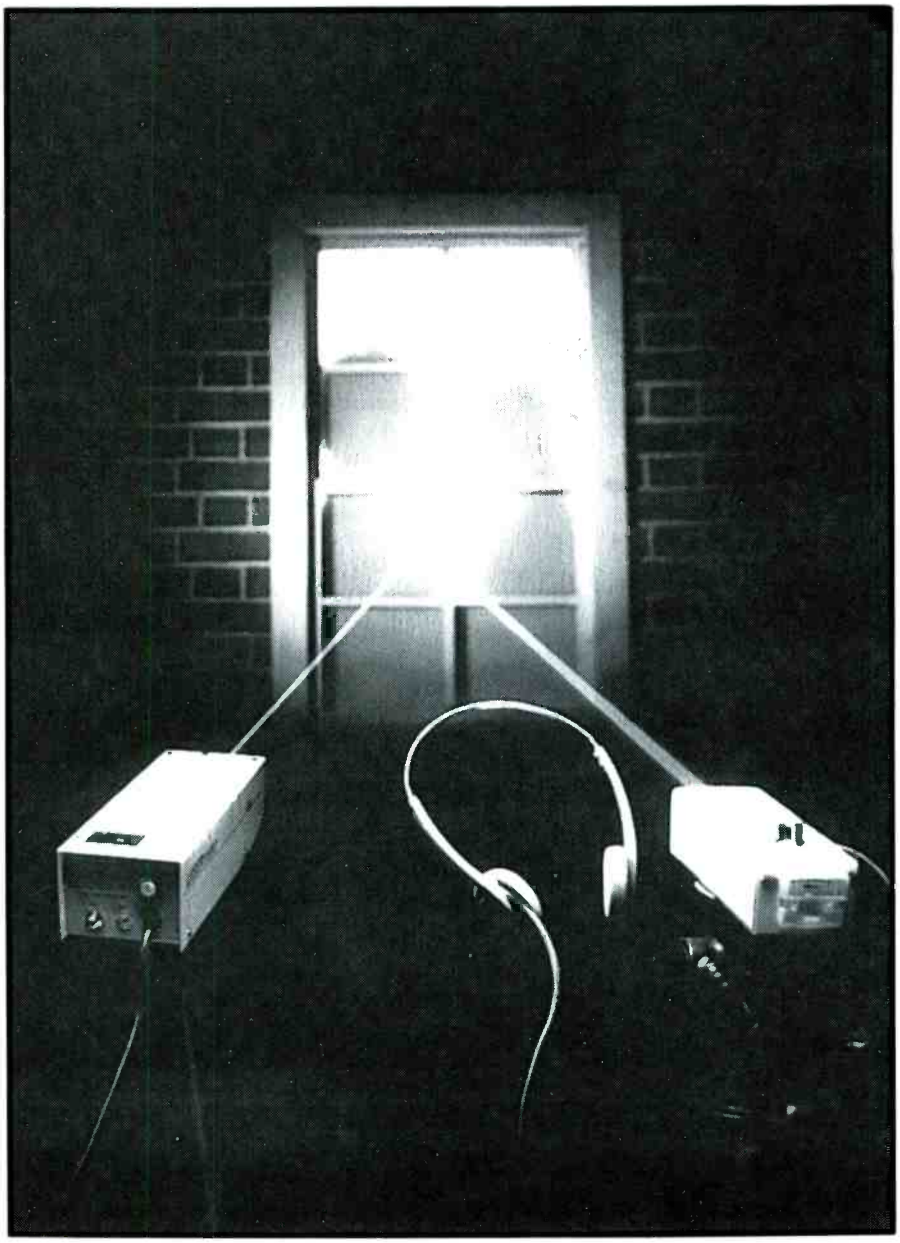


FIG. 9—USING BUTTON POWER, you can install the micro-sized amplifier in place of a headset radio.

LASER LISTENER

Our simple hobbyist circuit demonstrates how you can use a light beam to listen in to anything, anywhere, any time.

RICHARD L. PEARSON



BREAKING AND ENTERING TO PLANT A LISTENING device is one way to "bug" a room. But criminals have turned to high technology and now use laser beams to eavesdrop on a window from across the street.

The sound waves generated by nearby conversation will cause the glass in a window to vibrate very slightly. If a laser beam is bounced off the window, its reflection will be modulated by the vibrations. All that's needed to hear what is being said is a demodulating device that extracts the audio from the reflected laser beam. That technique is used by sophisticated "surveillance experts," but you can easily duplicate that feat by using a hobbyist's laser and the inexpensive Laser Listener demodulator shown in Fig. 1. If you need something a little more sophisticated, it can be made part of the riflescope aimed laser-bug system that is shown in Fig. 2.

Early light-wave communications

Communication using a modulated beam of light isn't a new idea. In the 1880's, Alexander Graham Bell experimented with something he called a *photophone*; a device that modulated a beam of sunlight. It had a mouthpiece that concentrated sound energy on a reflecting diaphragm, which, in turn, modulated a beam of sunlight that was aimed at the diaphragm. When a remote receiver con-

WARNING

Extra precautions must be taken because of a laser beam's intense concentrated energy. Among other factors, the hazards presented depend on the power density, the frequency of the beam, and the time of exposure. Guidelines have established the classification of lasers. A brief description of the classification is as follows:

Class I: Low-power beam. Not known to produce any biological injuries to the eye or skin,

Class II: Reserved for visible-light lasers only. They are limited to less than 1-milliwatt output. Eye damage will result if stared into for longer than 1 second. The normal blink response of the human eye will provide protection. Eye damage will occur if the beam is viewed directly by optical instruments. Direct (specular) reflection, as from a mirror, should be considered to be the direct beam. Diffuse reflection of the light may be viewed.

Class III: Instantaneous eye damage will occur if exposed to the direct beam.

Class IV: Both direct exposure or direct and diffuse reflections will produce eye damage. Exposure of the skin to the beam is hazardous. The beam is considered to be a fire hazard.

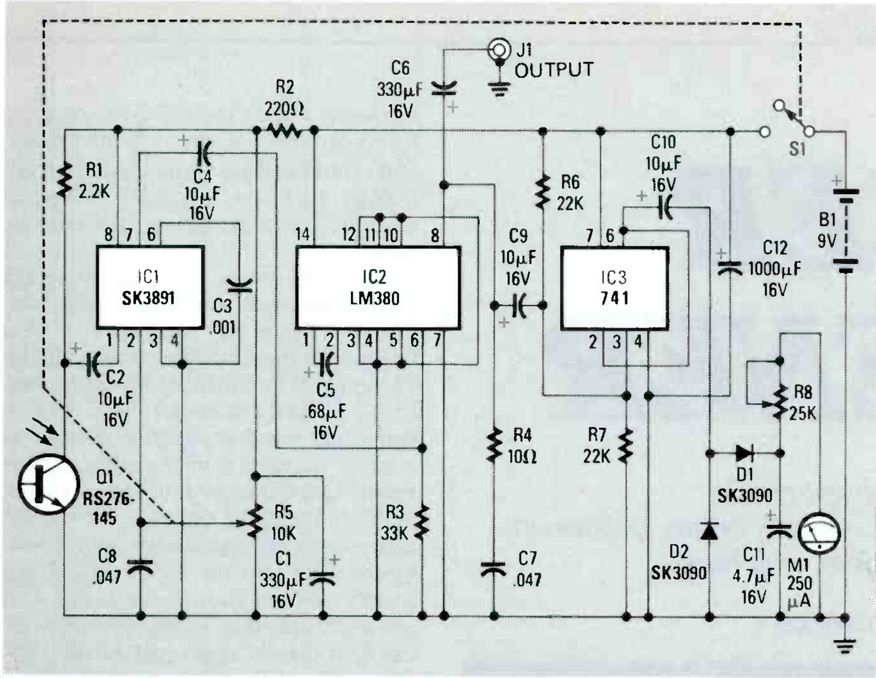


FIG. 1—THE LASER RECEIVER has extremely high gain, so be sure to keep the wiring of Q1 and IC1 separated from IC2's output and the connections to J1.

sisting of a photovoltaic cell and a sensitive earphone was positioned in the beam, the voice could be heard clearly from the receiver. The aiming problems presented by the movement of the sun, and the interruptions due to clouds and night, probably prevented the commercial exploitation of the device.

But by using coherent light—such as that produced by a continuous-wave laser—the principles used by Bell's device may again be applied in a meaningful way. After all, terrestrial lasers aren't influenced in any way by sunlight or clouds. And perhaps more important, unlike acoustic sound-detection devices, lasers aren't usually subject to interference originating between the sound source and the receiver.

For example, remote sound-pickup devices in the form of directional microphones have been available for many years. Unfortunately, any sound generated between the listener and the sound source usually renders the device useless because the interference is heard at the receiver, and it can be even louder than the source. On the other hand, lasers are not sensitive to sound of any kind between the source and the receiver. However, lasers may be subject to other kinds of interference: For example, AC-powered incandescent lights can produce a hum; gas discharge devices such as fluorescent, mercury, sodium vapor, and neon lights might produce a buzz; and direct sunlight might swamp the laser detector device. Also, where unusually long distances are involved, air currents can add flicker to the laser beam, which on windy days can result in a noise that is similar to that of blowing into a microphone. (But even though sensitive to some kinds of electrically-generated noise, laser-listening devices have an advantage: They can seemingly hear through walls or closed windows, and even selectively monitor only one window of a building from several hundred feet away.)

Commercially-available laser sound pickups use a laser device having an output in the infrared region. Because infrared is below the visible portion of the light spectrum, it cannot be seen by humans. However, some commercial devices have a power output rating as high as 35 milliwatts. **At such a power level there is clear potential for eye damage if someone in the target area unknowingly stares into the beam, or if the laser is operated carelessly by the user.**

Laser basics

Although the details underlying the generation of laser light are beyond the scope of this text, an understanding of some of the characteristics of a laser beam as compared to ordinary light will be helpful in assembling a laser-listener system.

Light is considered to be comprised of packages of energy particles called *photons*. However, light is also electromagnetic radiation and behaves like radio waves, although at a much higher frequency. The perceived color of visible light is determined by the radiation's wavelength, which is usually given in *micrometers* (one micrometer = 10^{-9} meters). The shorter wavelengths are perceived as violet, the longer wavelengths as red. The spectrum below the visible portion is called *infrared*; the spectrum above is called *ultraviolet*.

The light emitted by a conventional incandescent or fluorescent source contains a wide range of frequencies, and the photons are emitted randomly and spontaneously in all directions. On the other hand, in a laser light source the photons are released in one direction, at one frequency, making the laser light highly directional and pure in color. (An analogy would be to liken ordinary light to the white noise, while the laser is likened to a sinewave—a single pure tone.) Since all of the light emitted by a laser is coherent (has the same frequency), constructive or destructive interference occurs when two beams of laser light meet at the same place and time (Fig. 3).

As shown in Fig. 3-a, the beams cancel each other when out of phase (destructive interference). As shown in Fig. 3-b, the

FIG. 2—FOR LONG-RANGE USE the laser and the receiver should be combined into an integral unit so both are aimed together. The telescopic signal provides precision aiming on the target.

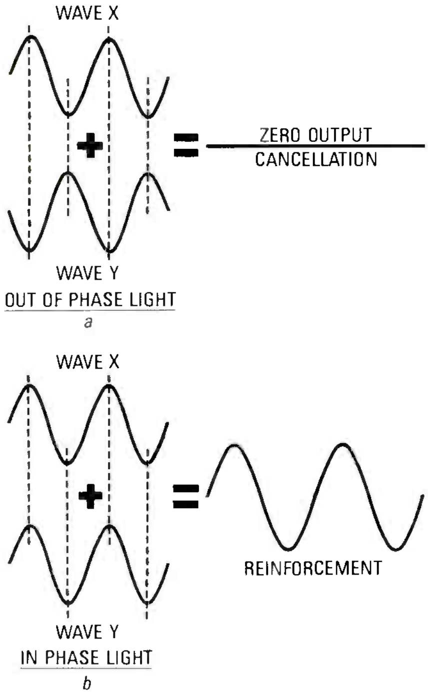


FIG. 3—SINCE LASER LIGHT IS COHERENT, reflections can both cancel and reinforce the direct beam.

beams are additive when in-phase (constructive interference). It is the interference between the beams that enables the movement of any reflecting surface to be sensed by a device called an *interferometer*. An interferometer is a beam splitter—usually a piece of partially-mirrored glass—that deflects only a small part of a beam aimed through the glass. As shown in Fig. 4, it can be used to reflect both the source and reflected laser beams so that their phasing or amplitude can be compared by a receiver.

The major problems with using interferometry for eavesdropping is that only a part of the laser's energy is directed at the target, limiting the working range, and the interferometer is sensitive to the diffusion of the sound target's reflections caused by tremors in the mountings of the interferometer, the laser, and the reflective target. For super-snooping, a direct reflection from the target is preferred because the collimated nature (parallelism) of laser light also allows modulation of the beam to occur just as Bell's photo-phone modulated the sunlight.

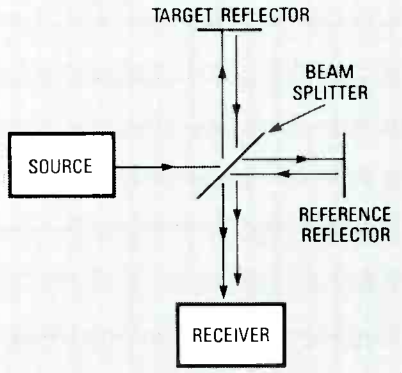


FIG. 4—AN INTERFEROMETER DIVERTS part of the laser to the target. Its chief advantage is that it can sense any kind of movement at all four points: the source, the reflector, the target, and the receiver.

The prototype's laser

Regardless how we choose to eavesdrop, we must start out with a laser, so we'll cover the prototype laser-bug's laser unit first. It's a Heathkit model *ETS-4200* Laser Trainer, a Helium Neon (HeNe) unit having an output power of 0.9 milliwatts. It has a beam divergence of 1.64 milliradians, which produces a spot of light 1½-inches in diameter at 200 feet. Although 0.9 milliwatts doesn't appear to be much power, **it can cause extreme eye damage if allowed to shine or be reflected directly into the eye, or if viewed directly through any optical device such as a telescope, binocular, etc. The beam may be safely viewed only if projected onto a non-reflective surface such as a white sheet of paper.**

If you want to keep costs at rock-bottom, or just want the excitement of a complete home-brew project, another alternative is to assemble the helium-neon laser shown in the June 1986 issue of **Radio-Electronics**. Also, if you want to build a laser from your own design, helium-neon tubes are often available from "surplus" distributors.

The receiver

The Laser Listener's receiver is relatively easy to build and adjust. It is designed to drive a 4–20-ohm headphone or speaker, which permits just about any high-fidelity or Walkman-type headphone to be used for monitoring. The circuit shown in Fig. 1, uses a photo transistor (Q1) for a sensor, and has a meter (M1) that indicates the relative signal strength of the reflected laser beam. Because the meter responds only to the amplitude modulation of the reflected laser beam, it is unaffected by ambient light and the relative intensity of the laser beam. An adjustable polarizing light filter can be installed in front of Q1 to avoid swamping of the phototransistor by very high ambient light.

Phototransistor Q1 is an inexpensive type usually called an *IR detector*, which means that it is specifically sensitive to infrared light. Tests comparing the unit specified in the parts list with other less readily-available and more-expensive devices show no measurable differences in performance in the prototype receiver. No base connection is used for Q1 because the reflected laser light controls the collector current. The audio signal developed across collector load-resistor R1 is coupled by C2 to voltage-controlled attenuator IC1, which has a greater than 30-dB gain variation; It serves as both a preamplifier and as an electronic volume control.

Resistor R2 and capacitor C1 decouple (filter) the power supply voltage to Q1 and IC1. Be sure to take extreme care not to eliminate or accidentally bypass the filter because that will cause unstable operation. The gain of Q1 and IC1 is too great to permit non-decoupled operation from the power supply.

The output from IC1 is fed through C4

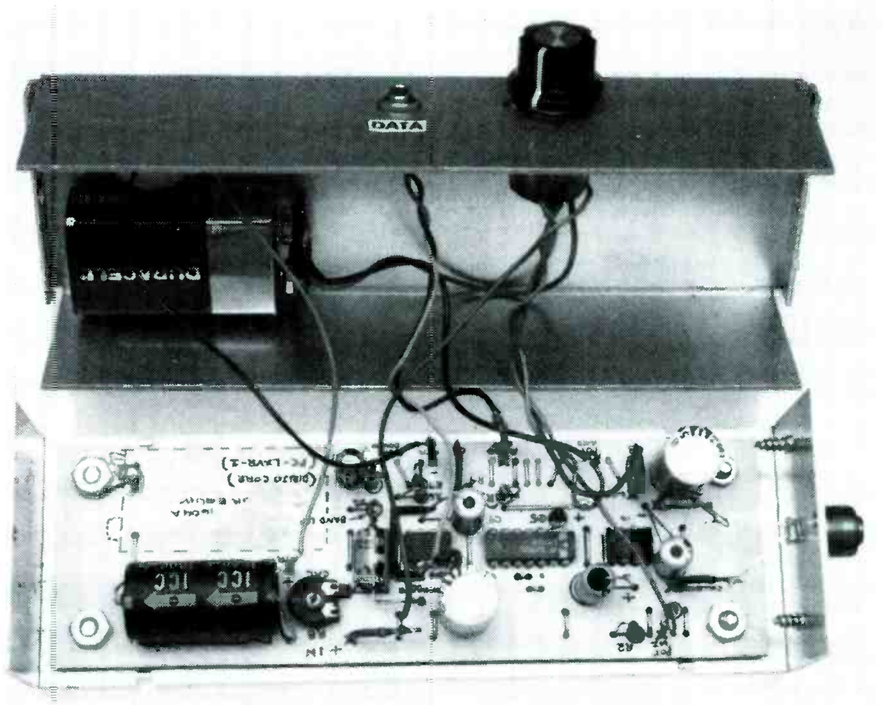


FIG. 5—A COMPONENT-POSITION TEMPLATE cemented to the pre-drilled PC board will simplify assembly.

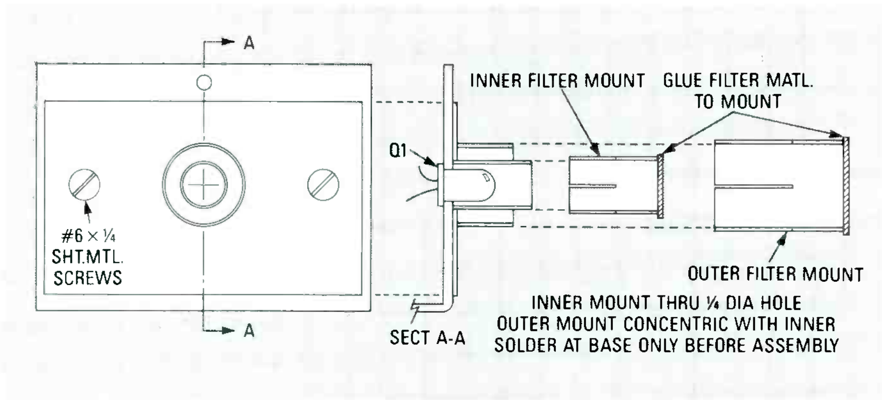


FIG. 6—THE OPTICAL ATTENUATOR assembly fits directly over phototransistor Q1. The front is painted white to help in aiming the reflected laser beam.

to amplifier IC2. Resistor R4, and capacitors C5 and C7, tailor IC2's frequency response and ensure stable operation with varying drive levels and output loads.

The output of IC2 is split into two paths: One goes to output-jack J1 via C6; the other feeds voltage-follower IC3, which drives the meter circuit consisting of D1, D2, C11, R8, and M1. The time constant created by the values of R8, C11, and M1's DC resistance was selected to provide a comfortable damping of the meter pointer's gyrations. The value of C11 may be varied to change the pointer's response. Increasing the value of C11 provides a smoother response; decreasing C11's value will cause the pointer to more closely track the variations in the laser beam's modulation.

Construction

The prototype receiver was assembled on a modified Radio Shack type *276-170* pre-drilled PC board, which has strips of copper foil on the underside that connect the component mounting holes. (A board with a parts-placement template in place, as shown in Fig. 5, is available from the source given in the Parts List.) Nothing about the layout is critical as long as you follow the usual precaution of keeping the input and output connections reasonably separated.

Check your parts layout against the foil strips on the underside of the board. If it appears that any will be too long, cut them to size before mounting any components. Cut each foil strip exactly as long as needed so that a foil carrying the input signal doesn't end up running adjacent to an output connection.

For best results when making connection to the foils, use a small pencil-tipped soldering iron and .040 diameter rosin-core solder. If your layout requires jumpers between component mounting holes, use #22 solid, bare wire. Insulated jumpers are #22 solid, insulated wire. Connections between the copper foils should be #18 insulated wire because it's a precise push-fit for the holes in the specified prototyping board.

The enclosure is a 6½ × 2⅛ × 1⅝ inch aluminum cabinet. Phototransistor Q1 protrudes from one end of that enclosure and is mounted with a dab of household cement. Position Q1 correctly before gluing it in place and be very careful to not get glue on the surface of the lens. Do not use cyanoacrylate-based instant glue because it might cloud the transistor's plastic lens. Output-jack J1, gain-control potentiometer R5, and the meter are mounted on the side of the cabinet so as to encourage the user to face at a right-angle to the source of the laser light, thereby lessening the chance of looking directly into the reflected beam.

The board is mounted in the enclosure with four ¼ inch 6–32 machine screws. Use ⅛ inch insulated spacers between the board and the enclosure to insure adequate clearance between the enclosure and the board's foil side. A ground lug located at one mounting screw is soldered to the circuit-board's ground foil to provide the ground connection between the board and the cabinet. The connections between the board and the panel-mounted components can be #18–22 stranded, insulated wire.

Optical attenuator

The optical attenuator assembly, for which construction details are shown in Figs. 6 and 7, mounts over phototransistor Q1. Figure 6 shows how it's installed over Q1; Fig. 7 shows the individual details for each component in the assembly. The front of the assembly is painted flat white

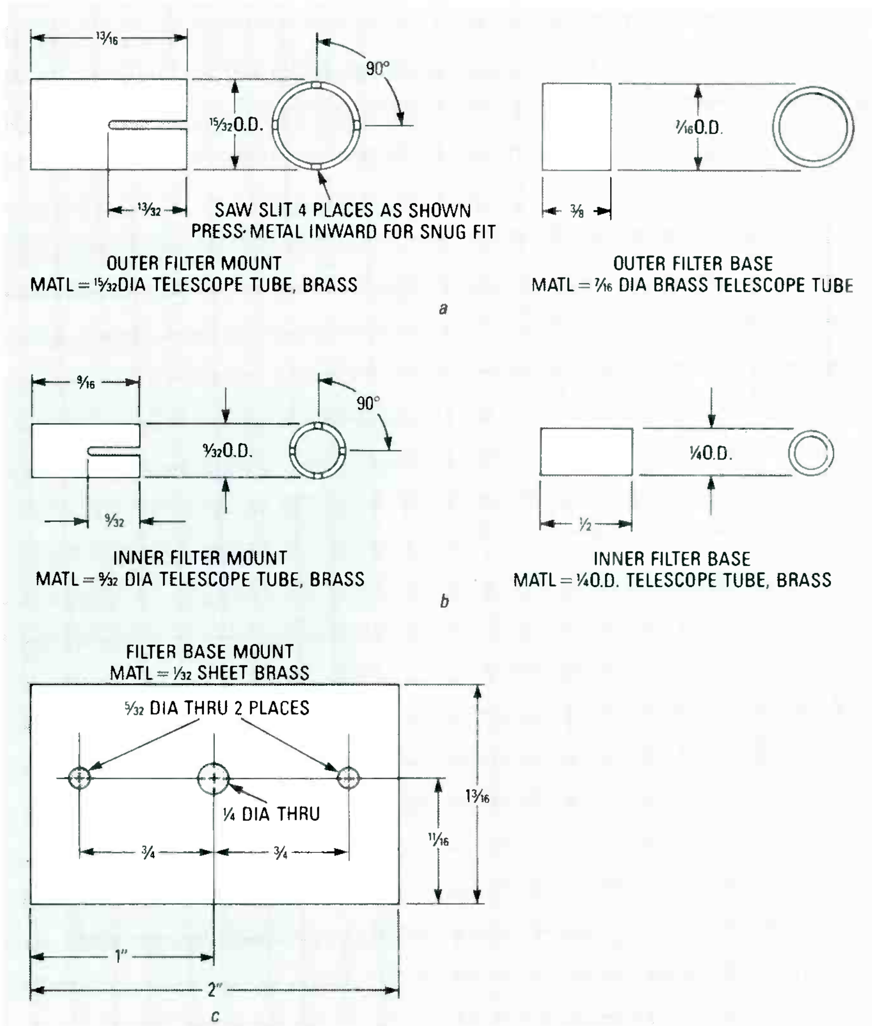


FIG. 7—All PARTS OF THE OPTICAL ATTENUATOR are made from brass sheet or tubing. Both the inner and outer filter bases are soldered to the brass mounting plate.

so that the reflected laser beam can be easily seen. The attenuator is built in such a way that the phototransistor can see the laser beam directly, or through a combination of one or two polarizing filters. When both filters are in place, rotation of the large-diameter filter-mount will cause a gradual decrease in light transmission (to almost total blockage within 90° of rotation), which allows the receiver to be used over a wide range of light intensities without swamping the photo detector. Figure 8 shows the installed assembly and the two filters.

The attenuator has an inner filter and an outer filter made from brass telescopic tubing. Each filter consists of two sections: a filter base that is soldered to small mounting plate made from brass sheet (the painted target), and a filter mount that slips over the base. Polaroid filters cut from neutral-tint polarized sunglasses are cemented to one end of each filter mount to complete the attenuator. When complete, the entire optical attentuator's mounting plate is secured on the enclosure over phototransistor Q1.

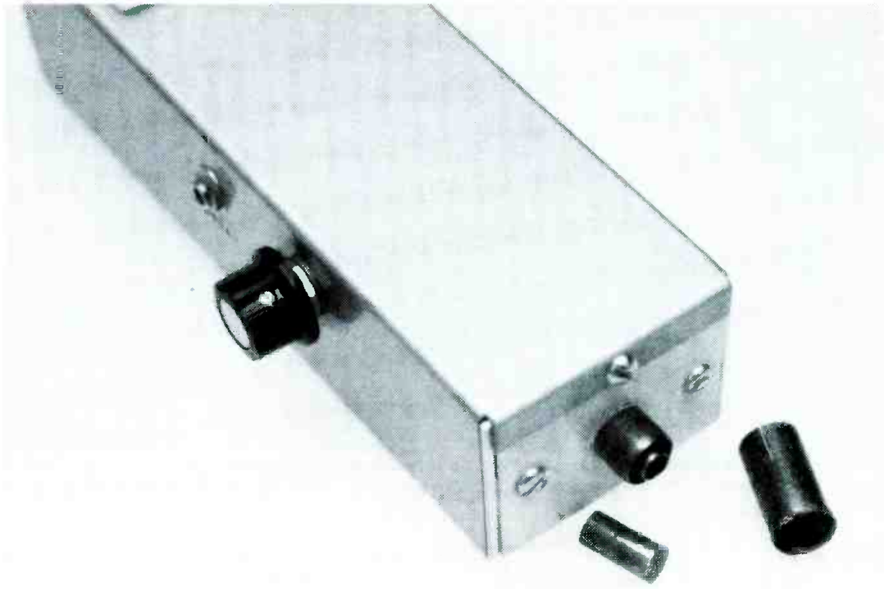


FIG. 8—THE ATTENUATOR'S mounting plate is installed directly over photoresistor Q1. The inner and outer filters are slipped into position when needed.

PARTS LIST

All resistors are ¼-watt, 5% unless otherwise noted.
R1—2200 ohms
R2—220 ohms
R3—33000 ohms
R4—10 ohms
R5—10,000 ohms, miniature potentiometer with SPST switch
R6, R7—22,000 ohms
R8—25000 ohms, trimmer potentiometer
Capacitors
C1, C6, C9, C10—330 µF, 16 volts, electrolytic
C2, C4—10 µF, 16V volts, electrolytic
C3—0.001 µF, 50 volts, ceramic disc
C5—0.68 µF, 16 volts, Tantalum
C7, C8—0.047 µF, 50 volts, ceramic disc
C11—4.7 µF, 16 volts, electrolytic
C12—1000 µF, 16 volts, electrolytic
Semiconductors
IC1—SK-3891 attenuator
IC2—LM380 audio amplifier
IC3—LM741 op-amp
Q1—TIL414, NPN phototransistor (Radio Shack *276-145* or equal)
DI, D2—SK-3090 germanium diode, or equivalent
Other components B1—9-volt transistor-radio type battery
J1—miniature phone jack
M1—250 µA meter, panel mounting
S1—SPST switch, part of R5
Miscellaneous—Cabinet, Pre-drilled PC board, brass sheet and tubing, wire, solder, etc.
The following is available from Dirijo Corp., Box 212, Lowell, NC 28098. A drilled prototype-board with a component layout overlay in place, model *LXVR-1*. $5.00 plus $3.00 postage and handling. NC residents please add appropriate sales tax.

Testing

We advise that a small speaker be used rather than headphones for the initial tests; then, if a wiring error or a defective component has created an audio oscillator rather than an amplifier, your ears will not be assaulted by a high-level tone or squeal.

With the volume control fully counterclockwise and power-switch S1 set to *off*, install the battery and connect the speaker. Turn the unit on and point it toward a source of daylight (not direct sun). Advance the volume control to maximum. Correct operation is indicated by a frying noise that sharply diminishes when the light is blocked. The meter-sensitivity control, R8, should then be set so that the meter's pointer just begins to move off the zero calibration. Decrease the gain and point the receiver toward an AC-powered light source, such as an incandescent or fluorescent light, or even an LED driven by an audio oscillator. Those sources should produce a loud hum or tone. Sound will be heard if the LED is driven from an audio amplifier at the correct level. If everything checks OK, assemble the enclosure.

Remote sound detection

To use the receiver as a remote sound pickup, you will need a laser and a reflective surface that sound waves will cause to vibrate; the receiver must be positioned so it can "catch" the direct reflection of the laser beam (Fig. 9). A particularly effective reflector for experimental use is a small piece of mirror (about ¼ × ¾ inch) cemented to the center of a speaker cone (see Fig. 10). There is no connection made to the speaker. The movement of the speaker cone caused by sound waves is transferred to the mirror-reflector, which in turn modulates the laser beam.

Due to the varying reflectivity and distances of the targets, the intensity of the light falling upon the detector may vary considerably from setup to setup. That will be readily apparent if the collector voltage of Q1 is measured while the illumination level on Q1 is adjusted. At some point of increasing illumination, the collector voltage will fall sharply and the audio output from the receiver will drop or disappear. The small-diameter polarized filter should then placed over Q1. If more light attenuation is required, slip the large-diameter filter in position and rotate it for maximum sound output.

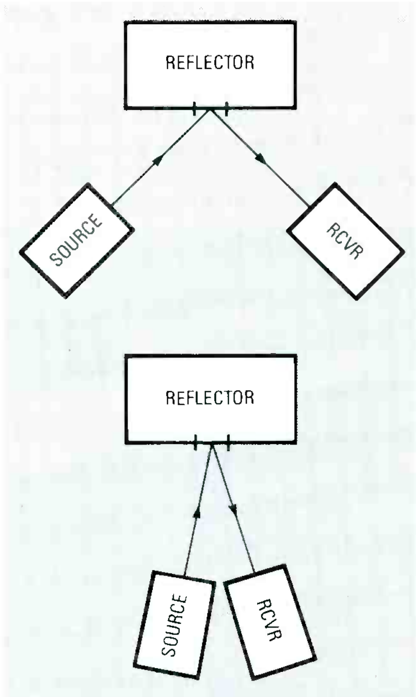


FIG. 9—A WIDE RANGE of reflection angle is possible. The laser source and the receiver can even be at the same location.

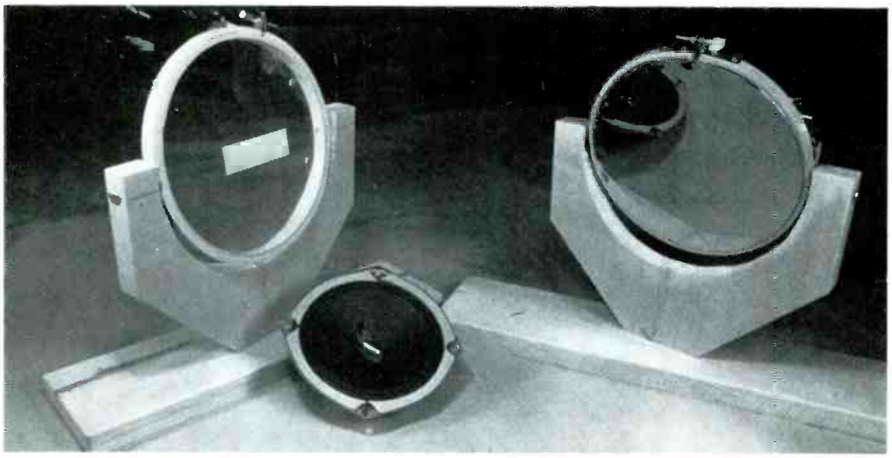


FIG. 10—FOR EXPERIMENTAL USE, an effective reflector can be made by gluing a small piece of mirror to the center cone of a speaker. Also shwon are Mylar, at left, and glass, at left, reflectors.

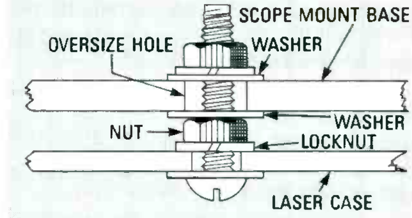


FIG. 12—DETAIL FOR THE RECEIVER mounting plate. An oversize hole mounting base allows coarse adjustment of the scope assembly. Use an oversize washer on both sides of the hole, and a lockwasher at the laser's case.

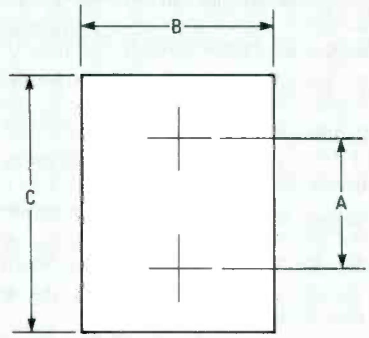


FIG. 13—THE AIMING TARGET for the scope/laser assembly should be made of dull-finish paper or cardboard. Dimension "A" is the measured distance between the laser beam and the optical center of the scope. Dimensions "B" and "C" are whatever you think will be convenient. The aiming cross-marks should be made with a soft pencil or a medium-point marking pen.

Thin is in

The thinner and more responsive to sound the reflective medium is, the greater the laser bug's sensitivity. Most window panes will work. Moving the beam to different spots on the glass can make a dramatic difference in the sensitivity.

For testing, no additional optics are needed for the receiver, Set up any convenient reflector—the mirrored speaker, or even an embroidery hoop holding plastic wrap or Mylar film (see Fig. 10)—aim the laser at the reflector, and then position the reflector so that the beam bounces back to the receiver. If you speak in the room, or play a radio or a tape recorder, the sound will be heard in the receiver's headphones. Another test can be done by modulating the laser with a 1-kHz tone while having an assistant move the target reflector for maximum tone reception—as indicated by maximum volume in the highest meter reading.

A non-adjustable target, such as a window pane, requires that the operator select a site where a direct reflection can be caught. That can be done from hundreds of feet away if conditions are right. Use the modulated beam for setup, and then remove the modulation to listen in. Double-pane glass and storm windows tend to greatly reduce sound transmission to the outer glass. It is possible, however, to aim through the glass to an object within the room, such as the glass front of a china cabinet or a hanging picture. The returned reflection is usually modulated.

At long range

At ranges greater than 100 feet or so, or when a high ambient light level obscures the reflected beam, a means must be provided to accurately aim the receiver to the reflected laser. As shown in Fig. 11, the receiving unit of our prototype laser-bug system uses a telescopic gunsight; and that assembly is, in turn, mounted directly on the laser housing as shown in Fig. 2 so both the laser and receiver can be aimed as a single unit.

The design of a combination receiver and laser mounting bracket will depend on the particular laser and scope that's being used. In general, the mounting bracket should be sturdy and have provisions for coarse elevation and azimuth adjustments; all gun scopes have provisions for fine adjustments. The adjustment details for the prototype mount are shown in Fig. 12.

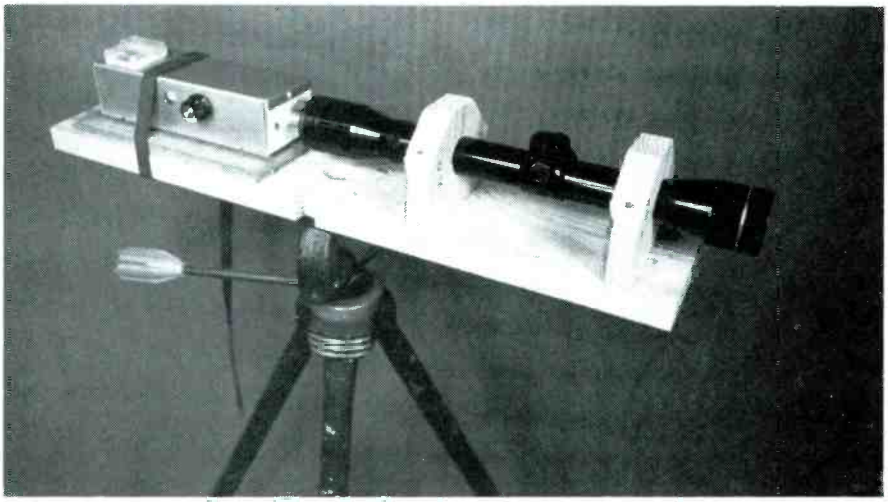


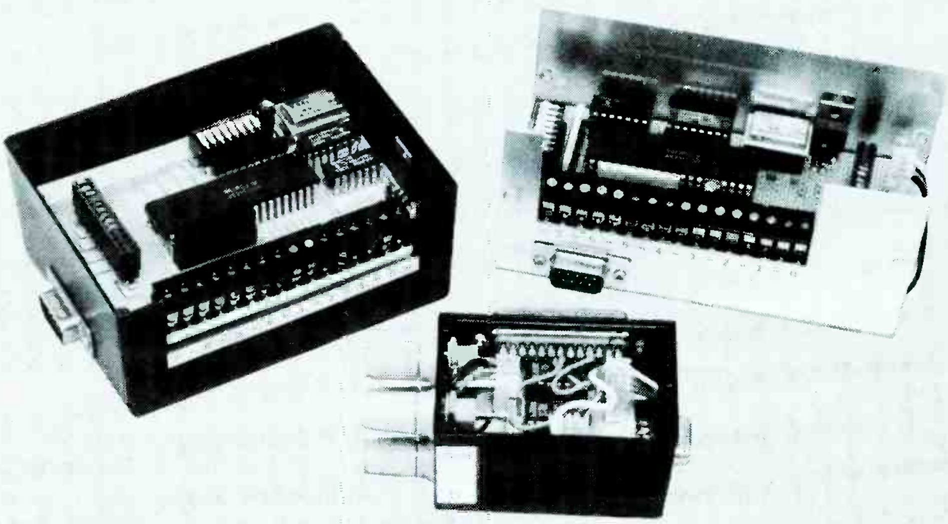
FIG. 11—AT LONG DISTANCES, a telescopic gun sight is used to accurately aim the receiver. That assembly is then strapped to the laser, as shown in Fig. 2, so that both units can be aimed together.

The scope-to-laser alignment is done in two stages. First, the distance from the center of the laser beam to the center of the scope is measured and used as the spacing for the cross marks of the target shown in Fig. 13, which is made from dull, white cardboard. Then, the target is taped to a wall about 50 feet away from the laser assembly. Next, with the scope's cross-hair adjustments at the center of their range, position the laser beam at the center of the *lower* cross. Looking through the scope, adjust the scope's mounting bracket so that its cross-hairs are close to being centered on the target's *upper* mark. Making sure that the laser beam stays centered on the lower mark, tighten the mounting bracket's nuts and use the scope's fine adjustments for the final alignment. In this instance, the diffuse reflection of the laser beam from the card should present no eye hazard.

When using the laser/scope assembly, remember that at a range of under 300 feet you must compensate for the aiming error introduced by the offset between the scope and the laser beam centerlines.

Again, let us stress that under no circumstances should the laser beam or its direct reflection be viewed through optical devices of this type because severe damage to the eye can result. R-E

RS-232 MONITOR/CONTROL SYSTEM



Control the environment with your PC and our simple interface.

STEVEN J. FRICKEY

PC's aren't just for word processing, spreadsheet analysis, and database management. In fact, when a PC can collect data from remote locations it can make decisions based on that data, so it becomes a powerful tool for controlling the environment. The problem is that special I/O cards might be required, and they typically cost hundreds of dollars. Also, I/O boards usually require installation within the PC, taking up yet another slot.

In this article we will describe the hardware and software of an I/O control system that can be implemented for less than $50.00, will interface to any personal computer through an RS-232 port, is modular, and has full duplex operation for both input and output.

The heart of the system is a little-known special-purpose IC made by Motorola, the MC14469. The MC14469 is an addressable asynchronous receiver/transmitter that is especially well-suited for remote data collection and control.

The control software is written in Microsoft "C" for the IBM PC and compatibles. Adapting the software to other compilers and computers should be easy.

System overview

Figure 1 shows an overview of the system. It's composed of a PC, control software, a combination RS-232 interface and power-distribution center, and one or more control nodes connected in parallel over a four-conductor bus. The conductors carry power and ground, and the transmit and receive signals.

A control node is shown in Fig. 2. Each node has a unique 7-bit address that is set via DIP-switch S1, which connects to the seven address lines (A0–A6) of IC3.

To communicate with a node, the software on the host PC must first transmit an address byte, over the common receive line (RI). Each node on the bus then compares the received address against its own address, which is set by the DIP switch. If the values match, then that node will accept the control byte that follows

The control byte is latched until a new address and control byte are received by the node. The control and address bytes are distinguished by the value of the most significant bit.

The control data may be used in conjunction with two other MC14469 control signals to direct the activity of the node. The other control signals are Valid Address Pulse (VAP), which is generated after a valid address is detected, and Command Strobe (CS), which is generated after a valid control byte, has been received.

Data transmission back to the host PC is initiated by toggling the SEND input (pin 30) from low to high. The

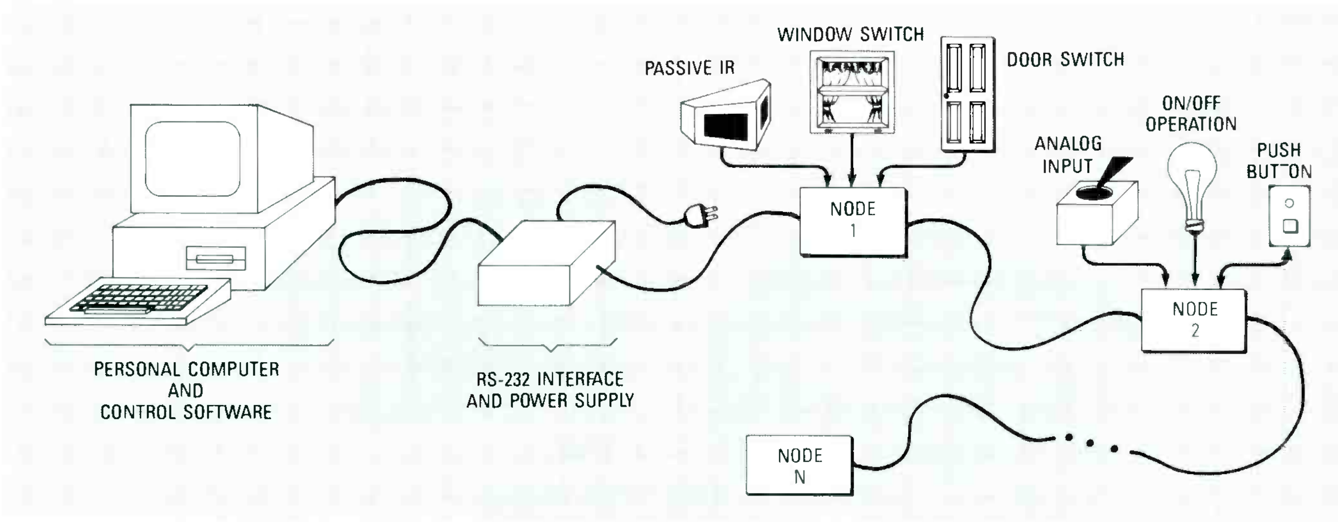


FIG. 1—THE RS-232 INTERFACE buffers communications between the host PC and all nodes.

data that is present on the sixteen input pins (ID0–ID7 and S0–S7) will be transmitted back to the host after SEND is toggled. Data is sent one byte at a time; we'll discuss the details shortly.

After receiving the data from the selected node, the host software could compare that value against the previous value from the same node, perform some action based on the comparison, and then continue on, polling the next node.

By creating an appropriate interface between external devices and any given node, the software can be tailored to a number of monitor and control situations. For example, a number of inputs could be connected to door and window switches. If one of those switches were opened before a master switch, an alarm might be sounded.

Node circuit

Connector J3 provides eight pulled-up input lines (S0–S7) that may be driven by reed switches, pushbuttons, mercury switches, tilt switches, relays, and other mechanical-switching devices. That connector also provides eight ground lines for attaching lead wires.

Connector J4 provides access to the seven output-control lines (C0–C6) of the MC14469, eight more input lines (ID0–ID7), and various control signals. To use the node in its basic configuration, jumpers should be installed across pins 9 and 10, 11 and 12, and so on, through pins 25 and 26. Later on, we'll show how J4 can be used to interface an 8-bit A/D converter to a node.

As shown in Fig. 2, the four-conductor bus runs straight through each node from J1 to J2. One line is for ground, another for +12-volts DC, one for the common transmit line (TRO), and another for the common receive line (RI). The overall length of the bus (from the RS-232 interface to the last node on the bus) depends on the degree of electrical noise in the operating environment. The author has successfully operated three nodes, using 20-gauge unshielded cable, at a cumulative length of 200 feet.

With a seven-bit address, the possible number of nodes in a system is 127, but that is not a practical limit. Realistically, the number of nodes is limited by the amount of current supplied by the +12-volt power source. Each node (with no expansion circuitry) draws 50 mA.

IC4, a 7805 voltage regulator, drops the +12-volt bus voltage to +5 volts for powering the logic circuitry. Because the +12-volt line is also available at J4, you can attach off-the-shelf alarm-system components, such as passive infrared detectors, buzzers, beepers, etc.; all of which typically operate at +12 volts.

The MC14469's baud-rate clock can be generated internally across pins 1 and 2, or an external clock can be fed directly to pin 1. The maximum baud rate (4800) is re-

NODE-CIRCUIT PARTS LIST

IC1—74ALS161, synchronous 4-bit counter
IC2—74ALS05 or open-collector hex inverter
IC3—MC14469, addressable asynchronous receiver/transmitter
IC4—7805, 5-volt regulator
IC5—4-MHz TTL crystal oscillator
RP1, RP2—4700 ohms, 10-pin SIP
S1—8-position DIP switch.
C1—0.33 µF, 12 volts, tantalum
C2—22 µF, 25 volts, electrolytic
C3—0.1 µF, monolithic ceramic
J1—9-pin D, female
J2—9-pin D, male
J3—16-pin, PC-mount, screw terminal block
J4—26-pin dual-row header strip

RS-232 INTERFACE PARTS LIST

IC1—1488, quad RS-232 line driver
IC2—1489, quad RS-232 line receiver
R1—4700 ohms, ¼ watt, 10%
J1—25-pin D, male
J2—9-pin D, male
J3—4-pin power connector
Miscellaneous: Power supply with ±12- and +5-volt outputs, cases, interconnecting cables, etc.
The following are available from Steven J. Frickey, 3661 North Lena Ave., Boise, ID 83704 (FAX: 208-377-9410); MC14469P with spec sheet and ap note, $15.47; Node PC board, Rev 2.0 with assembly notes, $19.40; Interface PC board, Rev 2.0 with assembly notes, $19,40; Monitor V2.0 software with source code for IBM PC's and clones, $10.00; Node kit Version 2, $56.37; Interface kit, Version 2, original option, $28.29; Interface kit Version 2, MAX232 option, $34.19; Prototyping board Kit, $25.56; DC-DC converter kit, $15.97. All orders should include $3.50 for shipping and handling.

stricted by the +5-volt supply. The required clock rate is 64 times the baud rate, or in this case, 307.2 kHz.

Because that's a non-standard frequency, the circuit uses a readily available 4-MHz TTL clock oscillator (IC5), a 74ALS05 (IC2) open-collector inverter, and a 74ALS161 (IC1) four-bit counter to divide the 4-MHz signal by 13, thereby providing a 307.69-kHz signal. The communications protocol is fixed at one start bit, eight data bits, an even parity bit, and one stop bit. So at 307.69 kHz, the maximum sampling time error over the entire 11 bits is 35.7 µs, well within one-half of a data bit period, which is 104 µs at 4800 baud.

A second gate on the 74ALS05 (IC2-d) inverts the serial data from IC3 and drives the common transmit line (TRO). The pull-up resistor for IC2-d is actually located in the RS-232 interface circuit (shown in Fig. 3 as R1). The open-collector outputs of all nodes are pulled up by that resistor, which makes it a wired-OR circuit.

A local reset is generated by each node at power up by an RC circuit consisting of 22-µF capacitor C2 and a 4.7K resistor inside RP1. The reset signal is also provided at J4, should your expansion circuitry require access to that signal.

The 7-bit address for each node is set on pins 4 through 10 (A0–A6) of IC3. Table 1 shows the relationship between switch settings and node numbers.

The voltage supplied to IC3 can range from 4.5–18 volts. At five volts, the output drive current of each pin (I_{OH}) is typically 0.35 mA, providing a fan-out capacity of 17 ALS devices. The output-high voltage (V_{OH}) is typically 5.0; the low voltage (V_{OL}) is typically 0.0. The input high voltage is typically 2.75; the input-low voltage is typically 2.25. For more information on the MC14469, consult *CMOS/NMOS Special Functions Data,* Motorola Inc., 1984, and Application Note AN806A, *Operation Of The MC14469,* Motorola Inc., 1984.

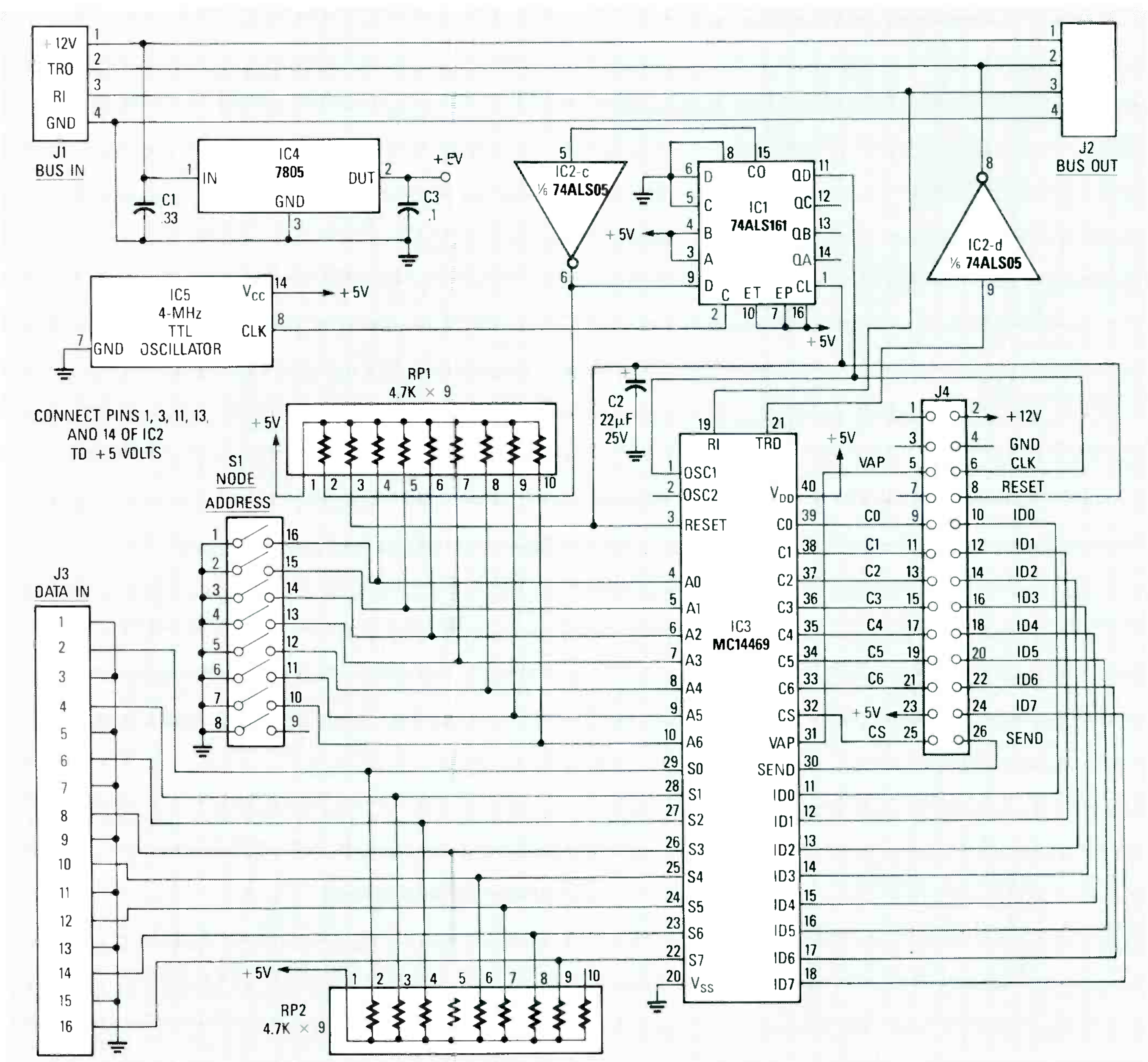


FIG. 2—THE HEART OF A NODE is the MC14469, an addressable UART. When a node is addressed, data present on pins 11–18 and 22–29 is transmitted to the host. The address is set on pins 4–10.

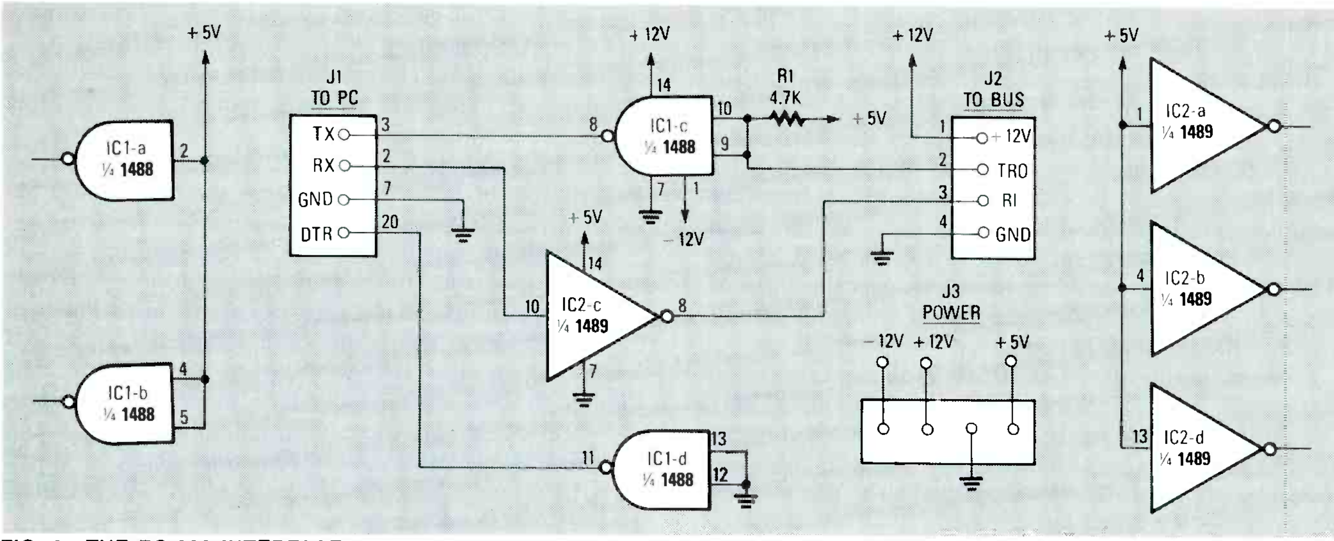


FIG. 3—THE RS-232 INTERFACE routes 12-volt power to the nodes, and buffers data between the nodes and the host PC.

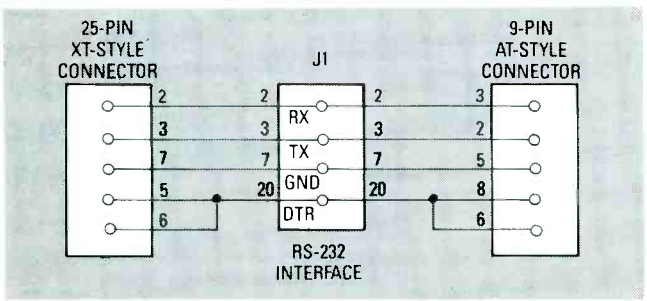


FIG. 4—CONNECT AN XT TO J1 of the RS-232 interface as shown at left, and to an AT as shown at right.

Node operation

The communication software first transmits a seven-bit address that is received simultaneously on pin 19 (RI) of all MC14469's in the system. Each node then checks the state of the most significant bit. If it's high, then the remaining seven bits are compared against the address set on A0–A6. If the values are identical, then VAP is generated on pin 31. VAP is not used in the node circuit shown in Fig. 2, but it is used internally by the MC14496 to latch a control byte on output pins 33–39 (C0–C6). Control-byte data is latched only after a valid address has been received, and it remains latched until another address byte is received.

Transmitting data back to the host PC is accomplished by toggling pin 30 (SEND) high. After receiving the SEND pulse, the MC14469 will transmit, via pin 21 (TRO), the data present on pins 11–18 (ID0–ID7), followed by the data on pins 22–29 (S7–S0). The only stipulation is that the rising edge of the SEND pulse must occur within eight bit times after the generation of either VAP or CS. At 4800 baud, eight bit times provides a maximum of 1.667 ms.

Receipt of a control byte generates a Control Strobe (CS) pulse on pin 32. In our circuit, CS is normally connected to SEND through J4. In this configuration, data will be transmitted to the host as soon as a control byte has been received.

What is the minimum interval between events that this system can detect? The time it takes to transmit and receive data from the same node twice, which works out to (1/4800) × 11 bits/byte × 8 bytes, or about 18 ms.

Realistically, the minimum time is much longer, at least on the order of hundreds of milliseconds, because of the amount of time the software processing takes, especially when relatively slow I/O devices (disk, BIOS video routines, printer) are being accessed. Just don't try to detect more than three events per second.

RS-232 interface and power supply

Figure 3 is the schematic for the RS-232 interface, which uses a 1489 (IC2) for the line receiver and a 1488 (IC1) for the line driver. Pin 2 of J2 is the common transmit line (TRO) that receives data from the open-collector output of each node, and R1 is the pull-up resistor.

Power is supplied to the system via four-pin connector J3. As stated earlier, a single node draws about 50 mA from the +12-volt supply. Low-current sources of +5 and −12 volts are also required.

Figure 4 shows the cable wiring required to connect the RS-232 interface to a 25-pin XT-style port (on the left), and to a 9-pin AT-style port (on the right).

Assembly and testing

Figures 5-*a* and 5-*b* show how to mount the components on the PC boards. The Node board, shown in Fig. 5-*a*, is a double-sided board. You can use the patterns shown in PC Service to build your own, or you can purchase the board from the source mentioned in the Parts List. The pattern for the RS-232 board is also shown in PC Service, but because it is so simple, a commercial product has not been made available.

After you assemble the system, test it using the sample

TABLE 1—NODE ADDRESSES

Node	A6	A5	A4	A3	A2	A1	A0
127	H	H	H	H	H	H	H
126	H	H	H	H	H	H	L
125	H	H	H	H	H	L	H
124	H	H	H	H	H	L	L
. . .							
2	L	L	L	L	L	H	L
1	L	L	L	L	L	L	H
0	L	L	L	L	L	L	L

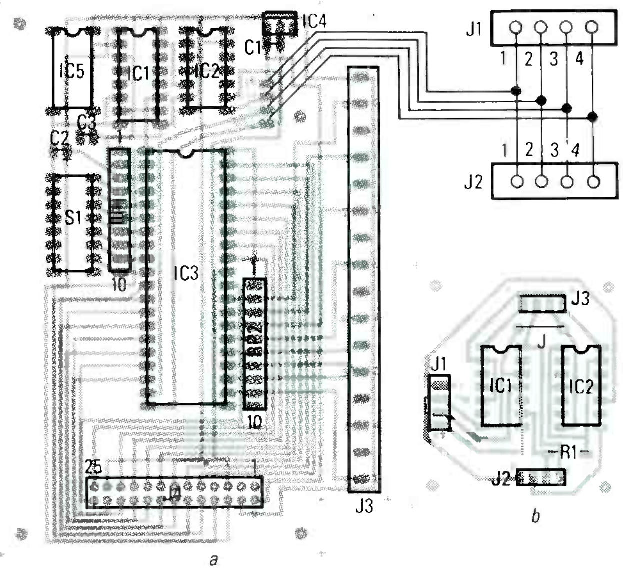


FIG. 5—MOUNT ALL COMPONENTS on the node circuit board as shown in 5-*a* and mount all components on the RS-232 circuit board as shown in 5-*b*.

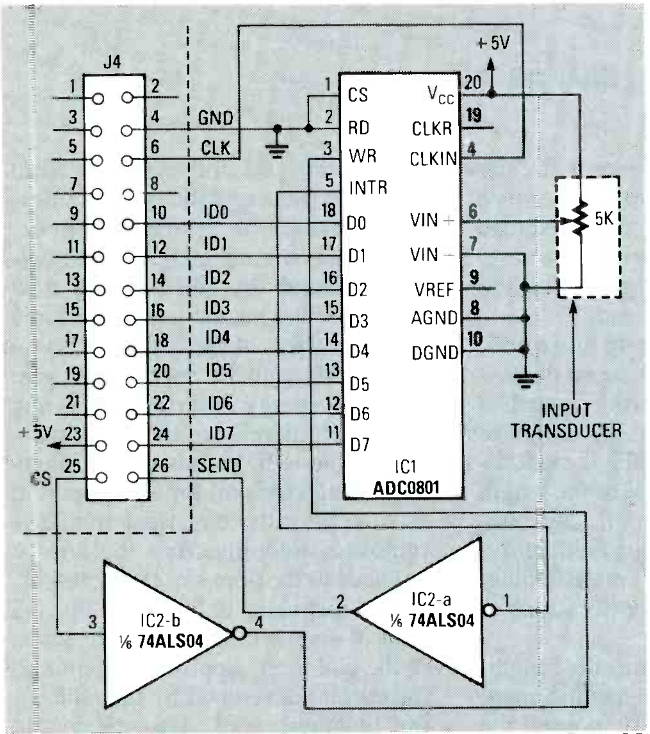


FIG. 6—THE OPTIONAL A/D CONVERTER is shown here. CS from the Node board starts the conversion process; INTR from IC1 here informs the Node that the process is complete.

program that will be discussed shortly. Apply ±12- and +5-volts DC to the RS-232 module, and connect it to your PC and to a single node configured as address 0. Then run the test program. If you receive any error messages (especially a time-out error), check your cabling carefully—the chances are that the RS-232 module hs not been connected to your PC properly.

When the software seems to be running correctly, temporarily short several of J3's even-numbered pins to ground, one at a time. Then terminate the test program according to the directions given on the screen. An ASCII text file called MONITOR.LOG should be present in your current directory. That file should contain a number of messages corresponding to the state of the input lines of J3 at startup, and it should also include messages indicating that it sensed the shorts.

A/D expansion example

Figure 6 shows how to interface an eight-bit analog-to-digital converter (the ADC0801) to a node via connector J4. The component labeled Input Transducer is shown as a 5K potentiometer, but in real life it might be a temperature sensor, a pressure sensor, etc.

In this circuit, CS initiates the analog-to-digital conversion (WR), and the end-of-conversion (INTR) pulse from the ADC initiates data transmission to the host by toggling the MC14469's SEND input.

The ADC uses the 307-kHz node clock. At that rate, a single conversion will take at most 240 µs, which is well within the 1.667-ms time limit between the CS and the SEND pulses.

The software

Because of space limitations, we are unable to print the 600-line C source listing here. However, we will give an overview of how the software works. In addition, both executable files and the full source code have been posted on the RE-BBS (516-293-2283). Download file RS232MON.ARC at 300 or 1200 baud, eight data bits, one stop bit, and no parity. (Source and executable files of an additional program that demonstrates use of the A/D converter is also included.)

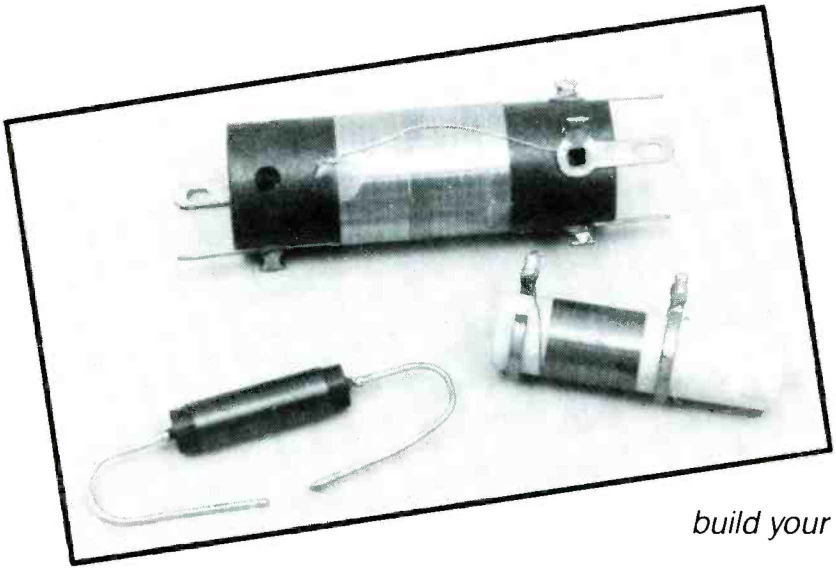
The program is a simple event-logging system that continually polls a single node, logs the date, the time, and the input device(s) that changed state since the last time that node was polled. Execute it by typing the name of the program followed by the number of the serial port being used (0 = COM1, 1 = COM2, etc.).

The program communicates directly with the serial port through BIOS interrupt 14h. That means the program can reconfigure the port-communications protocol, read a byte, write a byte, and check the status of the port. Several error conditions can also be determined when using the interrupt. If an error does occur during execution, the program stops and a message is displayed on the screen indicating the type of error.

In the program, each node is represented by a data structure that contains the node address, the initial value of the control byte, a mask value indicating which bit values to respond to, a copy of the last data values returned from the node, and sixteen other fields that correspond to the bit values returned from a node. The sixteen fields contain names that identify what a bit represents, what its *on* state is, and what its *off* state is.

When the program starts, each record is accessed sequentially, and the corresponding node address and control byte are sent. For each node, required functions are initialized, communications checked, and initial conditions logged in a disk file called MONITOR.LOG.

After initialization the program begins to loop, sequentially polling each node and checking the return values against the previous values from the same node. If a new value is different from a previous value, and if those particular bits that indicate a difference are not masked, then the event is logged in the log file with the date and time. Polling continues in that way until the user terminates the program by pressing a key. ◆CD◆



COPING WITH COILS

Coils of any kind can be hard to dig up. So design and build your own by using our BASIC program.

DAVID E. POWELL, KA4KNG

BACK IN THE "GOLDEN AGE" OF ELECtronics projects, even the local radio-repair shop often stocked an extensive assortment of RF coils. And most certainly, the major mail-order distributors, such as Lafayette and Allied Radio, stocked almost every inductor used in the civilized world. Today, however, there is little available in stock RF coils, and those that do exist can take a lot of effort to locate.

Although we have yet to develop an inexpensive solid-state substitute for coils, you don't necessarily have to give up on a radio-frequency project because your local parts distributor no longer stocks RF coils. Simply design and build the needed inductor yourself! If you have access to a computer, designing the coil shouldn't be any more complicated than typing your name if you use the BASIC program shown in Listing 1.

In fact, the only problem you might have will be to locate the needed wire type or size—because certain wire sizes can be hard to locate. But even that problem is easily resolved by our program, because you can keep plugging in the data for available wire types until the computer comes up with the needed design.

Electricity and magnetism

It is a basic characteristic of electricity that when electric current passes through a wire it creates a circular magnetic field around the wire. Since the magnetic field is weak and spread out along the entire length of the wire, we would have a hard time putting the field to a good, if any, use.

But if we wind the wire into a coil, we still have the same amount of overall magnetism; only now, instead of being distributed along the length of wire, the magnetic field is concentrated into an area equal to the length and diameter of the coil. By concentrating the magnetic field into a smaller space, we have created a magnetic field that is sufficiently strong to be useful.

But a coil having a specific length, and shape produces a specific magnetic field (see Fig. 1). To increase the magnetic field, it's necessary to increase the current flowing in the wire by increasing the voltage applied across the coil.

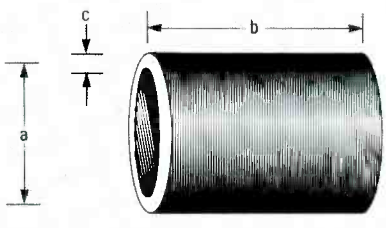


FIG. 1—THE INDUCTANCE of a coil is determined by its physical parameters (a, b, and c) and the number of turns

In a sense, the coil stores electrical energy in the magnetic field. Removing the source of electricity from the coil causes the magnetic field to collapse around the coil. As the field collapses, the magnetic lines of force cross the wires of the coil, converting the stored magnetic energy back into electrical energy. The net result is that the current developed by the collapsing magnetic field tries to keep flowing through the coil for a short period of time after the electrical source is removed. Reconnecting the source voltage has the opposite effect; that is, as the magnetic field builds up, the lines of magnetic force cross the wires of the coil in the opposite direction to the current developed by the collapsing magnetic field. That creates an opposing force to the current flowing through the wire. In other words, when the applied voltage is either AC or interrupted DC, the coil (also called an *inductor*) resists a *change* in electrical current, but not the actual current itself.

From the previous discussion, it would seem that the single most important thing we can measure about an inductor is the strength of its magnetic field. In a sense, that is true. However, the strength of the field depends on conditions external to the inductor, namely the amount of voltage applied to it. For this reason, the term *Hen-*

ry—named after the American physicist Joseph Henry—was coined to describe the electrical characteristics of inductors. The inductance of a coil is one Henry when a current variation of one ampere-per-second induces one volt of electrical opposition to current flow.

The inductor

But conditions other than the applied voltage can affect the strength of the magnetic field. If we want to increase the strength of the field without increasing the applied voltage, we can:

- Add more turns to the coil, because more turns means more wire, which means a greater concentrated magnetic field.
- Increase the diameter of the coil, because a larger diameter means more wire, etc., etc.
- Decrease the length of the coil, because this would have the effect of concentrating the magnetic field into a smaller area, thereby making it stronger.
- Wind the coil on an iron or ferrite core, because ferromagnetic materials such as those tend to attract and concentrate magnetic lines of force.

All of the ways in which the magnetic field can be increased can be merged into a comprehensive equation for calculating the inductance of a coil. However, to both simplify our equation and eliminate the research necessary to obtain ferromagnetic values, we are going to ignore ferromagnetic permeability and such.

The equation for calculating air-core inductors, as stated by the *Radio Amateur's Handbook* is:

$$L = 0.2a^2n^2/(3a+9b+10c)$$

where:

L = inductance in microhenries and as shown in Fig. 1:
a = average diameter of the coil in inches
b = length of the coil in inches
c = radial depth of the winding in inches
n = total turns of wire

LISTING 1

```
100 'program to calculate the number of turns for an inductor.
110 cls:pi=3.1415926545
120 k=1473061.855                'mhos per square inch of area of copper
130 print "                      +---------------------------+"
140 print "                      | Inductor Design Calculator |"
150 print "                      | by David E. Powell, KA4KNG |"
160 print "                      +---------------------------+":print:print
210 input "Desired inductance in microhenries";L
220 input "Gauge or diameter of wire in inches";diameter
230 input "Diameter of coil form in inches";form
240 if diameter >= 1 then diameter = .46 / 1.1229283027^(diameter +3)
250 print:print "calculating";
260 layers=1                     'Single layer starting out
500 a=diameter*layers+form       'Average coil diameter to center of thickness
505 print ".";
510 gosub 2000                   'calculate the number of turns
520 if prob =1 then layers = layers+1:if layers < 100 then goto 500
530 if b > 1 then layers=layers+1:goto 500
540 if n > 9999 then print "ERROR - turns count larger than 10000":system
550 n=cint(n):b=n*diameter/layers:ltry = (0.2 * a^2 * n^2)/(3*a+9*b+10*c)
560 w.length = n*a*pi
570 'calculate the resistance of coil
580 w.area = (diameter/2)^2*pi
590 r = 1/(w.area*k)*w.length
800 'show the results
810 print:print
815 print "Overall coil diameter......  ";diameter*layers*2+form;"inches"
820 print "Average coil diameter......  ";a;"inches"
830 print "Depth of coil.............  ";layers*diameter;"inches"
840 print "Length of coil............  ";b;"inches"
850 print "Length of wire (approx)....  ";int(w.length/12)"feet,";
855 print int (w.length-int(w.length/12)*12+.5);"inches"
860 print "Number of layers..........  ";layers
870 print "Number of turns...........  ";n
880 print "Number of turns per layer..  ";n/layers
890 print "Actual inductance.........  ";ltry;"microhenries"
900 print "Coil DC resistance........  ";r;"ohms"
1000 system          'Exit the program and BASIC
2000 'subroutine to calculate the number of turns
2010 min.n=1:max.n=10000:c=layers * diameter:prob=0
2060      n=(max.n-min.n)/2+min.n
2070      b=n*diameter/layers     'length of coil
2080      ltry = (0.2 * a^2 * n^2)/(3*a+9*b+10*c)
2090      if cint(max.n) = cint(min.n) then goto 3000
2100      if min.n => 9999 then prob=1:goto 3000
2110      if ltry < L then min.n=n:goto 2060
2120      if ltry > L then max.n=n:goto 2060
3000      return
```

Quality factor

Besides the inductance value, there is another important characteristic of a coil that we need to know about. An inductor can be thought of as an AC-only resistor, whose reactance (which can be considered as AC resistance) depends on the inductance of the coil and the frequency of the applied AC voltage. However, copper wire has a DC resistance, determined by its diameter and length. The ratio of AC reactance to DC resistance is known as the *quality factor*, or Q. For example, if an inductor has a reactance of 100 ohms at 1 kHz, and a resistance of 2 ohms, then it has a Q-factor at 1 kHz of 100/2, or 50. Of course, the Q will change with the applied frequency. To determine reactance, use the formula:

$$X_L = 2\pi fL$$

where:

X_L = the inductive reactance in ohms
π = 3.14
f = the applied frequency in hertz
L = the inductance in Henries

```
+----------------------------+
| Inductor Design Calculator |
| by David E. Powell, KA4KNG |
+----------------------------+


Desired inductance in microhenries? 28
Gauge or diameter of wire in inches? .008
Diameter of coil form in inches? .375

calculating.

Overall coil diameter......   .391 inches
Average coil diameter......   .383 inches
Depth of coil..............   8.000001E-03 inches
Length of coil.............   .6640001 inches
Length of wire (approx)....   8 feet, 4 inches
Number of layers...........   1
Number of turns............   83
Number of turns per layer..   83
Actual inductance..........   28.05109 microhenries
Coil DC resistance.........   1.348764 ohms
```

FIG. 2—THIS IS WHAT THE SCREEN or a printout will show when the program is tested by calculating the design of a 28-microhenry inductor.

The BASIC program

Listing 1 is the BASIC program for inductor design. Although written specifically for the IBM PC, it should run on any version of BASIC. The program text is available on the RE-BBS (516-293-2283). The full name is COILS.BAS.

Lines 110 and 120 are used to set up constants for later use in calculations to determine the overall resistance of the coil.

Lines 210 through 230 input the values you specify for the desired inductance value, the size wire you have on hand, and the diameter of the coil form you're going to use. The wire size can be specified in inches or its AWG wire gauge.

Line 240 decides whether or not you entered a wire diameter or a wire gauge. If you entered a number of 1 or greater, it figures it must be a wire gauge (who would want to wind a coil with six- inch thick wire?) and converts it to a diameter.

Lines 500 through 530 are the meat of the program. It starts by assuming that you're designing a single-layer coil. Line 500 calculates the diameter of the coil at the center of its thickness. (The diameter changes as the program adds more layers during its calculations.) Line 510 calls the subroutine that actually figures the number of turns necessary to have the specified inductance at the current number of layers. If it can't get there within 10,000 turns, line 520 adds another layer. Line 530 will add another layer if the length of the coil exceeds one inch.

Line 540 will print an error message if the required number of turns exceeds 10,000 and the number of layers is 10,000 or greater. (You really don't want to wind an inductor that big anyway.)

Line 550 rounds the number of turns to the nearest full turn. It then calculates all of the other parameters based on that rounded number. The inductor should be close enough for all but the most critical applications without having to worry about fractional turns of wire.

Line 560 calculates the approximate length of wire needed to wind the coil. The length is approximate because it is based on the average diameter of the coil; the program does not calculate each layer of the coil independently.

Lines 570 through 590 calculate the approximate resistance of the coil, based on the length and diameter of the wire.

Lines 800 through 900 display the results of all calculations. Keep in mind that electronics is not necessarily an exact science, and that for a variety of reasons all of the displayed values could be slightly off the "true" value.

Winding the coil

The primary advantage of having a computer calculate the specifics of a coil is that we can experiment with the materials that we have on hand, trying different combinations to see how they affect the results. Recalculating the values is so easy that we should be able to get a size and shape that suits us just right.

Let's use a 28-microhenry inductor as our target value. Let's also use part of that jumbo-sized spool of 32-gauge wire that you purchased at the last hamfest. For a coil form, we can use an ordinary ballpoint pen.

Run the program. The screen should clear and ask for the needed inductance value. Enter 28.

Next, the program will ask for the size wire to be used. Enter either the gauge (32), or the diameter of the wire in inches. Since we bought this wire at a hamfest and don't really know for certain what gauge it is, we wind an inch-long close-wound coil on a pencil and count the number of turns. It turns out that our "unknown" wire requires 125 turns to fill one inch. Dividing one-inch by 125 turns gives us 0.008 inches. Enter .008.

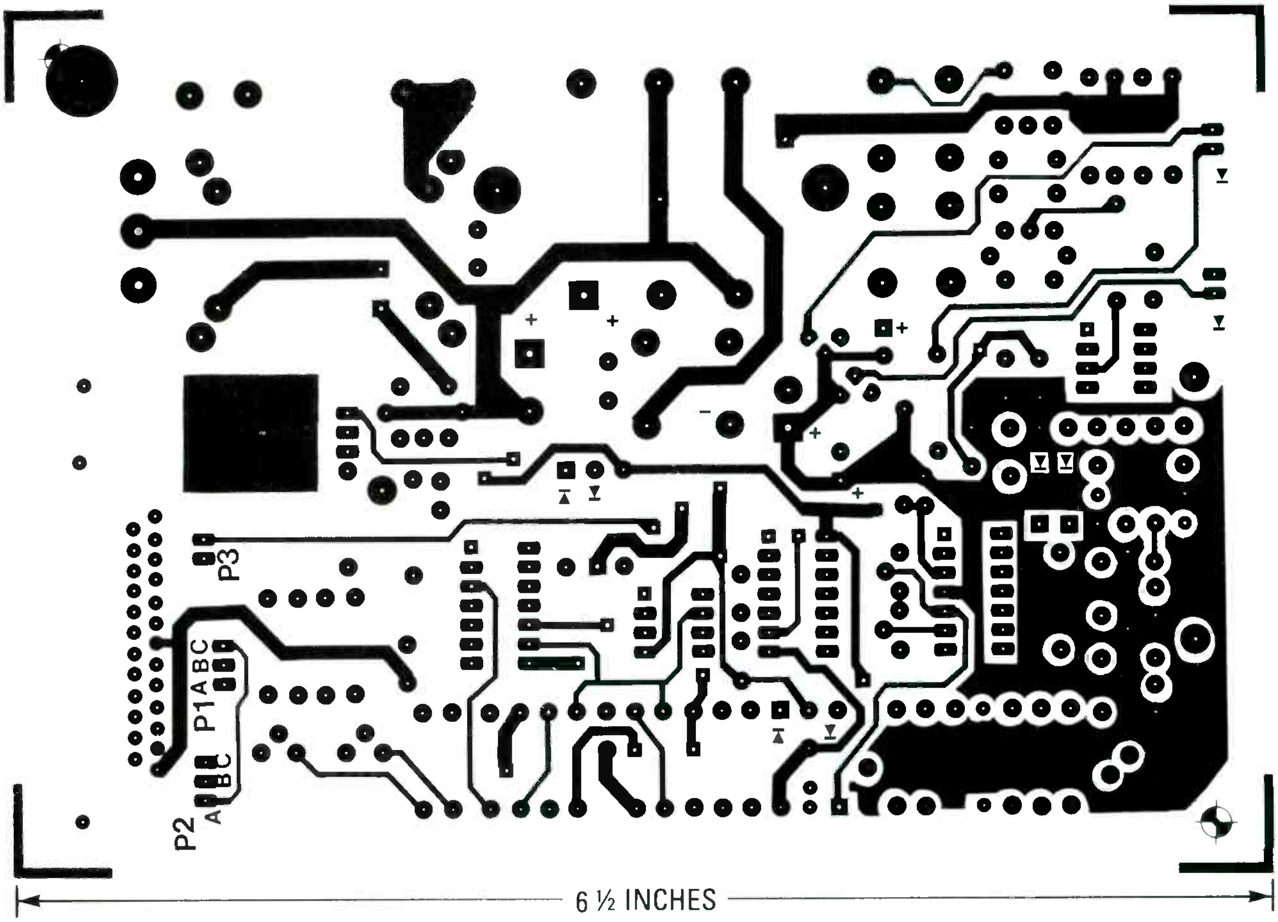
The last prompt asks for the diameter of the coil form. We measure the thickness (the diameter) of our pen and find it is ⅜ths of an inch. Since 3 ÷ 8 = 0.375, we enter .375.

If your computer has been set for printer output, you should get a hardcopy that resembles Fig. 2. If the results you attain do not match Fig. 2, re-check the program for typing errors or a misplaced decimal point.

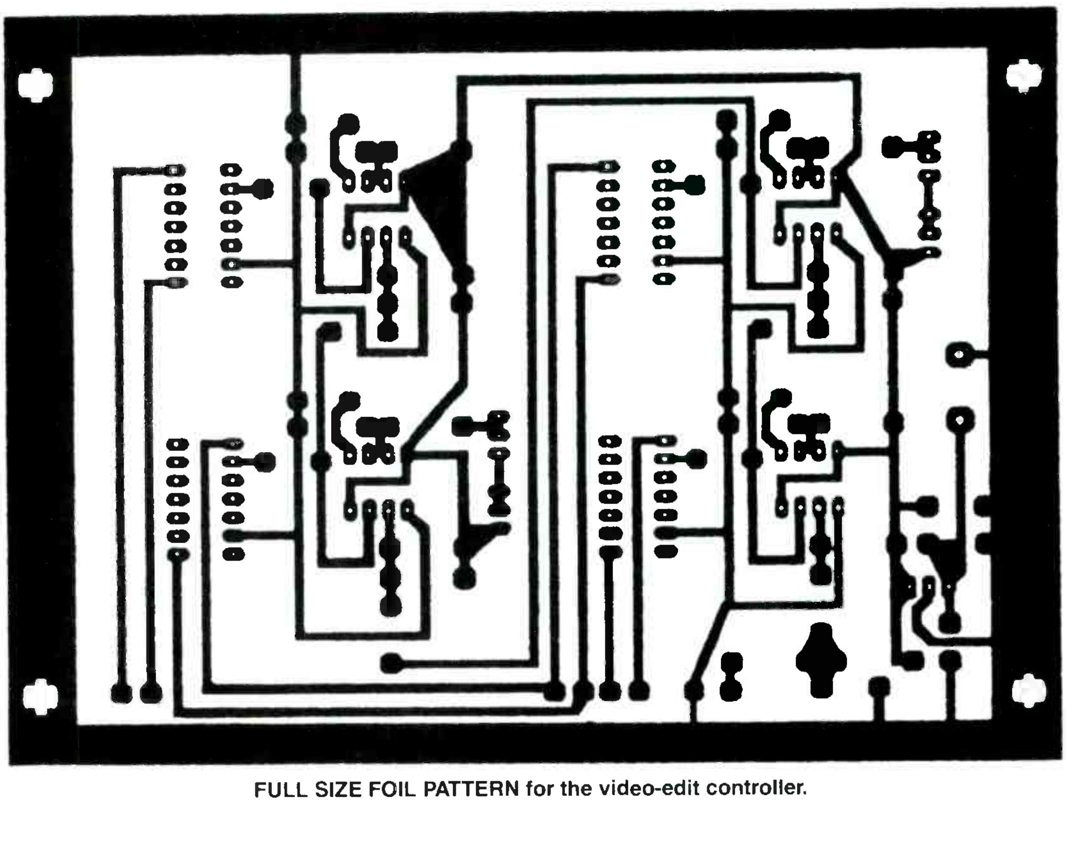
There are a few things to note at this point about the output of the program. First, notice from Fig. 2, that there are two coil diameters given, an overall and an average.

The overall diameter is given so

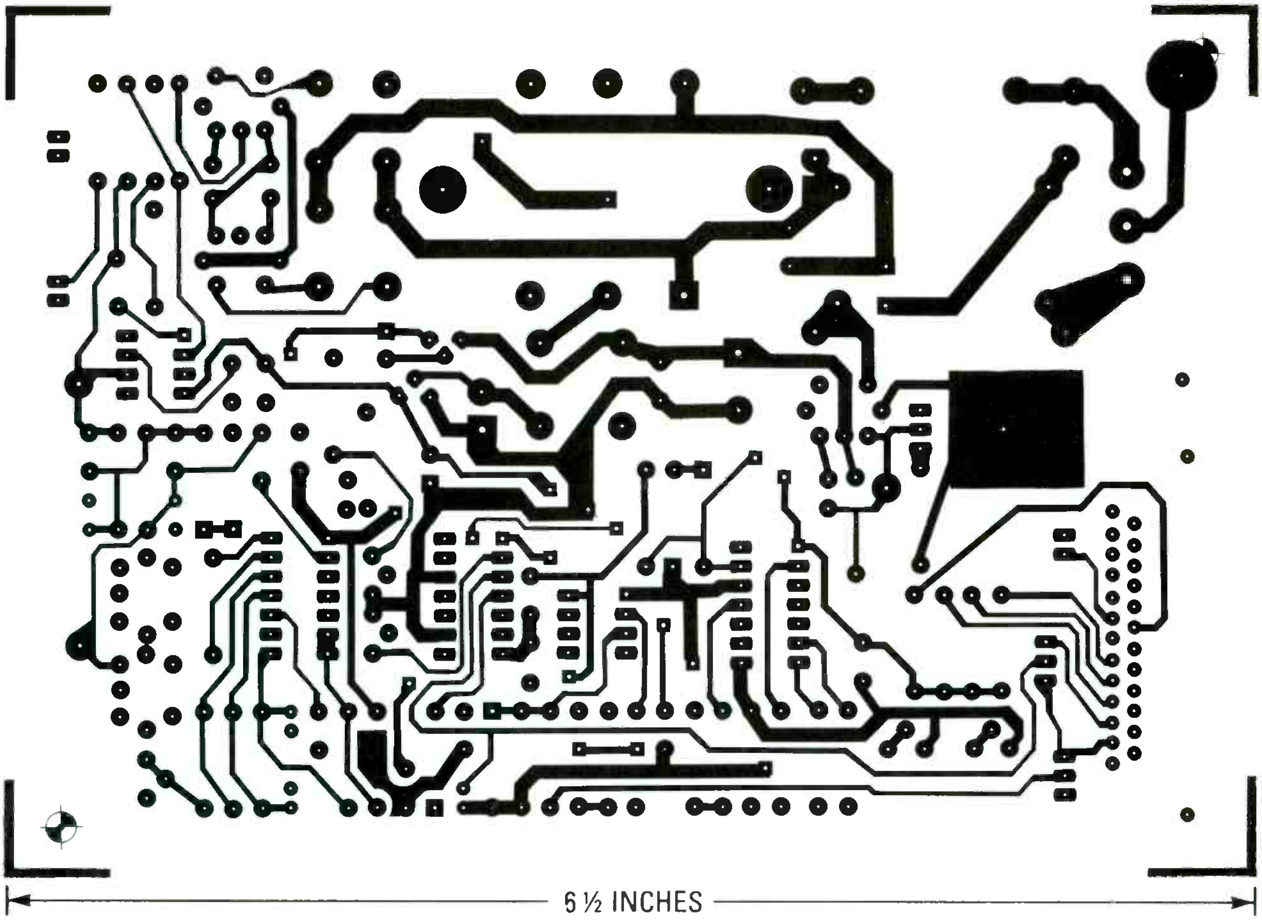
continued on page 140



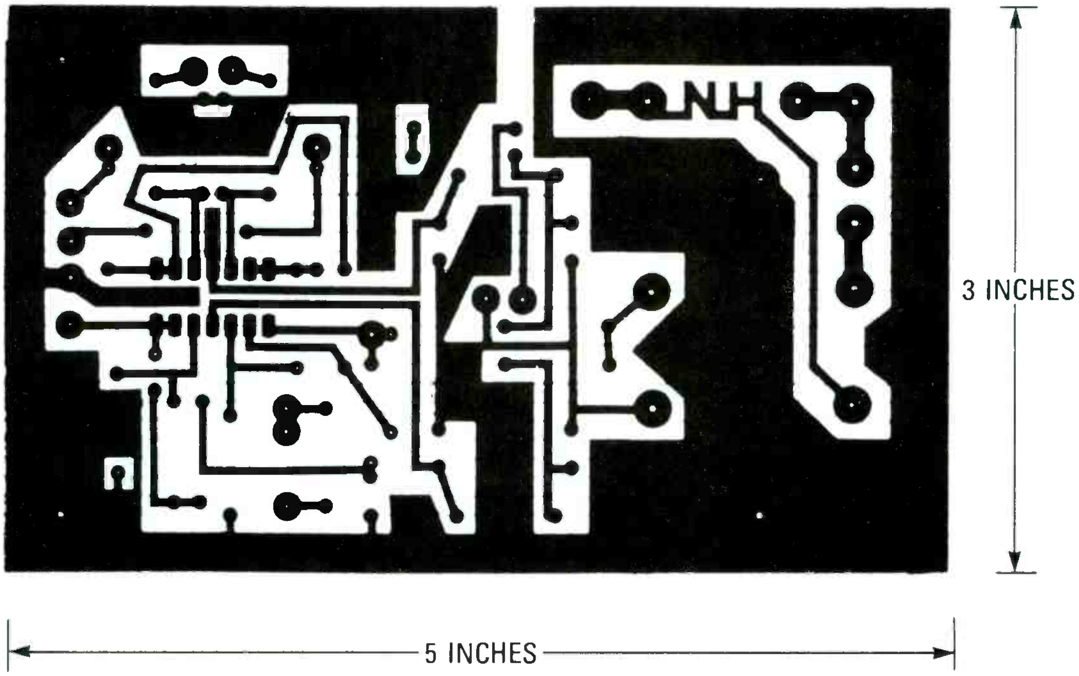
THE COMPONENT SIDE of the line carrier modem board is shown here.



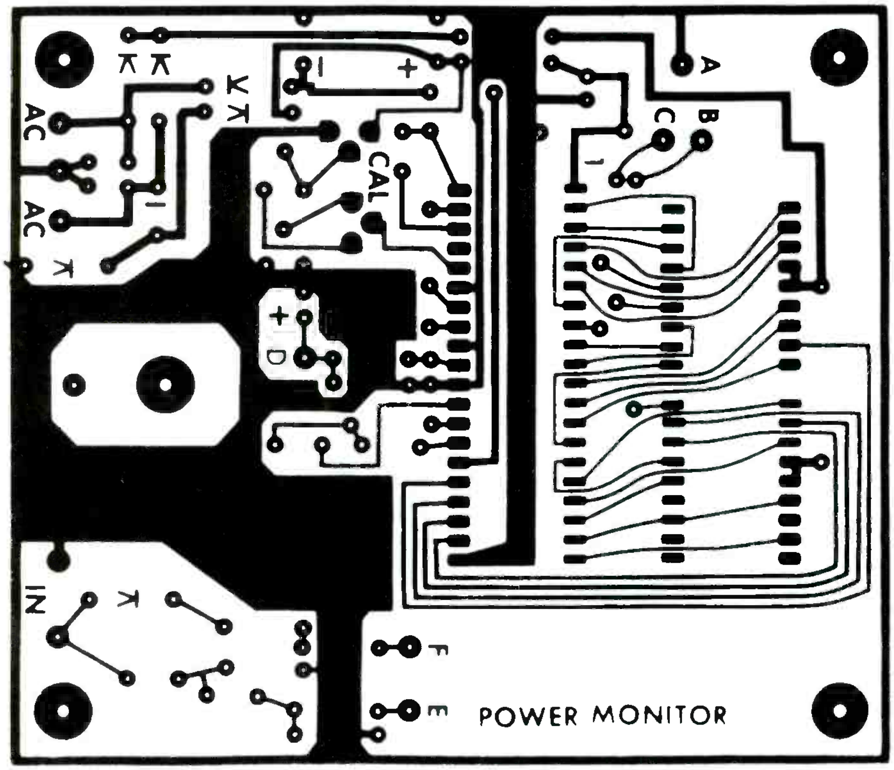
FULL SIZE FOIL PATTERN for the video-edit controller.



THIS IS THE SOLDER SIDE of the line carrier modem board.

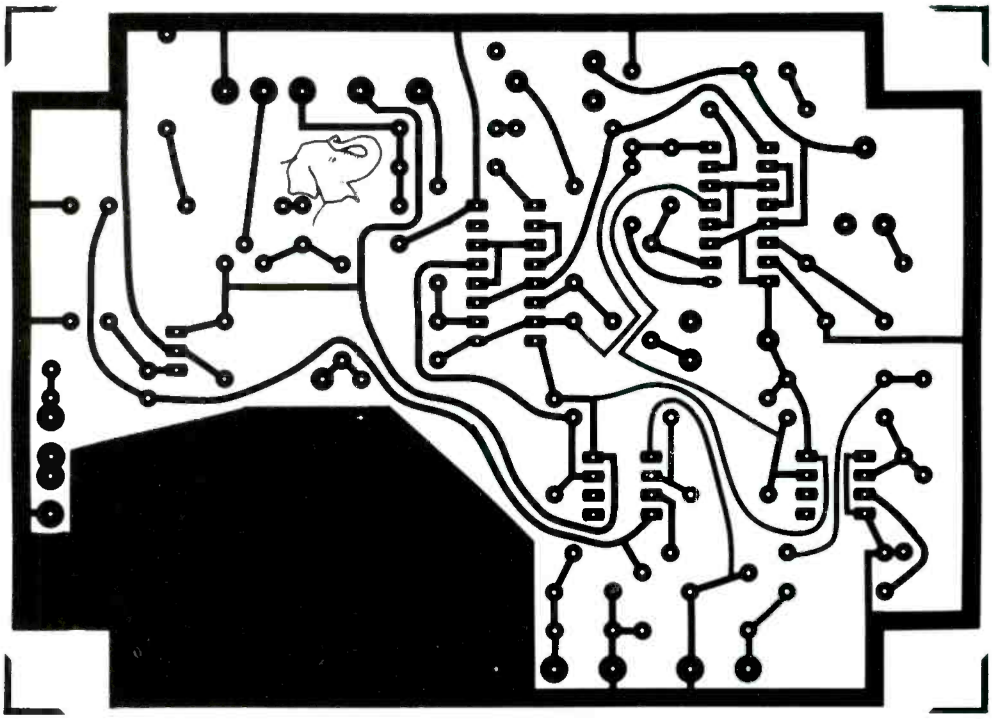


HERE'S THE PATTERN for the Surround-Sound decoder.



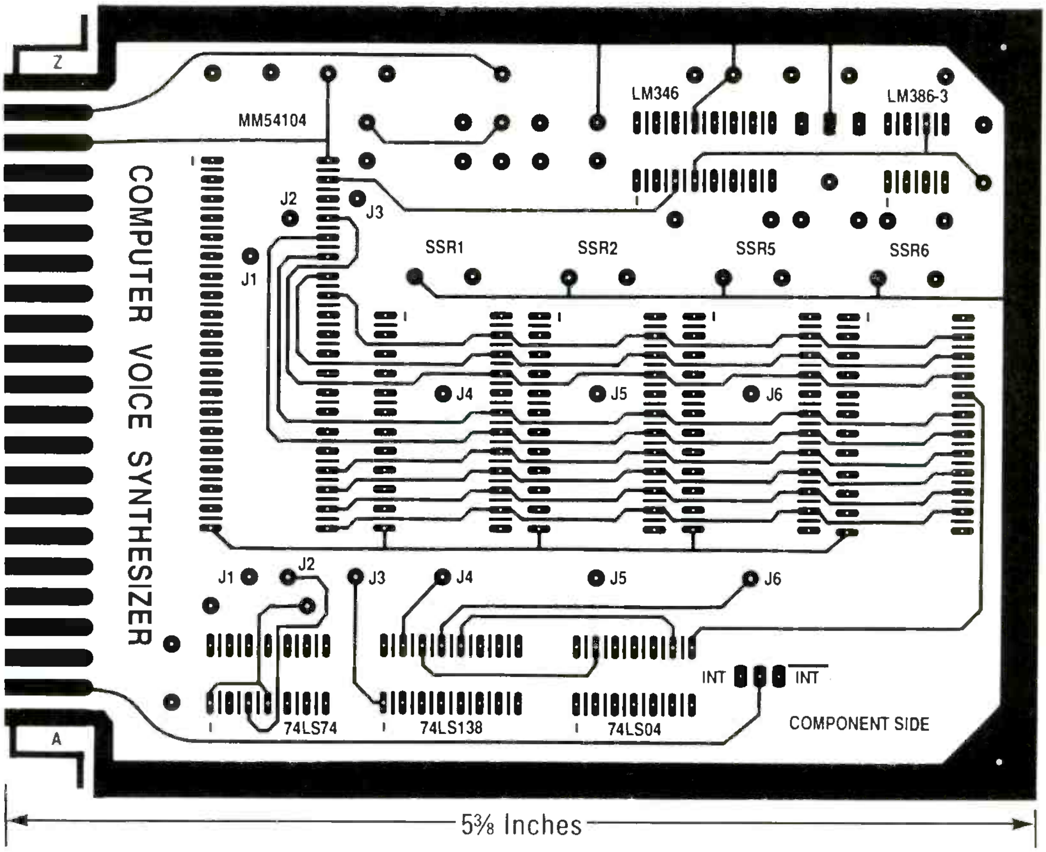
4 ½ INCHES

THIS IS THE FOIL PATTERN for the power monitor.

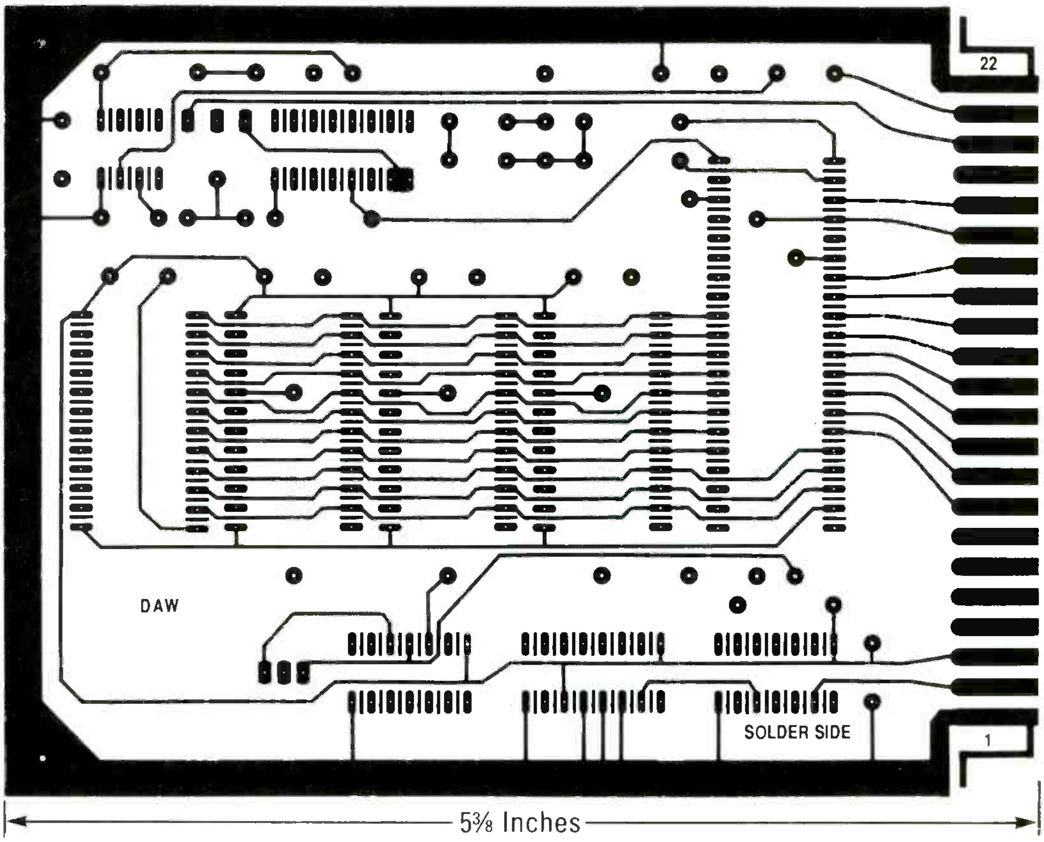


5 INCHES

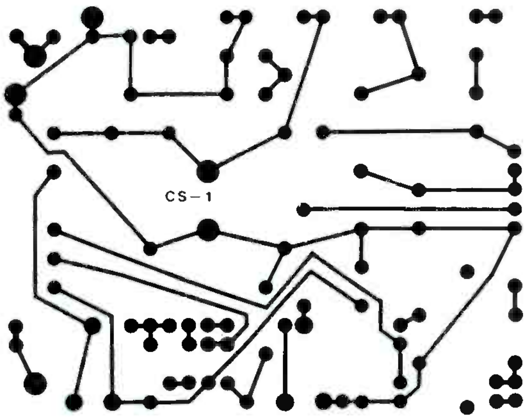
THE GATED SYNC experimenter's descrambler board.



THE COMPONENT SIDE of the voice-synthesizer board.

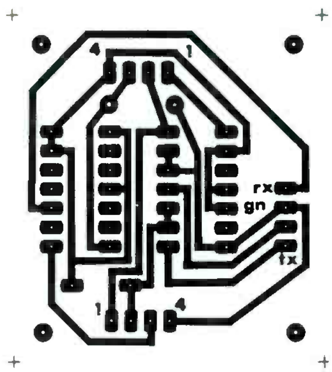


THE SOLDER SIDE of the voice-synthesizer board.



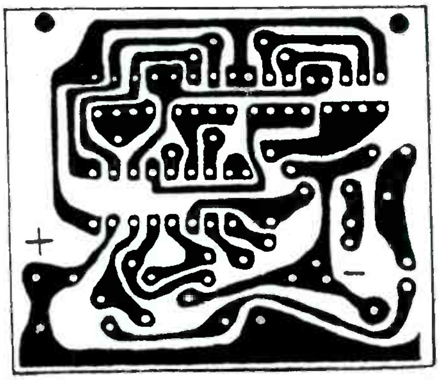
3 INCHES

PLASMA DISPLAY power-supply PC board.



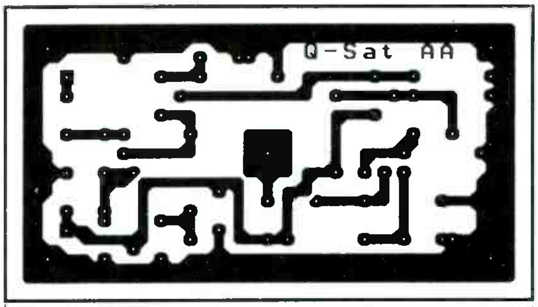
1⅝ INCHES

THIS IS THE COMPONENT SIDE of the RS-232 interface board.



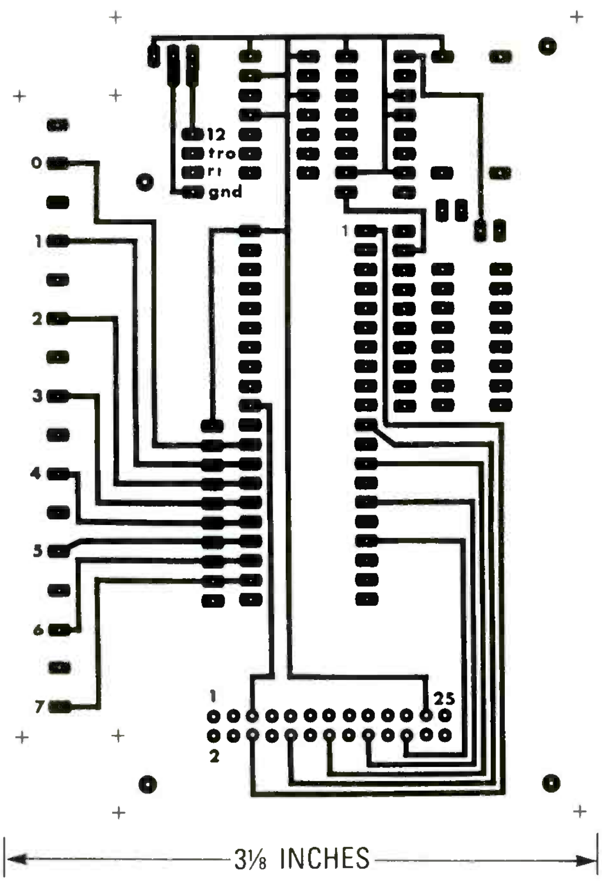
2 3/16 INCHES

THIS IS THE PATTERN for the electronic thermometer.

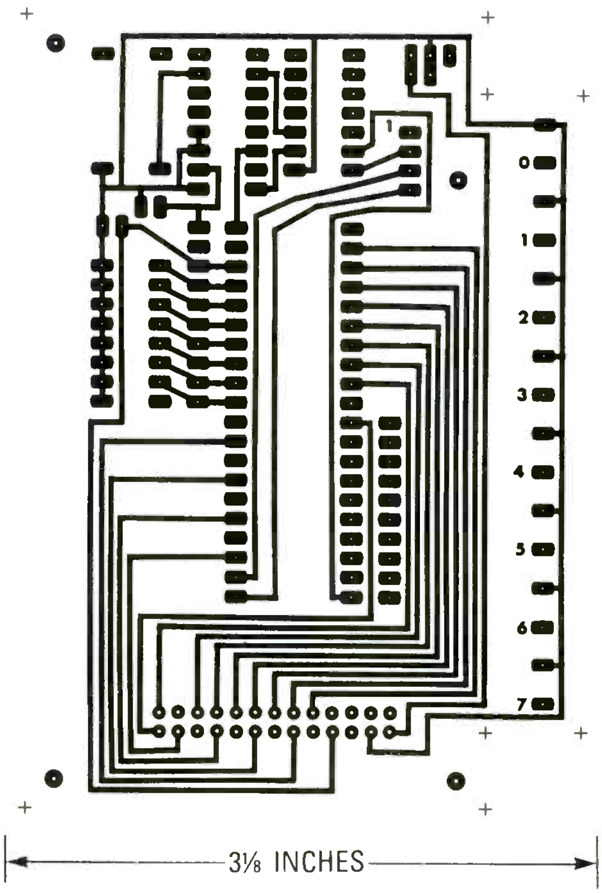


2¾ INCHES

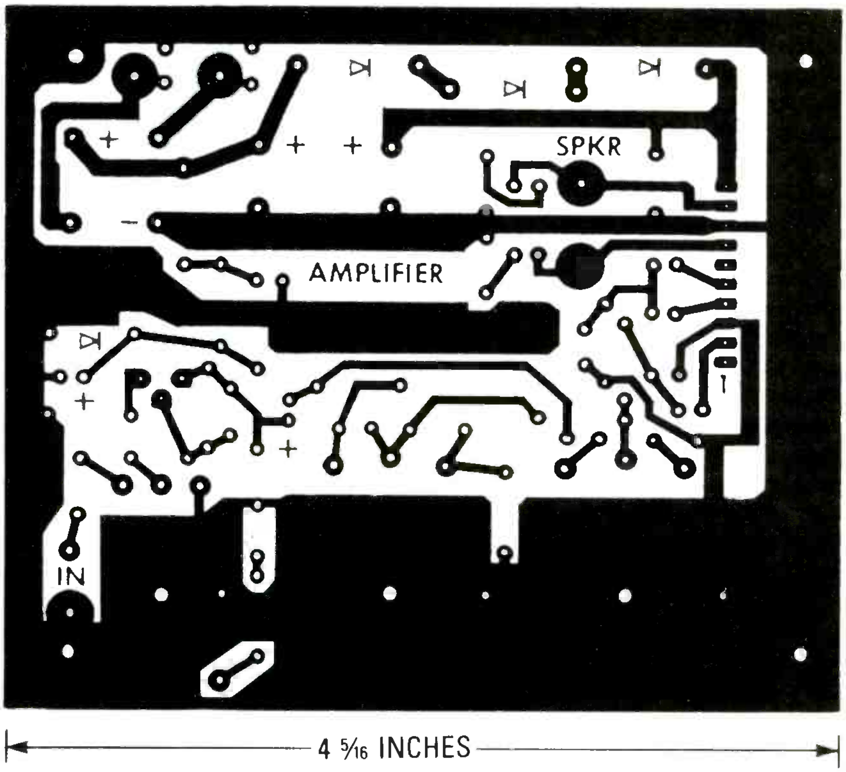
ACTIVE ANTENNA foil pattern.



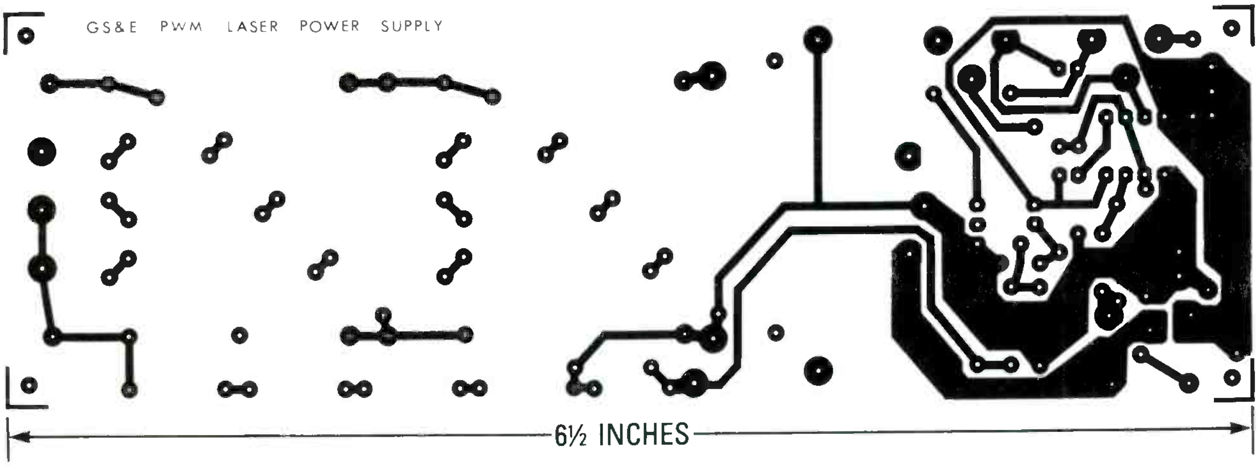
THE SOLDER SIDE of the RS-232 node circuit board is shown here.



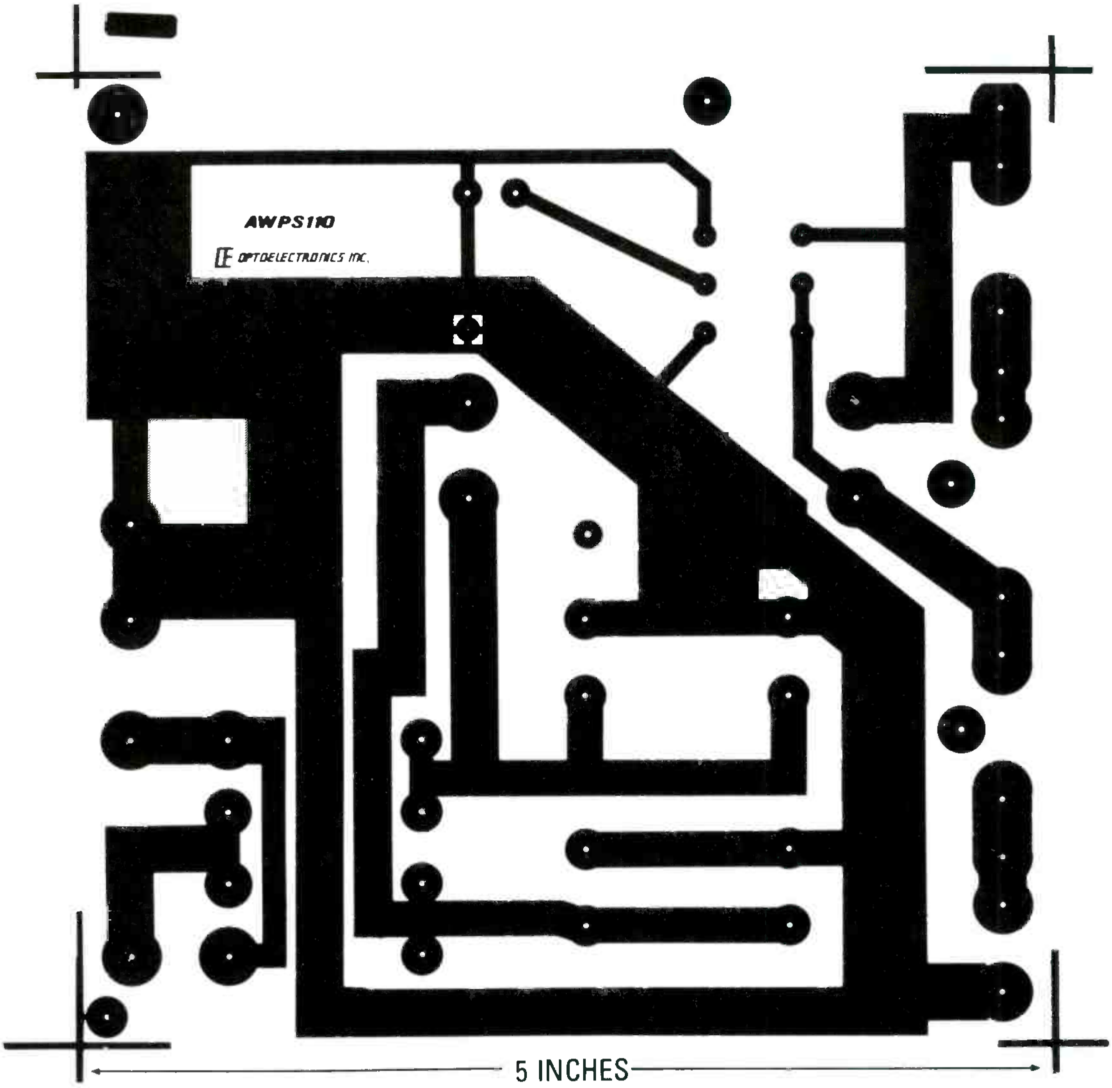
THE COMPONENT SIDE of the RS-232 node circuit board is shown here.



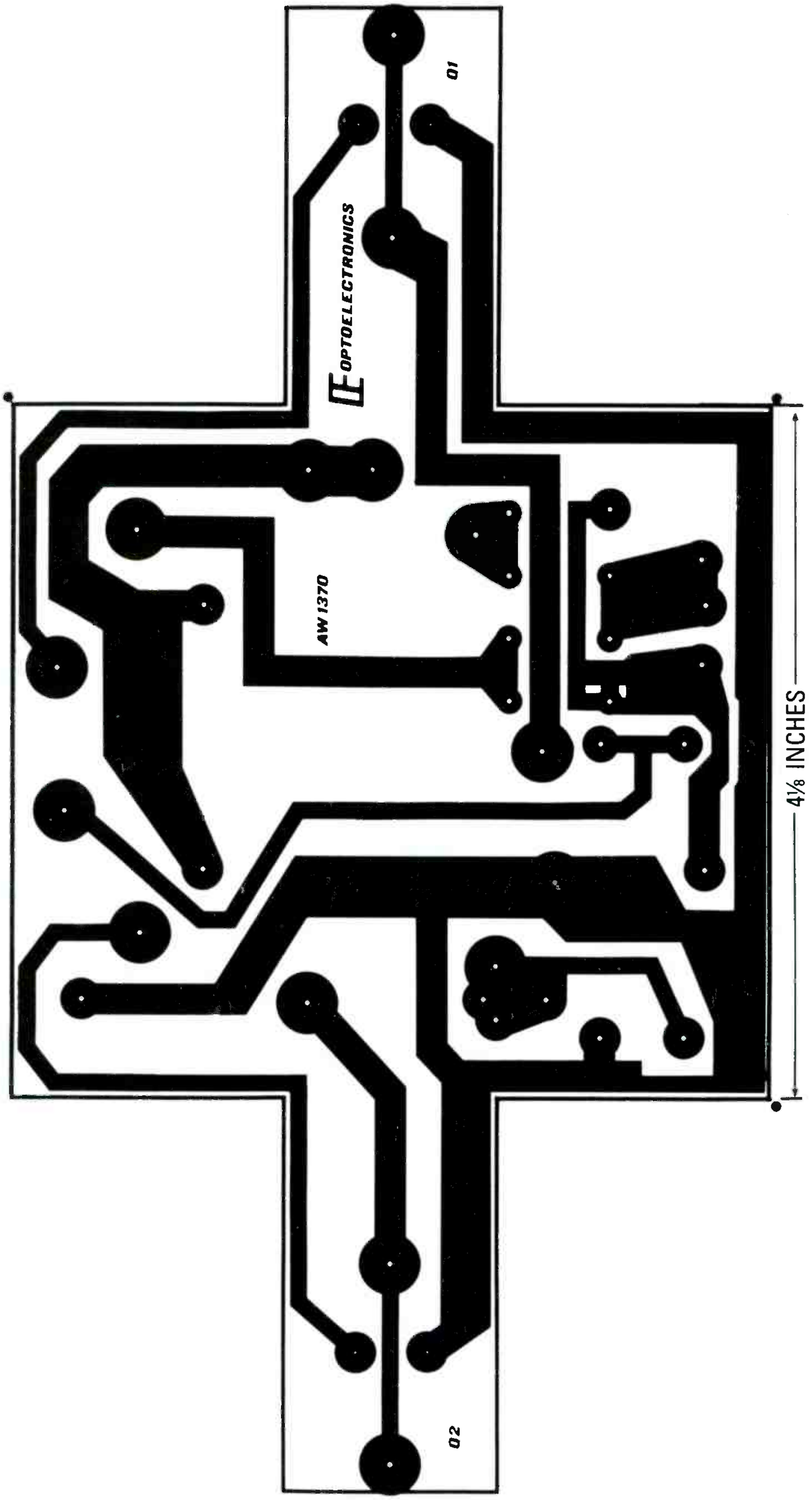
BUILD THE AMPLIFIED SPEAKER SYSTEM using this pattern.



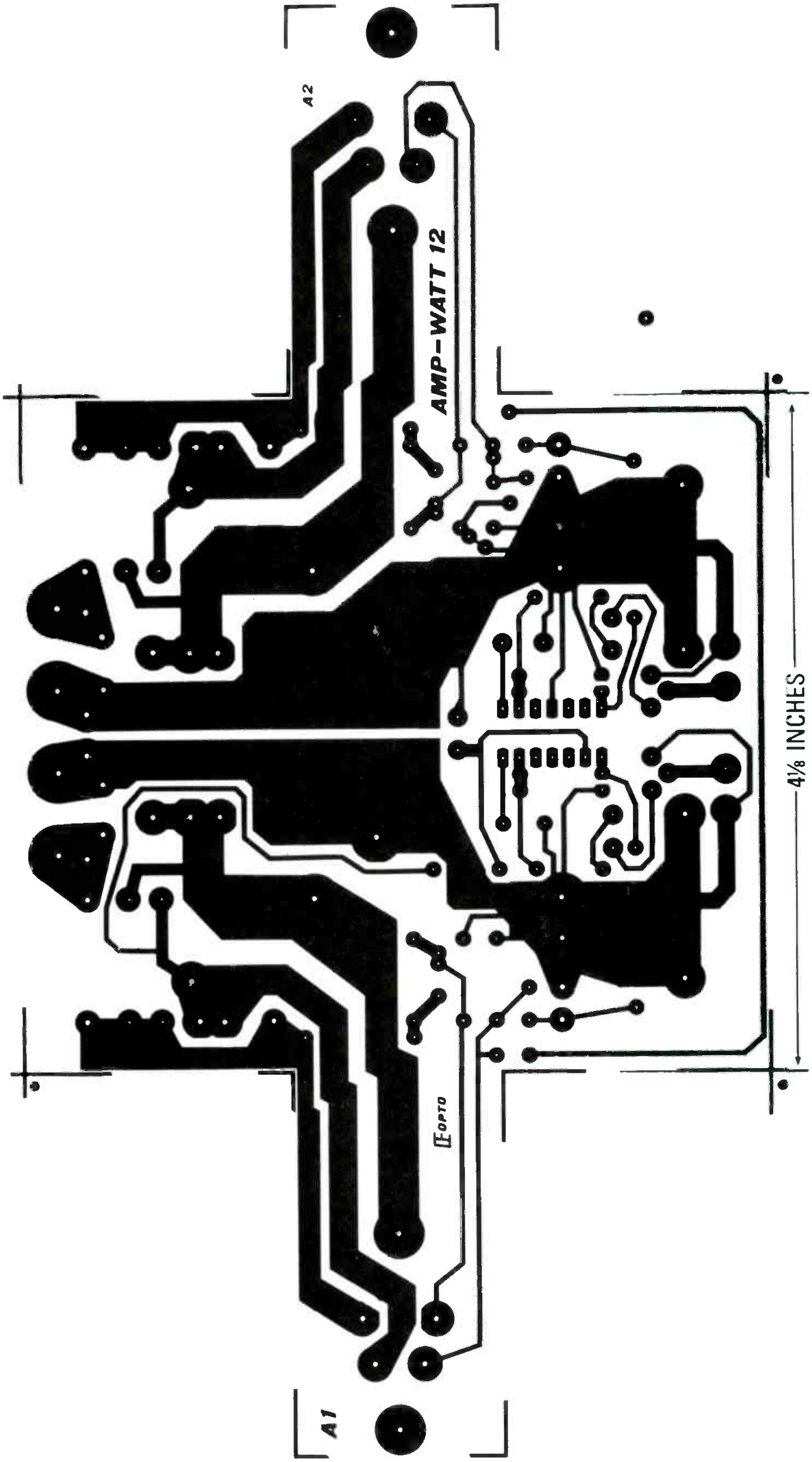
USE THIS FOIL PATTERN for the laser power supply.



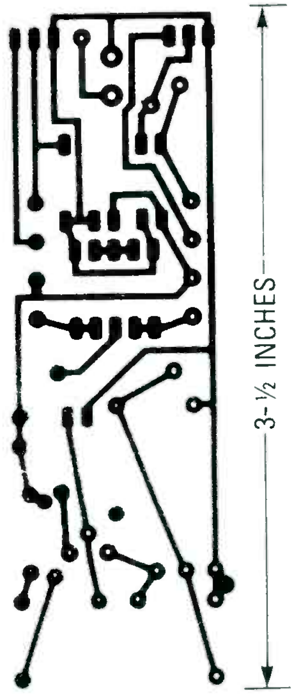
THE AC POWER SUPPLY for the high-power audio amplifier.



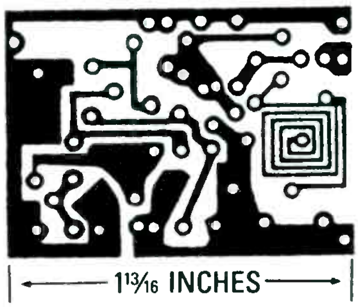
THE HIGH-POWER audio amplifier's foil pattern.



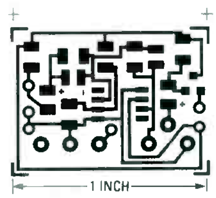
12-VOLT DC power supply for the audio amplifier.



BECAUSE OF THE DANGEROUS VOLTAGES that the stun gun develops, be extra careful when laying out and etching this PC pattern for that circuit.



WIRELESS FM transmitter.



THE SMT AMPLIFIER pattern is shown here at twice its actual size.

ACTIVE ANTENNA

continued from page 88

plifier's low-frequency response can be improved by increasing the values of capacitors C1 and C3. (You'll have to experiment with the values.)

Although a 9-volt battery is the recommended power source, the amplifier should work well using 6–15 volts. The inside of the cabinet of the completed prototype, using a 9-volt battery as the power supply, is shown in Fig. 3.

Troubleshooting

Circuit voltages for a 9-volt power supply are shown in Fig. 1. If the voltages in your unit differ by more than 20% from those in the schematic, try changing resistor values to get the voltages in their proper range. For example, if the voltage drop across R8 measures only 0.3 volt, you must decrease R4's value (the exact value is up to you to figure out) in order to increase Q3's base voltage and collector current.

The only critical voltages are those across R3 and R8. Performance should be fine if they are even close to the values on the schematic.

Since it's almost impossible to measure the voltage from the gate to the source (VGS) of an FET, you can measure the voltage that is present across R3, because it is the same as VGS. Adjust R3's value accordingly, if the voltage is not within the range of 0.8–1.2 volts.

Limitations

Use of the amplifier above 30 MHz is not recommended because of sharply reduced gain. While operation above 30 MHz can be accomplished by using tuned circuits in place of the resistive loads, that modification is beyond the scope of this article.

Take care when handling the FET (Q1). A common belief is that FET's and CMOS devices are safe from static damage after having been installed in a circuit, or after being mounted to a PC board. Although it's true that they are better protected from static electricity when installed in a circuit, they are still susceptible to damage by static; so never touch the antenna before discharging yourself to ground by touching some grounded metallic object. **R-E**

AMPLIFIER

continued from page 92

shown. After that, install an RCA plug on the other end for PL1. Then install two short wires at the pads marked SPKR for the speaker. Continue by connecting a 6-inch wire between S1 and the power pads (unmarked). Finish up by connecting transformer T1 and fuseholder between S1 and the other unmarked pad. Snap a 1-amp slow-blow fuse into the holder when you are finished.

Note that if you substitute a standard filament transformer for T1, the wiring is a somewhat different, as shown in Fig. 6. Wire the transformer's secondary directly to the unmarked pads, then wire the primary to S1 and F1 as shown. Also, be sure to use a ¼-amp fast-blow fuse for F1.

All that is left to do now is to install the board in the cabinet with 4-40 hardware, using spacers between the cabinet and the board, as shown in Fig. 5. Now connect the speaker wires, attach the knobs.

Operation

Now set all controls fully counterclockwise. Plug the unit into a nearby AC outlet, then turn it on by advancing the treble control. You will hear a brief "pop" from the speaker, then silence if all is well. Turn up the volume and touch the center terminal of PL1. You should hear a hum. If you are successful so far, you should connect a signal source, such as a tuner, and adjust the controls.

If you have any problems, check some voltages. From ground, you should read about 17 volts on C22, 15 volts on C23, and 9.1 volts on D1. The collector of Q1 should read about 4.9 volts. Start troubleshooting where the voltages are seriously off. Integrated circuit IC1 is more difficult to check, but start by measuring the voltages on the SPKR pads with the speaker disconnected; expect 7.5 volts on each pad, and if that voltage is not present, try replacing IC1.

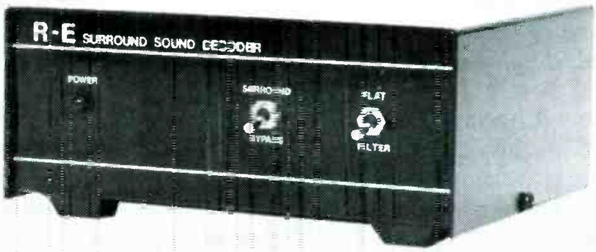
The project also works well from a 12-volt battery. Simply short out diodes D2, D3, and D4 with a jumper wire, and then connect the +12 volts through fuse F1 and switch S1 directly to the positive terminal of BR1. Wire the negative side of the battery to the negative terminal of BR1. **R-E**

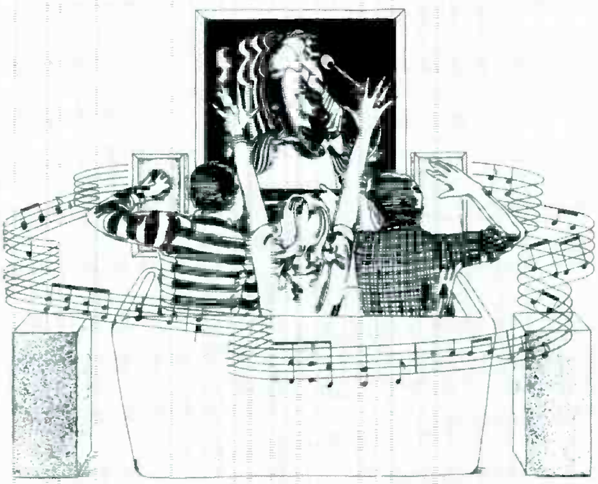
Radio-Electronics

Surround Sound Decoder

Add some excitement to your TV viewing! Our easy-to-build surround-sound decoder brings movie-theatre sound to your living room.

NORMAN M. HILL





AS STARFLEET COMMANDER, YOUR STARFIGHTER HAS THE LATEST in weaponry. From above and behind you hear the dull *thwup-thwup* of the laser pom-poms as the ball-turret tracks the incoming enemy spacefighters, whose energy bolts *zing* past your ship into the void behind. From your ship's right and left energy pods the phasor cannons fire a staccato stream whose roar fades off into a darkness that can be seen only by your ship's time-transporter.

But turn off the sound effects and once more the indefatigable starfleet commander is just another viewer in a movie theater. Without the imagery created by multi-directional sound —what we call *surround-sound*—even the most thrilling sci-fi adventure flick is not much better than an "olde-tyme" silent movie.

Just try to imagine *Star Wars* or *Top Gun* without surround-sound: They would be deadly dull. In fact, the lack of video-movie surround-sound is what turns many of the great action movies into a dull night at home on TV.

Surround-sound brings scenes to life by wrapping you in a sound environment that's as good as being there. If the picture is a forest, you become surrounded by wind and wildlife. In auto chases, cars roar out of the back of the room and onto the screen. In crowd scenes, you actually sense yourself in the center of the crowd. Surround-sound creates such a sensation of being there, that once you hear it, you'll lose interest in video and movies without it.

Here, we'll show you how to build a low-cost surround decoder. In the next article, we'll show you how to add even more excitement to your TV sound with a subwoofer simulator.

Concealed sounds

Every modern home video-movie now contains high-fidelity stereo tracks, which are output on the back panel of a modern VCR as left and right channels. When connected to a stereo system, they provide a *wide-screen* (semi-stereo) sound rather than the mono heard from a conventional TV or video monitor.

But *wide screen*, even genuine stereo, isn't surround-sound because it's still two-dimensional. The three-dimensional effect of surround-sound requires, at the very least, a rear channel, which might be provided by one or more additional sound tracks in the original theatrical release print; or, the rear sounds can be encoded within the stereo tracks. As far as home videos are concerned, there is only the stereo tracks, so the rear channel that creates the illusion of surround-sound is concealed by a special encoding within the left and right sound tracks. The encoded signals either blend into the front stereo channels or cancel each other; either way, they are not heard as distinct sounds when the sound you hear is played through a conventional stereo system.

It takes a special kind of decoder, such as our surround-sound decoder, to extract the rear sounds from the stereo signal, and it is the decoded rear sounds that cause the home viewer to be enveloped by a surround-sound that is very similar to what is heard in a movie theater.

Broadcast movies

What happens if the movie is broadcast by a TV station? The same thing, but only if the station is broadcasting MTS stereo. If you decode the MTS stereo signal you will again derive the rear audio channel. If you record the TV signal on a VCR, you can either decode the station's MTS stereo, or have the VCR do the stereo decoding (if it is so equipped).

How it began

The early 1970's saw the development of a technique (patented by Peter Scheiber) of encoding four channels into two stereo tracks. When decoded, the stereo signal produced four distinct outputs. By adjusting the phasing and relative levels of the signals blended into the stereo tracks, it was possible, by using the speaker placement shown in Fig. 1-a, to create the illusion of sound coming from the front, the sides, or the rear. Effectively, the sound could be located anywhere within a 360° field.

The technique was later modified so that a conventional stereo-front/stereo-rear speaker placement could be used; that is, left and right speakers in front of the listener and left and right speakers behind the listener. Unfortunately, the stereo-type technique eliminated wide stereo separation. In fact, left-to-right and front-to-rear separation was often reduced to as little as 3 dB. Since 3 dB is the *minimum* change in *program material* that can be sensed by the human ear, electronic enhancement of 4-channel sound was necessary in order to create the spectacular effects expected by the listener. Basically, it was done by electronic gain-riding. A monitor circuit determined which sound position (location) was dominant and adjusted the gain of the various channels so that the listener would perceive a stronger signal at that position. As a general rule, the electronic enhancement added 3 dB to the already existing 3-dB separation. The total of 6-dB separation was sufficient to trick the brain into believing it was sensing a precise sound location.

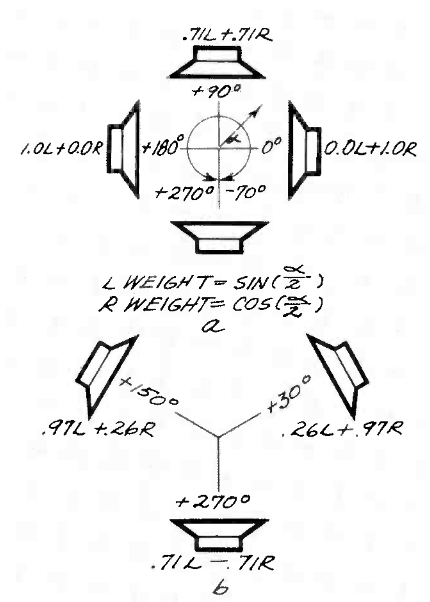


FIG. 1—THE EARLIEST OF MULTI-DIRECTIONAL sound systems used the unusual speaker arrangement in *a* which foreclosed true stereo listening.

For various reasons, among them being the extra cost of the rear amplifiers and speakers, and the eventual deployment of several kinds of encode/decode circuits, 4-channel sound, usually referred to as *quadraphonic* or *quadriphonic* sound, met with little success in the marketplace. But it did establish that a multi-directional sound could be encoded within conventional stereo tracks.

About that time, the movie industry was searching for a blockbuster technology that would bring in more patrons; something more attractive than just another form of wide-screen projection. The blockbuster was to be Dolby Stereo.

Dolby Stereo

The Dolby Stereo system was introduced for movie theaters in 1975. Under that system, 35-mm film carries two stereo tracks, and uses quadraphonic weighting to encode/decode the stereo signal into four outputs.

However, the need in a theater is not for 360° quadraphonic coverage. A theater needs only a single rear track to generate spectacular effects. There is no need for side sound because the primary sound placement is almost always on the screen, which is in front of the viewer. The needed speaker arrangement is shown in Fig. 2.

Unfortunately, that's far from a complete solution because the limited 3-dB channel separation of movie surround-sound is a real problem for all but the good seats at the center. Seats close to the rear will be swamped by the 3-dB leakage from front left and front right. Up front, better separation is also desired so that audio sources

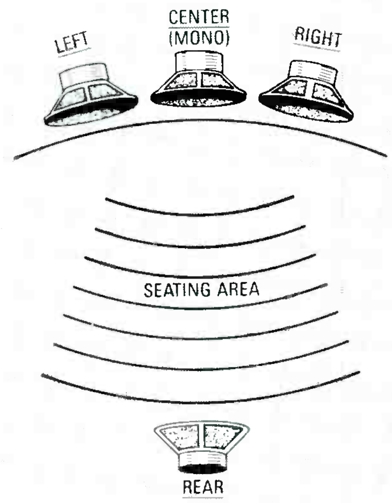


FIG. 2—THIS IS THE SPEAKER ARRANGEMENT for movie-theater surround-sound. Notice that a center speaker provides direct mono, rather than a mono image that's derived from left and right speakers.

track with the image on screen.

For those reasons, the quadraphonic concept of gain-control positioning of the dominant audio direction was incorporated into Dolby Stereo, and the smashing 1977 success of the Dolby-Stereo encoded *Star Wars* entrenched the system as the industry standard.

The gain-control circuitry is a serious complication, necessary to make all the seats in the house good ones. Home decoders loaded with such circuitry, such as the Shure *HTS5000* are available for around $750. Units that incorporate gain control are identified by the *Dolby Surround Pro Logic* logo.

The Dolby home decoder

In 1981, Dolby Labs acknowledged a need for a low-cost, no-gain-control decoder for home video and recommended an appropriate circuit. Decoders without gain-control carry the *Dolby Surround* logo.

Those lower-cost units are available from various licensed manufacturers for $200-$400, and to carry the *Dolby Surround* logo they must process audio according to the block diagram shown in Fig. 3.

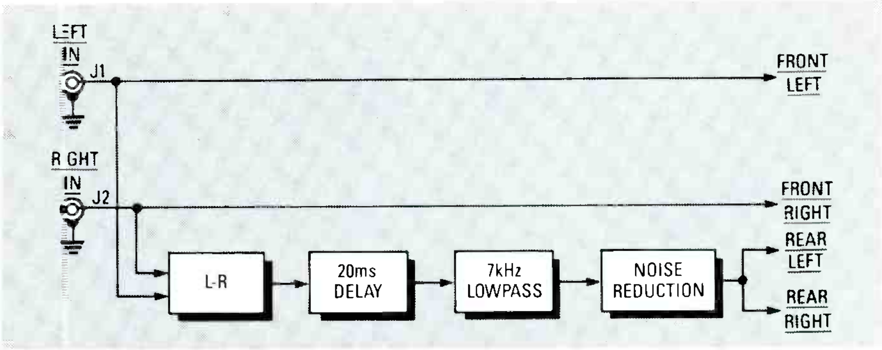


FIG. 3—DOLBY'S RECOMMENDED HOME DECODER includes a 20-ms delay and a noise-reduction system.

Dolby's decoder.

All processing is performed on the (L – R) difference signal, which is concealed within the left and right stereo tracks. While only a single rear-channel is decoded, it is intended that two speakers will be positioned at the rear of the room, hence, the rear output is shown as REAR LEFT and REAR RIGHT, even though they both carry the same signal. Two traditional stereo speakers provide the front sound.

As shown in Fig. 3, Dolby restricts the rear channel's high-end frequency response to 7 kHz. When the standard was being developed, the high-frequency coherence between the two channels of home-video equipment wasn't consistent. Directional placement could become random if high-frequency phase-coherence were to be lost on a wide-band signal; for example, an actor's voice might be reproduced with the lower frequencies from the front and the sibilants from the rear. However, the likelihood of that happening depends on the equipment used for recording and playback. While some tapes sound better with a rear filter, many tapes and the equipment they are played on have cohered high-frequency phase performance, and they sound better—at least more natural—without the filter. If you're finicky about sound quality, the 7-kHz cut-off should be switch selectable so that you can enjoy the best in sound when the tape and equipment make it possible.

Notice that Fig. 3 indicates a 20-ms time delay. The delay serves two purposes. First, since 20 ms represents the time it takes the sound to travel about 20 feet, it allows the rear speakers to be positioned close to the seating, yet the sound appears to originate from farther back, more closely simulating theater sound, where the rear speakers are located considerably behind the viewer. The time delay also proves useful when there is accidental leakage of the front-left or front-right sound to the rear. Since the 20-ms delay causes the sound to arrive after the front sound, it reinforces the perception that the sound is up front.

Fortunately, the positioning of home rear speakers can usually be juggled so that the delay isn't really necessary, which simplifies construction of a home decoder, reduces its cost, and also eliminates the noise and distortion that might be caused by a delay unit.

Noise reduction

In the Dolby system shown in Fig. 3, the rear-channel information is supposed to be encoded with a noise-reduction that is similar to the *Dolby B* processor used for cassette recorders. Listening tests and inspection of a frequency/gain table indicate that we could probably do without it as far as surround-sound is concerned, so we left it out of the prototype.

Note, in particular, that Fig. 3 does not show signal processing to the front speakers: Differential signals driving the rear speakers pass to the front unchecked. If we add some of each front channel to the other, we attenuate to the leakage of the rear signals while reducing the front stereo separation. The reduction in separation is desirable because it helps viewers in off-center seats hear a stereo spread without resorting to a center channel. (Note the center mono speaker used in the movie system shown in Fig. 2.)

WHICH IS WHICH?

The type of circuits used in a home *Dolby Surround* decoder is identified by the kind of *Dolby* logo used. If the decoder includes an adaptive matrix stage to provide left, center, right, and surround outputs, along with the stages shown in Fig. 3, then it is called a *PRO LOGIC* model and has this logo shown.

DOLBY SURROUND
PRO • LOGIC

If the decoder is the less expensive design that processes the signals according to the block diagram in Fig. 3, it is identified by this Dolby logo.

DOLBY SURROUND

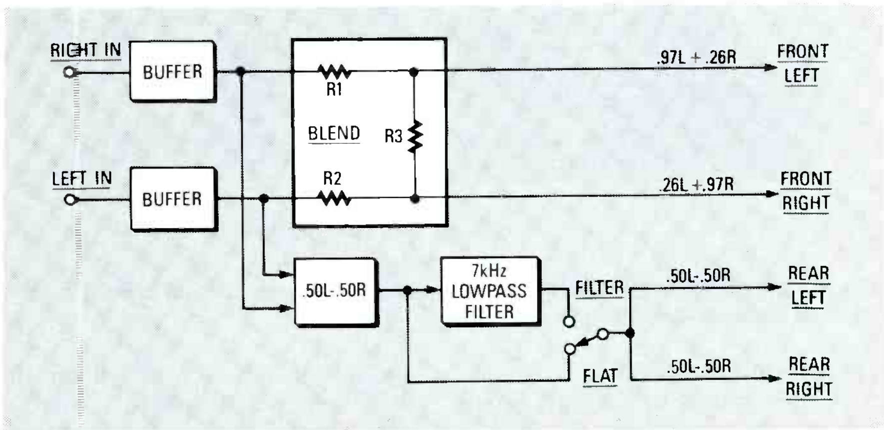


FIG. 4—OUR SURROUND-SOUND DECODER ELIMINATES both the time delay and the noise reduction, which doesn't seem to degrade how the three-dimensional effect sounds in the home.

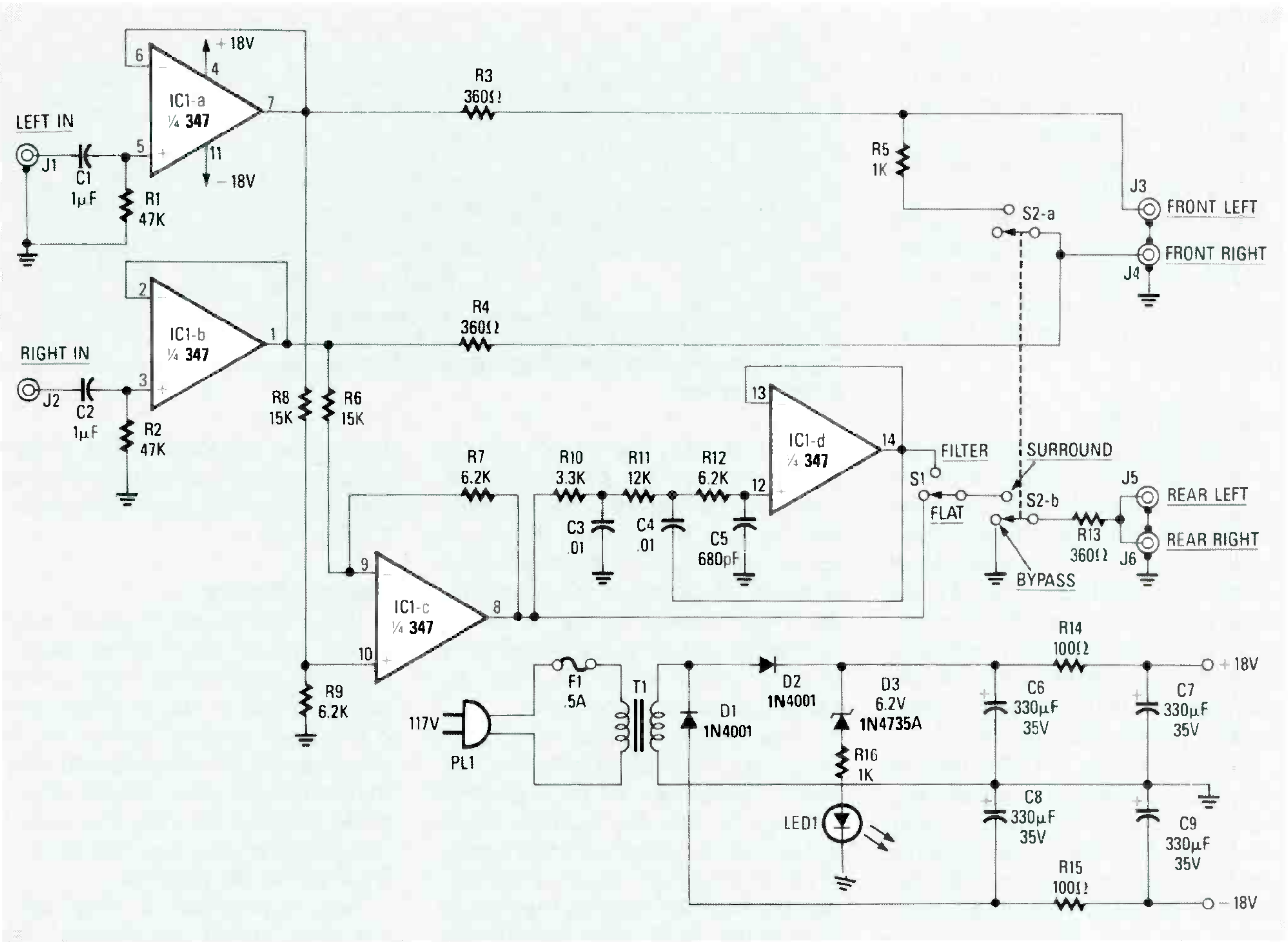


FIG. 5—THE DECODER'S CIRCUIT. Virtually nothing is critical because R3 and R4 isolate the buffer amplifiers from the capacitance of the shielded cables connected to J3 and J4.

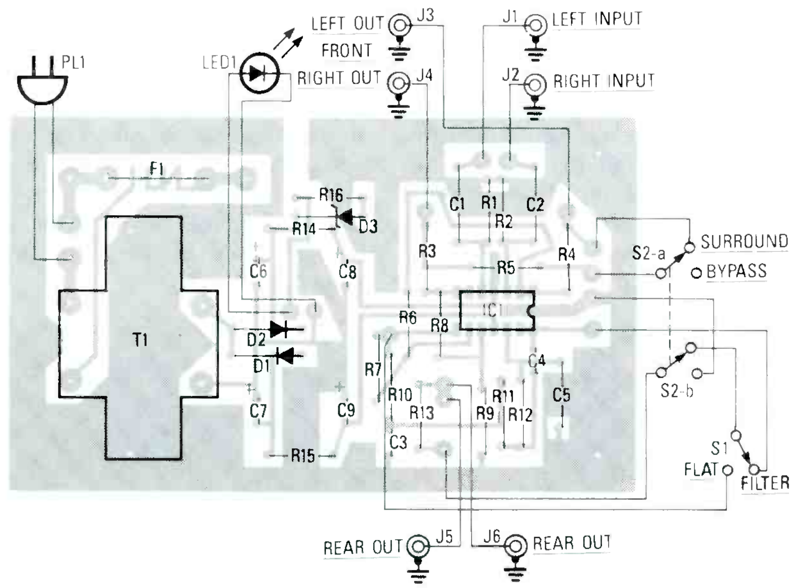


FIG. 6—THE COMPONENT LAYOUT for the printed circuit board. Double-check the polarity of all diodes and electrolytic capacitors.

A surround decoder

Figure 4 shows the block diagram for our surround-sound decoder. It consists of input buffers, a front blender, a rear difference decoder, and a switchable low-pass filter. The rear levels are such that, if all four speakers are identical, and the driving amps have identical gain, the system would be balanced for proper level with no need for level adjustments. In practice, however, the rear speakers are different and the level is adjusted on the rear amplifier.

If any one speaker sounds at full volume, the other two sound half as loud (-6 dB), ¼-power. A separation of 6 dB is a lot better than the 3-dB separation of a four-channel system, and such a decoder is easier to build than a "true" Dolby type, yet it sounds as good or better when it is fed from a Dolby surround-sound signal source.

Notice that the system actually puts out only three sound channels (the rear-right and rear-left are the same); it does not use a 20-ms delay, nor noise reduction, and although it lacks any form of gain control, the separation between channels is maximized.

In a typical home environment, the front speakers should just about flank the screen, because we want the sound to appear to originate up front, at the screen, just as it does in a theater. The rear speakers should be located as far behind the viewer as the front speakers are forward.

PARTS LIST

All resistors are 1/4-watt, 5%.
R1, R2—47,000 ohms
R3, R4, R13—360 ohms
R5, R16—1000 ohms
R6, R8—15,000 ohms
R7, R9, R12—6200 ohms
R10—3300 ohms
R11—12,000 ohms
R14, R15—100 ohms

Capacitors
C1, C2—1 µF, 100 volts, polyester
C3, C4—.01 µF, 50 volts, polyester
C5—680 pF, polyester
C6–C9—330 µF, 35 volts, electrolytic

Semiconductors
IC1—LF347N, quad op-amp
D1, D2—1N4001 silicon rectifier
D3—1N4735A, Zener, 6.2 volts
LED1—Light-emitting diode

Other components
F1—Fuse, slo-blo, 0.5 ampere
J1–J6—Phono jack
PL1—Power plug
S1—SPDT switch
S2—DPDT switch
T1—Power transformer: 120-volt primary; 12.6-volt, 300-mA secondary

Miscellaneous: Printed-circuit materials, fuse clips, enclosure, etc.

An etched and drilled circuit board is available for $10.25 postpaid from Fen-Tek, P.O. Box 5012, Babylon, NY 11707-0012. NY residents must add appropriate sales tax.

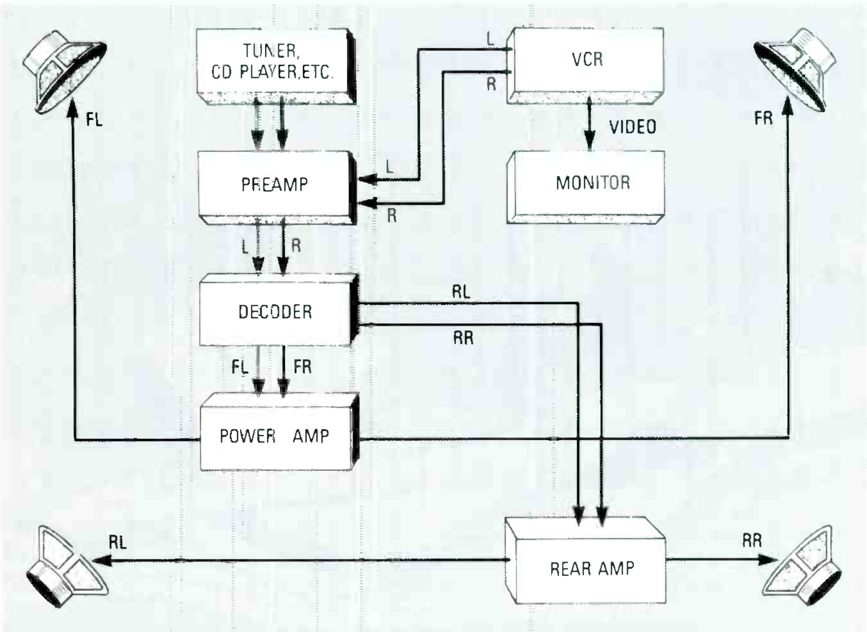


FIG. 7—THE MOST FLEXIBILITY IS ATTAINED if the decoder is used in a component system. This kind of arrangement also allows tuner and CD-player signals to be decoded.

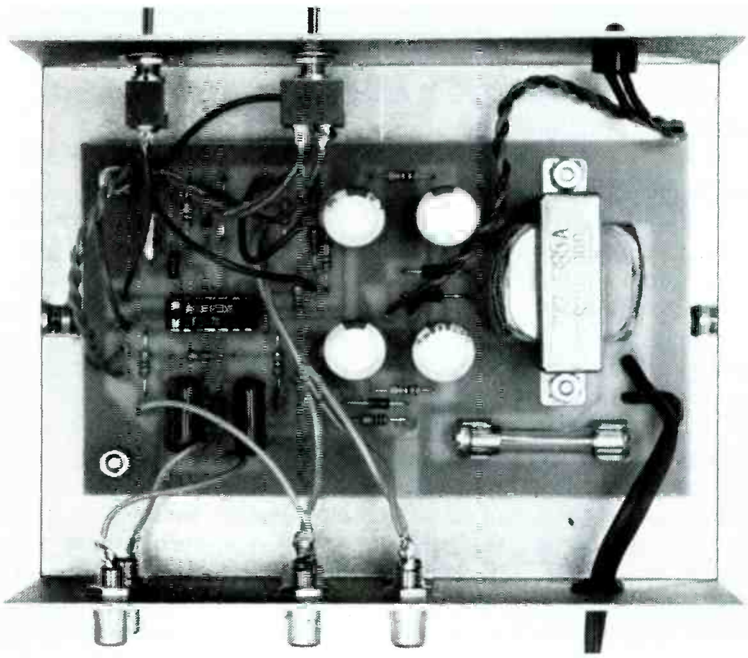


FIG. 8—THE PROTOTYPE USES PHONO JACKS for all input and output connections. Grouping them on the rear apron allows the decoder to be easily connected into any kind of component arrangement.

The circuit

The complete circuit is shown in Fig. 5. Components R1, R2, C1, C2, IC1-a, and IC1-b buffer the left and right channels at unity gain over the audio band. The front channel blending described earlier is attained when switch S2-a connects R5 across R3 and R4. When S2 is set to the BYPASS mode, R3 and R4 isolate IC1-a and IC1-b from the capacitance of the shielded cables that are connected to J3 and J4.

Resistors R6–R9, and integrated circuit IC1-c, make the L − R difference signal the correct level if all speaker/amplifiers are equal. Resistors R10–R12, along with capacitors C3–C5, and amplifier IC1-d, form a 3-pole Chebychev 7-kHz active filter. When the filter is selected, R13 isolates the capacitive cable loading from IC1-d.

The power supply is not regulated because precise voltage values are not critical. Diode D3 is used to slow the power-off loss of the positive-voltage output, reducing "turn-off" pops.

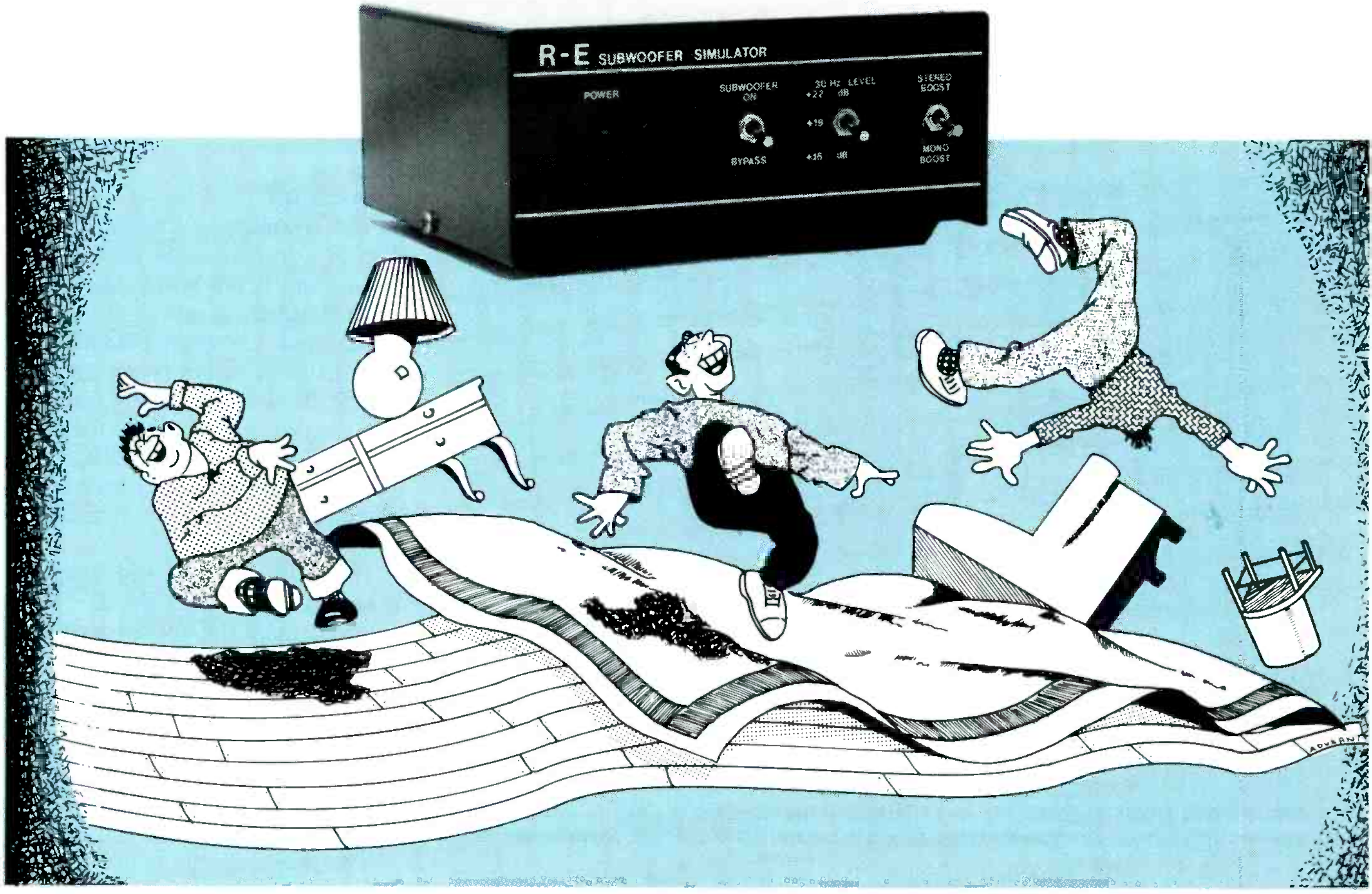
Our prototype decoder is assembled on a printed-circuit board; the template for the board is provided in PC service. There are no unusual assembly considerations other than insuring that there is isolation between T1's ground lead and C6–C8 (there should be only one power-supply ground, as shown). Also, ceramic capacitors should not be used because their tolerance varies with temperature and the applied voltage, thereby possibly creating distortion. Polyester capacitors are recommended.

The PC-board's component layout is shown in Fig. 6. Nothing is unusual or critical as long as the polarity of all diodes and electrolytic capacitors is

continued on page 140

BUILD THIS
SUBWOOFER SIMULATOR

NORM HILL



Build a subwoofer simulator and fill your living room with movie-theater sound you can actually feel.

A MOVIE THEATER CREATES REALISM BY projecting a large picture, using surround sound, and by extending the sound's low-frequency response with subwoofers so that the viewer can actually feel the special-effects. When a movie contains explosions, jet rumble, thunder, galloping horses, or other heavy-duty action, the subwoofer adds realism by literally shaking the floor.

Although it is generally accepted that a healthy ear can hear a frequency range of 20 Hz to 20 kHz, in fact, some of that range is not so much heard, but sensed. For example, many people cannot hear frequencies higher than 15 kHz, although they can sense that they exist. It's the same thing for frequencies in the deep-bass range of 20–50 Hz; many persons cannot hear frequencies within that range, although they can feel and sense them as vibrations.

In a theater, special effects are often exploited by enhancing the deep-bass frequencies, so that when the jets rumble, they rumble so powerfully that you can actually feel the runway vibrating under your feet. (And a flat frequency response ceases to be desirable once your feet become the listening transducers.) Below 20 Hz, sound is neither felt nor heard; at best there is a strange sensation of changing air pressure.

But although most people can perceive sounds in the 20–50 Hz range, because conventional woofers, even 12-inch and larger, roll off below 50 Hz, deep bass sounds are rarely heard unless some kind of deep-bass compensation is provided. The usual solution to providing deep bass in both theaters and the home is to add a monaural subwoofer that is driven off the front channels by an active filter and a separate amplifier.

Not that perfect

Unfortunately, there are some drawbacks to using a monaural subwoofer. It is commonly assumed that deep-bass information has such a long wavelength that it will be summed by the room to a mono signal, and that therefore a single transducer can be

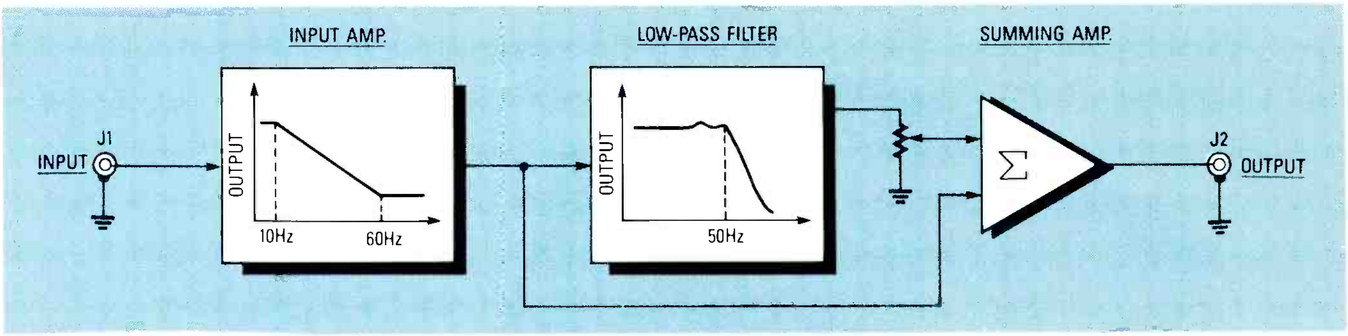


FIG. 1—TO ENSURE THAT ONLY THE DEEP-BASS FREQUENCIES are enhanced, the simulator's first stage amplifies the frequencies below 60 Hz before the low-pass filter attenuates all signals above 50 Hz.

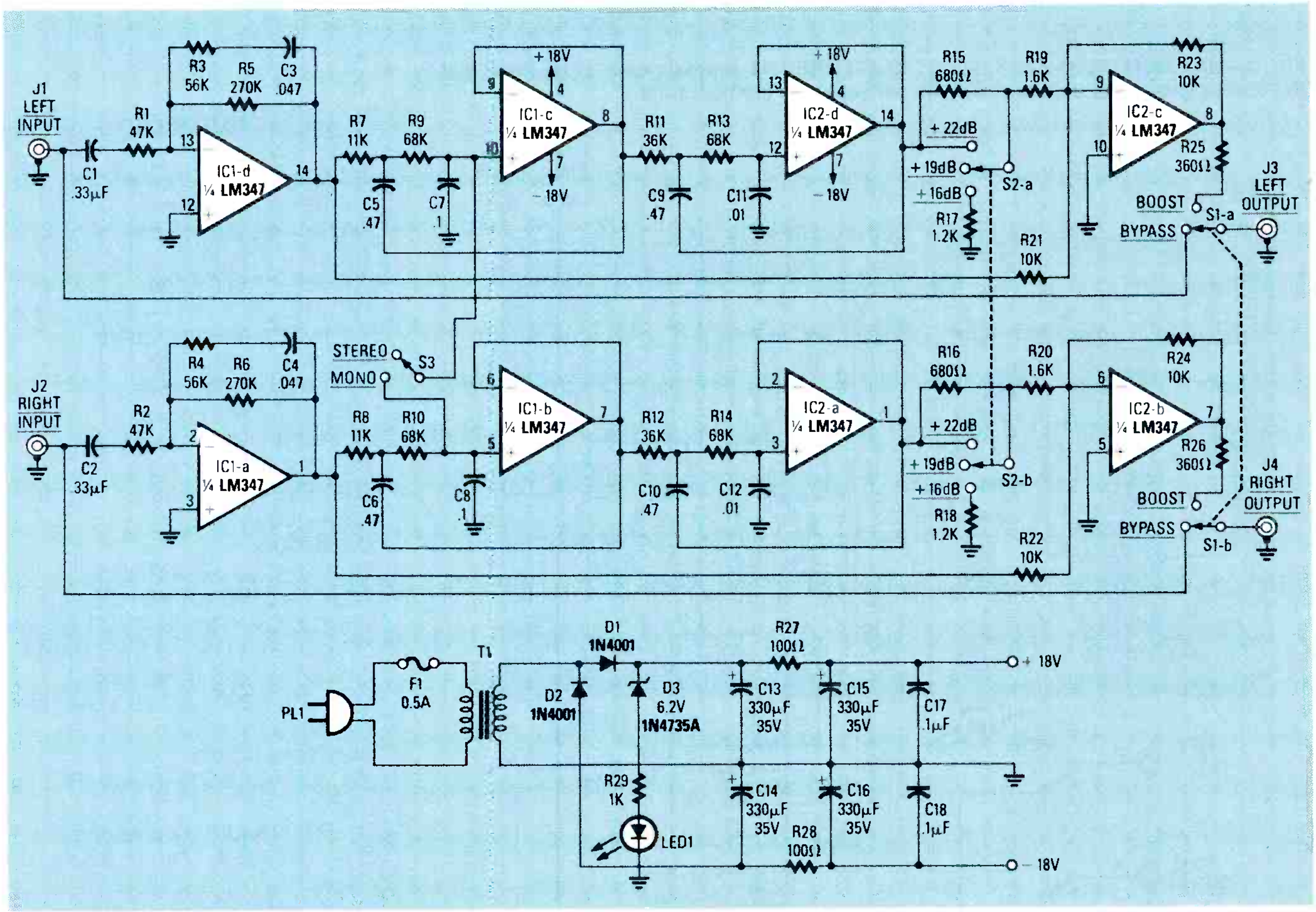


FIG. 2—THE LEFT AND RIGHT CHANNELS ARE IDENTICAL. Switch S3 blends the two channels when only mono deep-bass sounds are wanted. Switch S2 provides three levels of deep-bass amplification.

used. A simple comparison of mono and stereo bass-boosting calls that into question. Jet rumble, such as in the movie *Top Gun*, takes on a flatter, quieter, less spacious sound when boosted monaurally instead of stereophonically. A quick check of the low-frequency information (measured using a dual-trace scope and active 50-Hz stereo filters) shows that the two channels have little in common during jet rumble or numerous other situations. Only in music are the two channels similar.

Another concern is the type of filter used to feed the subwoofer. All filters have substantial phase shift at the roll-off frequencies. It can easily turn out that the high-band and low-band speaker cones will end up out of phase during the transition region, causing a loss of response over, say 60–90 Hz, which will produce a peculiar bass quality. It is likely that many subwoofer systems suffer that problem, especially those using simple passive crossovers for which 180° is a common roll-off phase angle.

Price is another objection to a mono-subwoofer system that includes a filter and separate amplifier: You'll have to spend a lot before your floor starts to shake, rattle, and roll.

A cheaper way

A less expensive way to simulate the "feelie" effect of the movie theater's deep-bass system is to simply boost the bass signal delivered to your existing front speakers. (Most home-stereo systems are overbuilt, at least when listening to a video movie at the

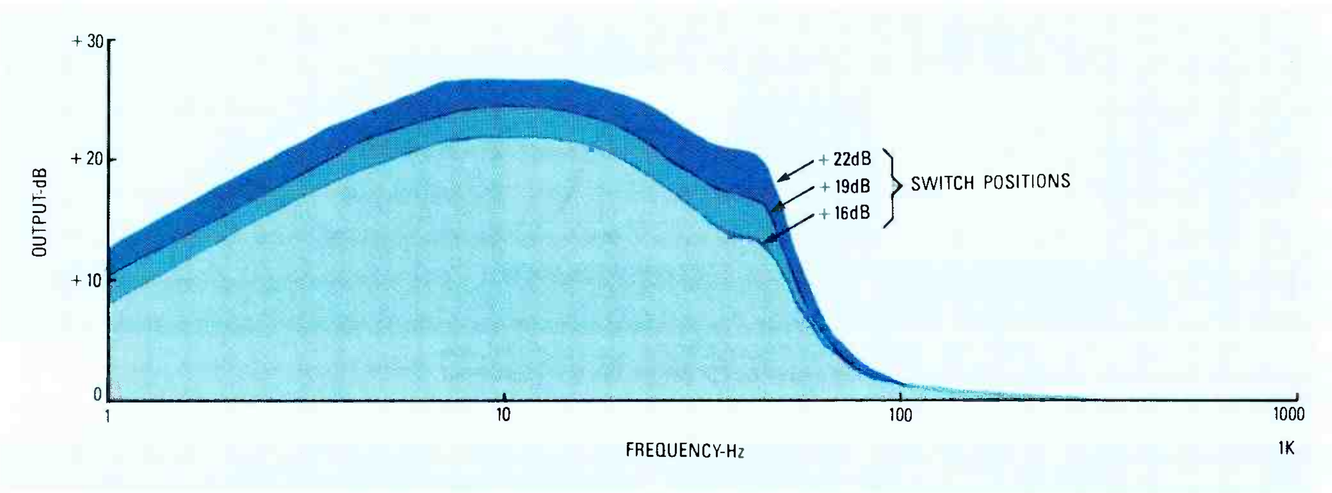


FIG. 3—MAXIMUM DEEP-BASS BOOST IS ATTAINED AT approximately 12 Hz. Note that the curves shown are unattainable with conventional tone controls.

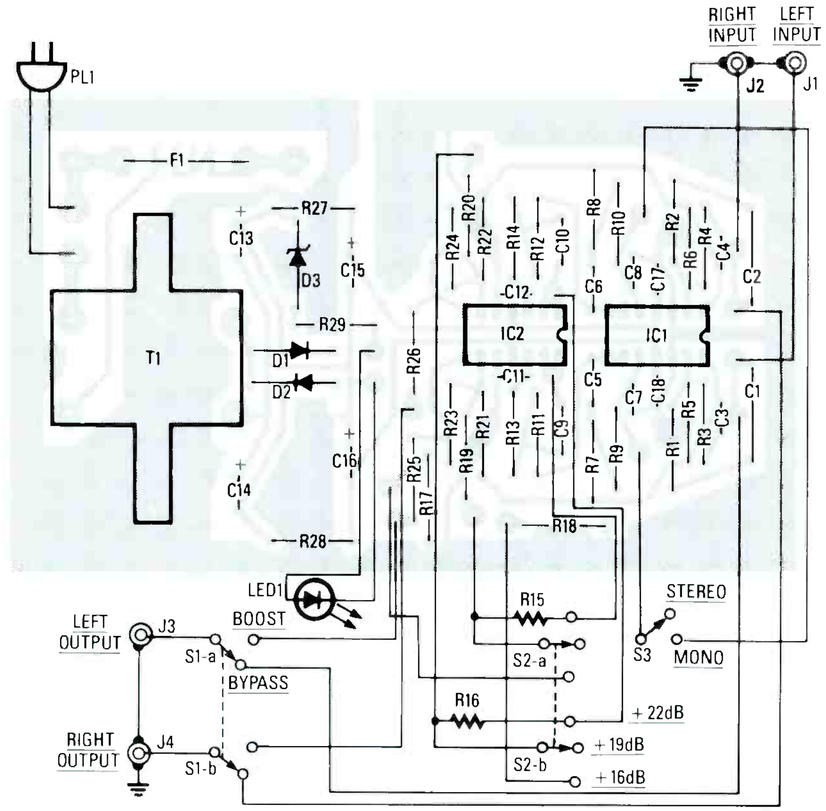


FIG. 4—THIS IS THE PARTS LAYOUT for the printed-circuit board. Take note that resistors R15 and R16 are mounted on switch S2, not on the board.

usual living-room volume level.) Although home-speaker systems having a 10- or 12-inch woofer may be rolling off between 20–50-Hz, that doesn't mean that they can't radiate energy in that range. We merely need to provide compensation so that they get more power in the deep-bass frequency range. An analogy is hitting the loudness switch or turning up the bass, except that the boost must be more selective to create the illusion of a subwoofer's sound & feel.

Figure 1 shows the block diagram of a subwoofer simulator that can be used for either the left or right channel. The first stage is a buffer-amplifier that provides gain below 60 Hz to compensate for the fact that most speakers roll off in that range. The buffer is followed by an active low-pass filter that removes everything except the deep-bass frequencies. The output from the filter is summed with its input so that the total bandwidth is at a substantially higher level than it

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R2—47,000 ohms
R3, R4—56,000 ohms
R5, R6—270,000 ohms
R7, R8—11,000 ohms
R9, R10, R13, R14—68,000 ohms
R11, R12—36,000 ohms
R15, R16—680 ohms
R17, R18—1200 ohms
R19, R20—1600 ohms
R21–R24—10,000 ohms
R26, R26—360 ohms
R27, R28—100 ohms
R29—1000 ohms

Capacitors
C1, C2—0.33 µF, 100 volts
C3, C4—0.047 µF, 50 volts
C5, C6, C9, C10—0.47 µF, 50 volts
C7, C8, C17, C18—0.1 µF, 50 volts
C11, C12—0.01 µF, 50 volts
C13–C16—330 µF, 35 volts, electrolytic

Semiconductors
IC1, IC2—LF347N, Quad JFET op-amp
D1, D2—1N4001 rectifier diode
D3—1N4735A, Zener diode, 6.2 volts,
LED1—Light-emitting diode

Other components
F1—½-amp slo-blo fuse
J1–J4—Phono jack
S1—Switch, DPDT
S2—Switch, DPDT, center off
S3—Switch, SPST
T1—Power transformer, 117 volt primary; 12.6-volt, 300-mA secondary.

Miscellaneous: PC-board materials, fuse clips, wire, linecord, solder, enclosure, etc.

An etched and drilled PC board is available for $10.25 postpaid from Fen-Tek, P.O. Box 5012, Babylon, NY 11702-0012. NY residents must add appropriate sales tax.

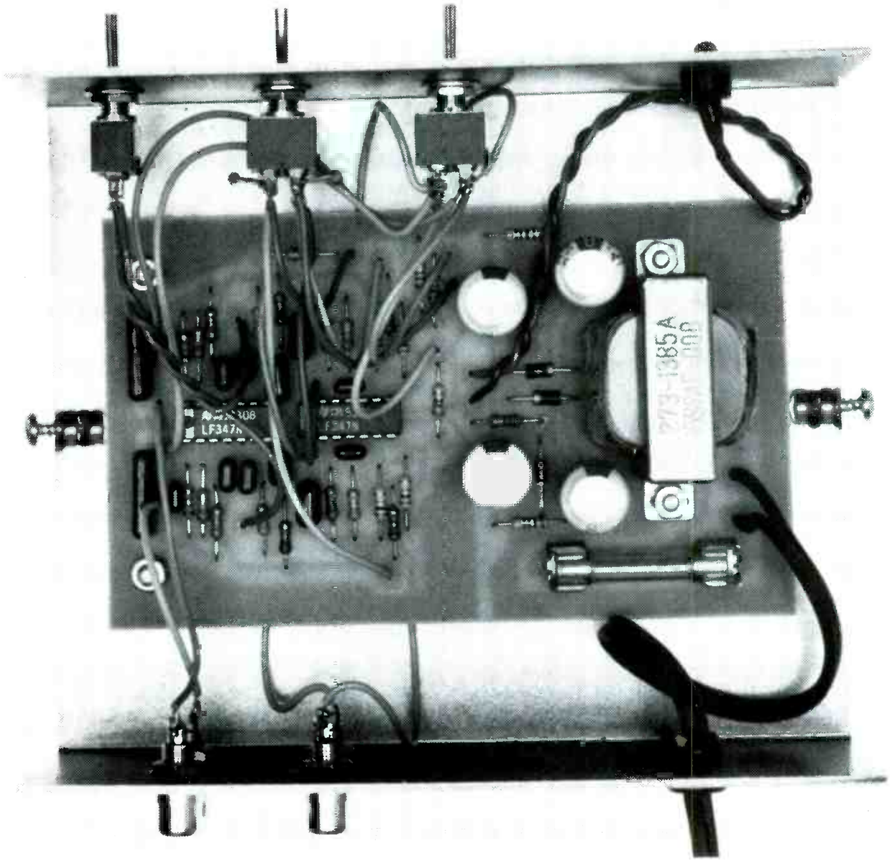


FIG. 5—TO AVOID NOISE PICKUP the simulator should be enclosed in a metal cabinet. Cabinets that are partially metal and partially plastic aren't suitable.

would be if only the deep-bass frequencies were filtered.

Figure 2 shows how the block diagram becomes the schematic for our stereo-subwoofer simulator.

How it works

Both channels are identical. Buffer amplifier IC1-a has unity gain above 60 Hz, and a rising gain characteristic below 60 Hz to compensate for the speaker's deficiency in the deep-bass range. Active low-pass filters, IC1-b and IC2-a, pass the frequency components below 50 Hz. Amplifier IC2-b sums the input and output signals of the filters. Switch S2-a provides three levels of bass summation—a fancy way of saying "bass boost." The subwoofer simulator's frequency-response curves for the three switch positions are shown in Fig. 3.

Construction

The project should use printed-circuit assembly to avoid introducing noise. A foil template for the PC board is provided in PC Service. You'll find that the template has holes to accommodate either a pigtail-lead fuse (F1), or individual fuse clips (which take two holes per clip) Use whatever is most convenient for you.

The parts layout for the PC-board and the connections for the panel-mounted components are shown in Fig. 4. For simplicity, an on/off power switch was not included so that the unit would be switched on and off by the master power switch for the entire system. If you want separate power control for the subwoofer simulator, simply install a SPST switch in series with one leg of the power cord.

Although the circuit will accept conventional part tolerances for the resistors and capacitors, for best results we suggest you use 5% capacitors for the active-filter components. As shown in Fig. 5, the prototype is mounted in a metal enclosure; do not use a cabinet that is part metal and part plastic.

Hookup

If your sound system has a separate pre-amp and power-amp, the subwoofer simulator connects immediately before your front power amplifier—after any surround-sound decoder. If you have a receiver, your only option is to connect the simulator before the receiver's AUX input, or within the tape-monitor loop—which isn't quite ideal because the simulator will be receiving a line-level 1-volt rms signal

Since the bass boost can exceed a factor of 10, the subwoofer simulator may occasionally output more than 10-volts rms, so to avoid blowing out your speakers, be careful when first trying the subwoofer simulator.

Increase the amplifier's gain slowly. Back off the amplifier's output power if you hear distortion. The author developed the circuit using a 200-watt-per-channel amplifier and speakers rated for 250 watts. If your system is more modestly powered, you may not want to use S2's higher boost positions. Also, if your amplifier is rated for less than 60 watts per channel, or if your woofers are smaller than 10-inches, you may not attain sufficient deep-bass output to create the sense of feeling.

Clipping within the simulator is possible, although we have seen no problems because of the device's relatively high DC supply voltage. A bigger concern is an audio amplifier that wasn't built to handle an unusually large deep-bass signal. For example, one time we absent-mindedly installed the simulator between a VCR and a *Trinitron* monitor, which has an audio switching function. It took quite a while to figure out that the sound's distortion was caused by the *Trinitron* monitor's inability to handle more than a few volts of input. Moving the simulator so that it was installed after the monitor, between the TV and preamplifier, completely resolved the problem.

The payoff

Once your system is wired for surround sound you'll discover that some movies have effects that you can literally feel, while others don't. There is a wide variation in the quality of the effects, usually from one studio to the next, not from one movie to the next. Some outfits put in plenty of enjoyable, surround-sound and "feelie"effects, while others put in few sound effects. Unfortunately, the only way to find which is which is through trial and error. **R-E**

COPING WITH COILS

continued from page 120

that you can determine (before you wind it) whether or not the coil will physically fit in your project. The average coil diameter is listed just in case you don't believe the computer and want to re-calculate the inductance value by hand. Second, there appears to be something amiss about the depth of the coil windings. We entered .008 for the wire thickness, and it is a single-layer coil, so the depth should be .008 inches, right? Well, the .000001 discrepancy comes from the way computers represent numbers internally. The coil-length calculation suffers from the same malady. Suffice it to say that the error is small enough to be safely ignored without affecting our end result, which is, we hope, a 28-microhenry inductor.

Speaking of 28 microhenries, Fig. 2 shows that our inductor is actually 28.05109 microhenries, instead of an even 28. That is the result of rounding the turn count to the nearest whole number.

The DC resistance of the inductor is given so that we can calculate the Q-factor of the coil after we decide at what frequency the inductor will be used.

Winding the coil

To make the coil, peel off about nine feet of wire from that jumbo-sized spool and start winding it on the ballpen. Make sure that the windings are even and closely spaced.

A couple of strips of hot-melt glue across the length of the coil will hold the windings in place. If you don't have a glue gun, epoxy adhesive will do if you don't mind wait.

After the glue sets (or cools, or whatever), you should carefully slide the coil off the pen. (It would be a good idea to apply some glue to the inside of the coil to help hold the windings in place. That way you can be sure that the coil won't come apart on you when handling it.)

That's really all there is to making your own coils. From now on, not only will you save money, but you can also avoid the aggravating and time-consuming task of having to search high and low for a parts supplier that has the exact coil you're looking for—and you won't have to wait for it to come in the mail. **R-E**

SURROUND SOUND

continued from page 135

correct. Note that there is no power switch between power plug PL1 and T1's primary winding. That was done because the power to the prototype is switched with the rest of the system to avoid turn-on pops.

Setting up

Figure 7 shows how the surround-sound decoder can be set-up in a component video-sound system. Notice that by having the decoder connected between the preamplifier and the power amplifier it can also be used to decode signals that originate in a conventional tuner, a CD player, or whatever. Also note the use of left-rear and right-rear speaker signals even though the left and right decoder outputs, as previously discussed, are the same. Obviously, your particular video-audio system will be different, but Fig. 7 will give you a good idea of the various ways in which signal sources and amplifiers can be combined with the surround-sound decoder. As shown in Fig. 8, all of the decoder's inputs and outputs are made through phono jacks that match the conventional phono-plug patch cords that are used for all home video-sound connections.

If your system doesn't use components, and the stereo outputs of your your VCR or TV normally drive an integrated amplifier or a receiver, simply connect the decoder between the VCR or TV and the amplifier's or receiver's AUX or VIDEO-SOUND inputs.

If all four speakers were identical, and if their driving amplifiers had identical gain, and if the front and rear speakers were equidistant from the viewer, no level balancing or adjustment would be necessary. But that's a lot of ifs. More than likely, you'll spend some time fiddling with the amplifier controls. **R-E**

HIGH DEFINITION TELE-VISION

The many ways of HDTV

LEN FELDMAN

AT LAST COUNT THERE WERE NEARLY 20 separate and distinct proposals for high-definition television systems. They generally fall into three major categories: fully compatible, semi- or backward-compatible, and those not compatible.

There are systems that are fully compatible with our presently used NTSC TV standards. Such systems display a conventional picture when tuned to on an older television receiver. Tuned to on receivers of the future, such systems would, generally speaking, offer increased resolution or picture detail as well as a new, preferred aspect ratio of either 5:3 or 16:9. Present NTSC picture displays have an aspect ratio of 4:3. That explains why many wide-screen motion pictures, when broadcast by TV stations, often have the edges of the picture cut off, forcing motion picture producers to concentrate the major action of their stories towards the center of the screen. Those systems that claim full compatibility with NTSC require no additional bandwidth or spectrum space, beyond the 6 MHz presently assigned to over-the-air-broadcast TV stations.

A second category of high-definition television systems might well be described as semi-compatible or "backwards compatible." Such systems will deliver a standard NTSC picture for those owners who tune in with older NTSC sets. Transmission of those types of HDTV signals, however, would require additional bandwidth beyond the standard 6 MHz—anywhere from 8 MHz to 12 MHz, which is two full channel widths. As was true of the first category, the benefits of such semi-compatible systems will only be realized by owners of new sets designed specifically for those systems.

The drastic difference in size and clarity between an NTSC TV's picture (inset) and the HDTV picture surrounding it, spells the demise of the aged NTSC format.

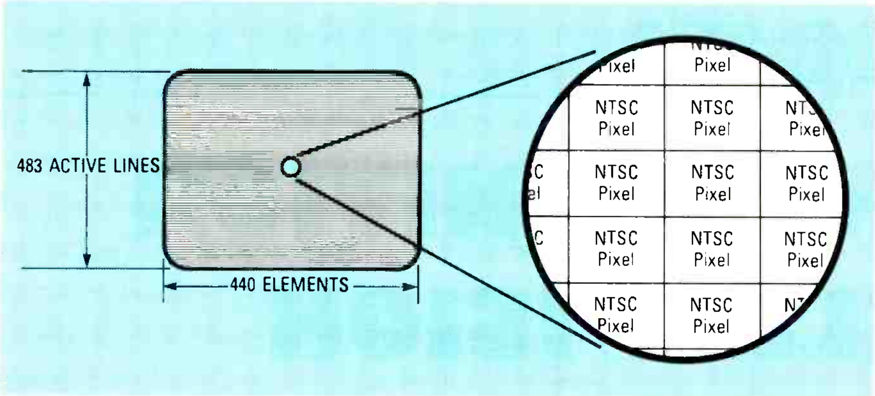


FIG. 1—THE NTSC PIXEL is represented as a rectangle of 1.46:1 ratio, corresponding to the present 4:3 NTSC aspect ratio.

The third category of the HDTV system is one that can be best categorized as the "no compromise" approach. That is, systems in this category are totally incompatible with the existing NTSC system used in this country. Generally speaking, these systems require extended bandwidth, but provide the greatest number of scan lines (1050 or 1125) and the greatest picture detail, both horizontally and vertically.

Any attempt to describe fully all of the proposed systems in all three categories would require more pages than are in this entire magazine. To give you some idea of the complexity and diversity of the ongoing HDTV debate, we will instead describe, briefly, one or two systems in each category.

HD-NTSC

An interesting and fully compatible system for a new high-definition NTSC broadcast system was proposed more than two years ago the The Del Rey Group, of Southern California. The system, dubbed HD-NTSC, can best be understood by regarding the smallest resolvable area of the NTSC picture as a "pixel," much as that term is used in referring to computer-screen resolution. In Fig. 1, the NTSC pixel is represented as a rectangle of 1.46:1 ratio, corresponding to the present 4:3 NTSC aspect ratio. A pixel, however, does not have to be rectangular or square in shape. It could be triangular, or even diamond shaped as shown in Fig. 2. One way to increase the number of addressable points of an image (and therefore the image detail) is to subdivide the pixels into smaller units, which might be called sub-pixels, as shown in Fig. 3.

Now, suppose a TV camera is able to scan only sub-pixel 1 during its first pass. After completing that frame 1/30 th of a second later, the camera scans again, this time hitting only sub-pixel-2 areas, and finally sub-pixel-3 areas. That approach is called a "Tri-Scan" technique. At the receiving end, a conventional NTSC receiver would not be aware of "sub-pixels" and would simply paint areas 1, 2 and 3 on top of each other as they come across in successive frames. A new, specially designed HD-NTSC TV set would reconstruct the same, higher detail image seen by the camera, placing the sub-pixels in their correct offset positions on the CRT. To change the aspect ratio, The Del Rey Group would simply "chop off" a few lines at the top and bottom of the existing NTSC line format, as illustrated in the comparison of Fig. 4. That arrangement would result in an aspect ratio of 14:9, as opposed to the present 4:3. As a side benefit, the HD-NTSC system creates 69 horizontal lines per frame that are no longer needed for the transmission of picture information. That new "data window" might well be made available for other information, such as encoded stereo digital audio!

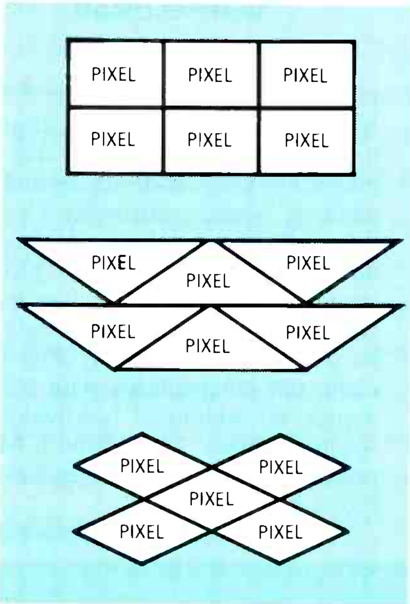


FIG. 2—A PIXEL does not have to be rectangular or square in shape. It could be triangular, or even diamond shaped.

ACTV

Originally introduced through the joint efforts by RCA, NBC, GE, and The David Sarnoff Research Center, ACTV was another system that was fully compatible with NTSC, in that it required only a single 6-MHz channel width for its implementation. Since then, the system has been divided into two systems, ACTV-1 (the original 6-MHz wide channel proposal) and ACTV-2, a system that remains compatible with NTSC but requires two full 6-MHz channels of bandwidth for its implementation. Here is how ACTV works: An original wide-

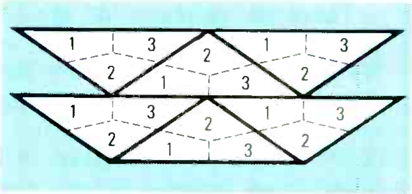


FIG. 3—ONE WAY TO INCREASE the number of addressable points of an image is to subdivide the pixels into smaller units, which might be called sub-pixels.

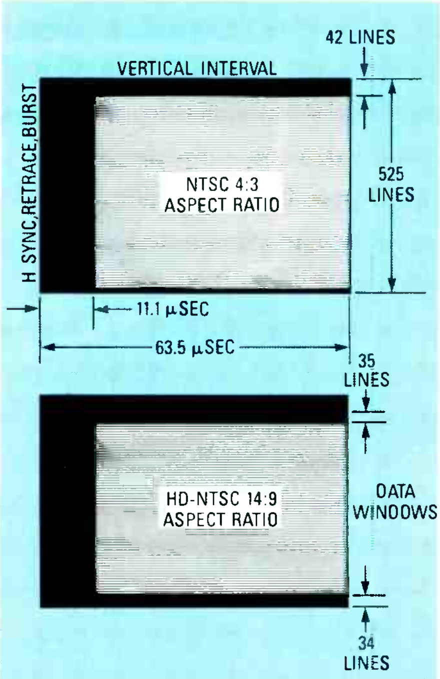


FIG. 4—TO CHANGE THE ASPECT RATIO, The Del Rey Group would chop off a few lines at the top and bottom of the existing NTSC line format.

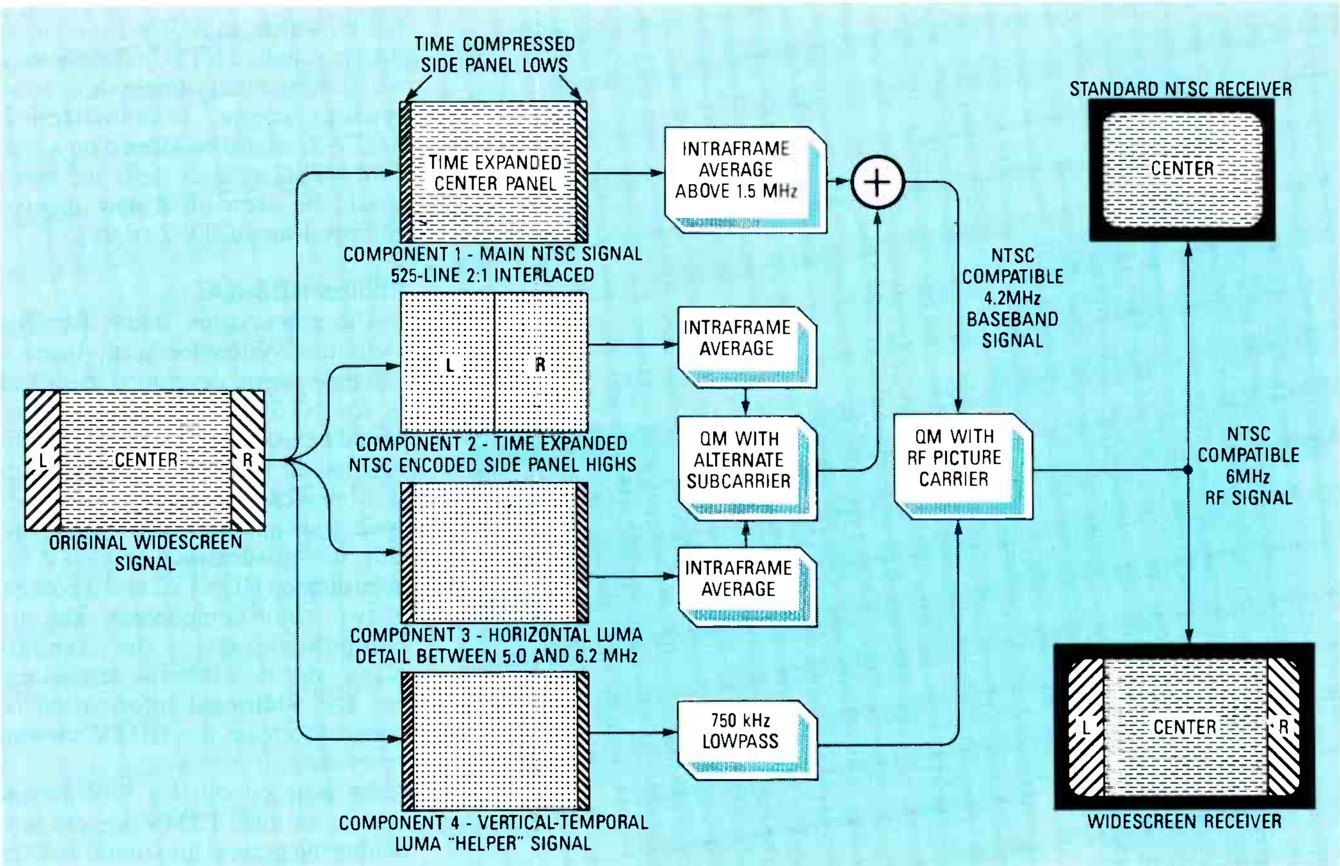


FIG. 5—THIS IS HOW ACTV WORKS: An original wide-screen signal is digitized and encoded into the four components shown.

screen signal, provided from any high-definition source, is first digitized at the studio and encoded into the four components shown in Fig. 5.

1: The first component is a main, NTSC-compatible, interlaced signal with the usual 4:3 aspect ratio. It consists of the central portion of the picture that has been time-expanded to nearly the entire active line time plus the side panel low-frequency horizontal information that has been time compressed into left and right horizontal overscan regions, where they would be hidden from view on most standard home receivers. This signal is color encoded in standard NTSC format.

2: There is an auxiliary 2:1 interlaced signal consisting of side panel high-frequency horizontal information that has been pre-comb-filtered, NTSC encoded, and time expanded to half the active line time. The time expansion reduces the horizontal bandwidth of this component to a little over 1 MHz.

3: The third component is an auxiliary 2:1 interlaced signal consisting of horizontal luminance detail between approximately 5.0 and 6.2 MHz. This band of frequencies is first shifted downward to the range of from 0 to 1.2 MHz.

4: The fourth and last component is an auxiliary 2:1 interlaced "helper" signal, consisting of vertical-temporal (V-T) luminance detail that would otherwise be lost in the down conversion to 525-line interlace. On new, wide-screen receivers, this signal helps to reconstruct missing lines and to reduce or eliminate line flicker artifacts.

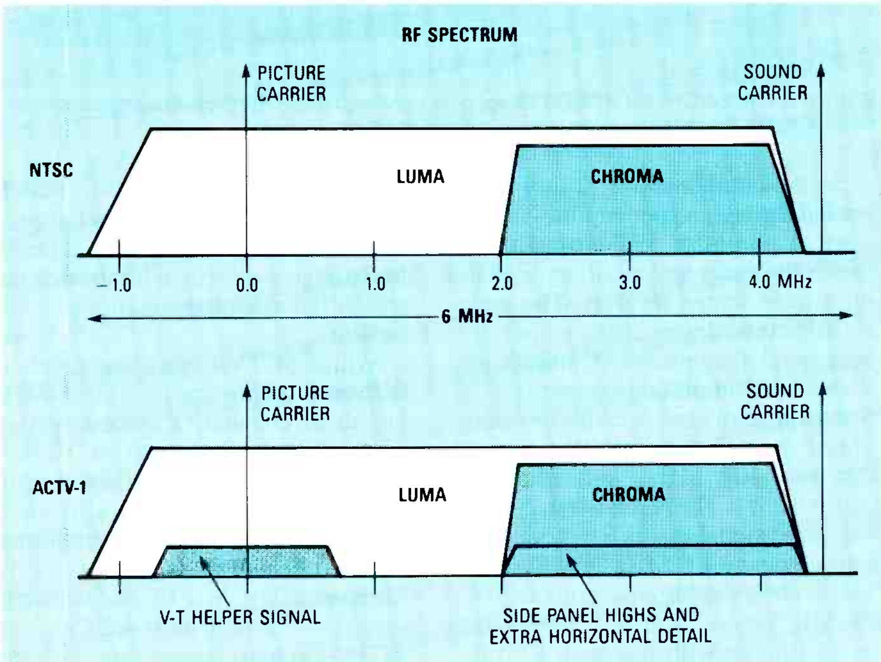


FIG. 6—A 4.2-MHz BASEBAND SIGNAL is RF modulated into a standard 6-MHz NTSC channel.

FIG. 7—A WIDE-SCREEN RECEIVER recovers and equalizes the picture components and reconstructs the original wide-screen progressive scan signal.

Signal-components 1, 2 and 3 are passed through a special time-variant filter to eliminate V-T crosstalk between the main and auxiliary signals on a wide-screen receiver. The main signal is intra-frame averaged over all horizontal frequencies. Components 2 and 3 are amplitude-compressed in a non-linear manner, quadrature modulated on a phase-controlled subcarrier at 3.108 MHz, and added to component 1. The result is a 4.2-MHz baseband signal that is RF modulated into a standard 6-MHz NTSC channel, as shown in Fig. 6. Component 4, the VT "helper" signal, is modulated in quadrature with the main RF picture carrier.

When received on an existing NTSC receiver, only the central portion of the main signal is seen. A wide-screen receiver, such as that shown in Fig. 7, recovers and equalizes components 1–4 and reconstructs the original wide-screen signal. Relative to NTSC, the reconstructed signal has left and right side panels offering standard NTSC resolution and a central portion with superior horizontal and vertical luminance detail in the stationary sections of the picture.

While ACTV-1, just described, is delivered within the existing 6-MHz broadcast channel, a second version of the system, known as ACTV-2 is envisioned as well, when and if additional spectrum space is allocated. ACTV-2 would require an additional 6-MHz channel of bandwidth. As illustrated in Fig. 8, a TV station might someday transmit both ACTV-1 and ACTV-2 signals. Both systems would offer an aspect ratio (on new sets) of 5:3 or 16:9, and both would have 1050 lines per frame and 29.97 frames per second. However, ACTV-2 would offer still greater improvements in luminance resolution (650 horizontal and 800 vertical, as compared to 410 horizontal and 480 vertical for ACTV-1) and a doubling of chrominance resolution, which, in ACTV-1 is no better than in standard NTSC. The photos in the opening of this article show how a typical scene, transmitted in ACTV-2, would be viewed on a standard NTSC receiver (left) and how it would be seen on a new receiver equipped for ACTV-2 (right).

Philips HDS-NA

The abbreviation stands for *H*igh *D*efinition *S*ystem for *N*orth *A*merica, and the system, developed specifically for NTSC-TV based countries, would be usable on an equal basis for over-the-air broadcasting, CATV, direct-broadcast satellite or even fiber-optic transmission. The signal suitable for broadcasting or CATV has been dubbed HDNTSC and it consists of two major components. The first component carries the standard NTSC signal, while the second carries the additional information required to create the HDTV viewing experience.

As pointed out by Philips and others, an ideal HDTV system with double the present horizontal and vertical resolution and an increased aspect ratio would require about five times the bandwidth or spectral space of the current NTSC signal, or as much as 300 MHz! To reduce those impractical bandwidth requirements, various signal-processing schemes have been proposed by the various HDTV proponents. One class of signal processing is based upon combining several picture frames from both the "past" and "present" in the scene captured by the video camera. In our article last month, we discussed such basic picture-enhancement schemes under the general heading of IDTV, or *I*mproved *D*efinition *T*ele*V*ision systems. Philips has chosen a second approach that applies signal processing without the need for inter-frame picture information. The HDS-NA system can deliver 1.5 times the normal horizontal and vertical resolution of NTSC, wide aspect ratio, plus multiple channels of CD-quality digital sound.

The main HDNTSC signal carries NTSC and is a standard 6-MHz channel. The extra information needed to create the HDTV viewing experience can be transmitted eventually as a digital bit stream with a bandwidth of 3 MHz (or one half the extra width of a present-day NTSC channel). Philips has suggested that the signal energy

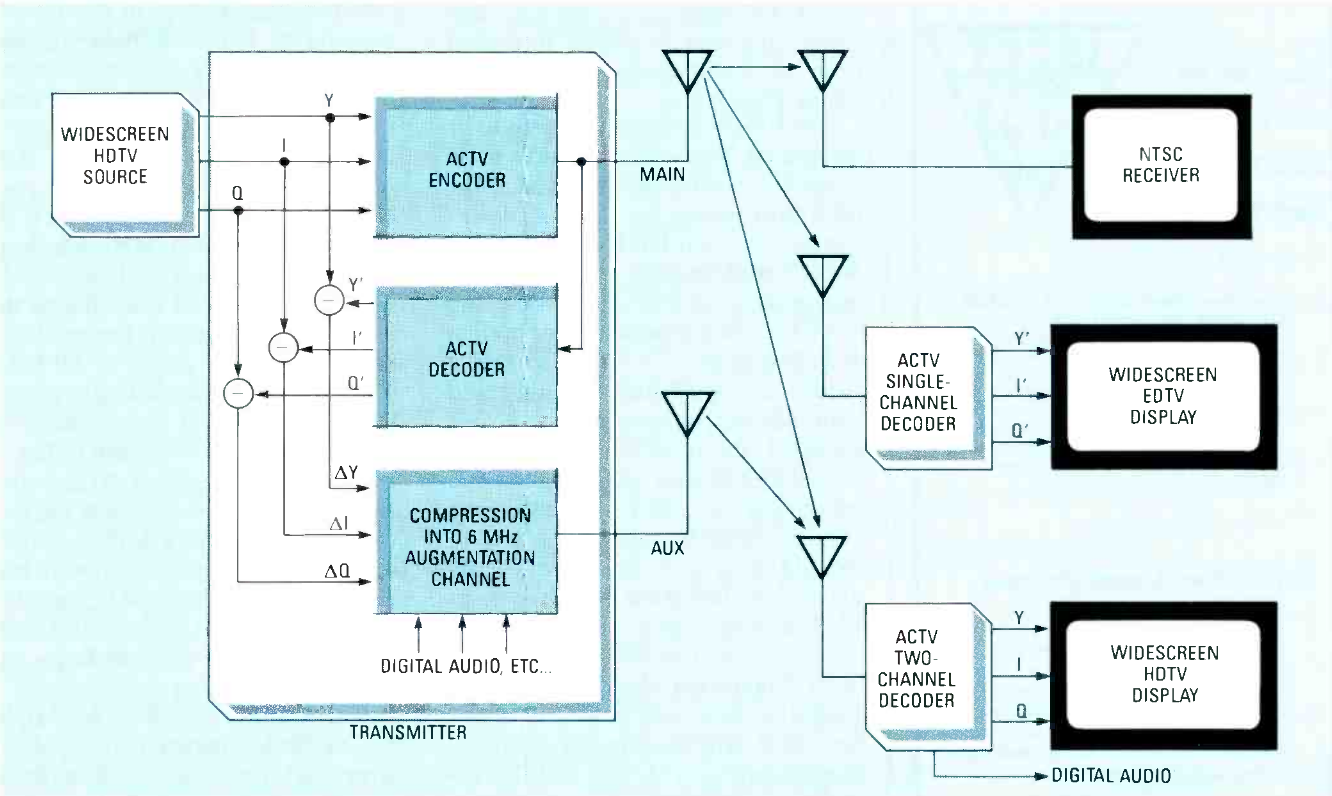


FIG. 8—A TV STATION MIGHT SOMEDAY TRANSMIT BOTH ACTV-1 and ACTV-2 signals. Both systems would offer an aspect ratio (on new sets) of 5:3 or 16:9, and both would have 1050 lines per frame and 29.97 frames per second.

of that extra augmenting channel can be well below the main NTSC signal level. That being the case, the extra signal might even be transmitted via the so-called "tabu" channels in each geographical area.

By "tabu" channels, we mean the TV channels that normally remain unassigned in a given area because they are adjacent to used channels. For example, if Channel 2 is assigned in a given city, Channel 3 remains unassigned. The same holds true for Channel 5 and 6, etc. (Channels 4 and 5, in the New York area, for example, are not really adjacent, as there is a 4-MHz space between them.) If Philips is correct about that, then in the New York area, for example, both Channel 2 and 4 might "share" Channel 3 for their augmentation channel; each using one half (3 MHz) of the otherwise unassigned channel spectrum. Using the tabu channels is not a necessary requirement for the Philips system—it is just one possibility. The augmentation channels could just as easily be positioned at other, non-contiguous frequencies which would have to be assigned for that purpose by the FCC if the Philips system were to prevail. As was true of ACTV, the Philips system is "backward compatible." Owners of older NTSC TV sets will continue to receive "normal" pictures while owners of newer sets designed for the HDS-NA system will receive the benefits of higher definition and a wider aspect ratio.

Battle Of Incompatibles

Finally, we come to the group of HDTV systems that are totally incompatible with our present day NTSC system (and, for that matter, with the PAL and SECAM systems used in other parts of the world). Aside from the incompatibility problems of these systems, there is also the problem of attempting to establish a world-wide standard for a no-compromise HDTV system. That problem arises primarily because of the fundamental difference in TV frame rates between U.S. (and Japanese) NTSC and European PAL. The European frame rate is 25 frames per second while the NTSC frame rate is 30 frames per second.

That difference is a throwback to the early days of TV, when scanning fields were synchronized to the power-line frequencies used (50 Hz in Europe, 60 Hz in North America and many sections of Japan). Today, much more sophisticated systems of vertical synchronization are in use, but, unfortunately, the standard frame rates are well entrenched in their respective counties. Thus, it may well be that two "world" standards may evolve for no-compromise, incompatible HDTV. The European proposal is for a 2:1 increase in number of lines per picture and a doubling of the pixel density or horizontal resolution with respect to their present broadcast systems. The Europeans would retain their present frame rate of 25 Hz. However, much work has already been done to reduce the large area flicker problem that is so noticeable to those of us who travel to Europe and

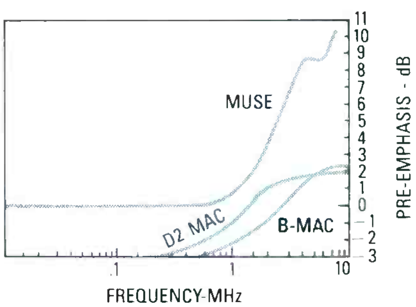


FIG. 9—ALL FORMS OF MAC, including MUSE, employ various amounts of pre-emphasis for the video signals.

watch TV there. It is planned that future displays would be refreshed from the frame storage memory at a 75- or 100-Hz rate.

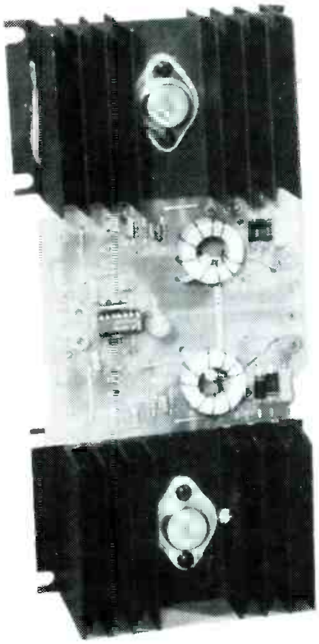
The HDTV system that seems to be favored for North America has a more complex relationship to NTSC. The line ratio would be 15:7. A down-conversion from HDTV to broadcast NTSC would require either a digital interpolation of 15:7 or the cropping of 69 lines at top or bottom or both to give 966 active TV lines, so that a simple 2:1 digital interpolation could yield 483 active lines per the NTSC standard (the remaining lines of the so-called 525 line NTSC system are not visible on screen, but are in the vertical blanking interval). Many of the HDTV systems that are currently under consideration are known as MAC systems, which is an acronym that stands for Time *M*ultiplexed *A*nalog *C*omponents. MAC systems, it should be noted, are inherently free of the color artifacts that have always plagued both NTSC and PAL broadcast pictures.

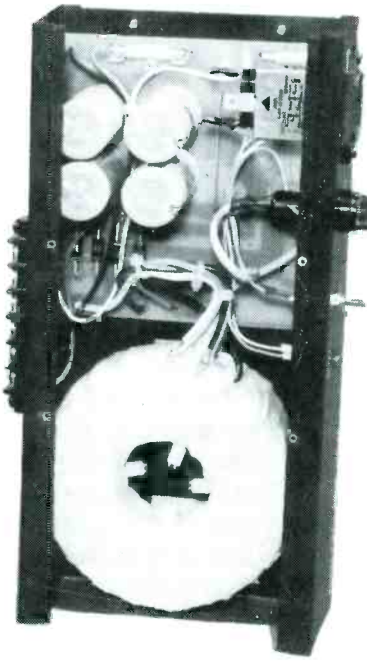
In Europe, the consensus seems to be that the HDTV production standard used in studios will be fully compatible with a version of MAC called D-2 MAC which is intended to be used shortly as the *D*irect *B*roadcast *S*atellite (DBS) transmission signal of the *E*uropean *B*roadcast *U*nion (EBU). The emphasis there is on compatibility with D-2 MAC, and not necessarily with PAL or SECAM. Some see the eventual use of D-2 MAC for terrestrial transmission with the eventual replacement of the existing PAL and SECAM.

B-MAC, a system developed by Scientific Atlanta, while not a true HDTV system in that it transmits an interlaced 525-line picture and is therefore limited in vertical resolution, might more properly be called an Enhanced Definition System. NHK, the Japanese government-sponsored broadcast authority, has taken a totally different approach to the transmission of HDTV pictures. Since their 1125-line picture is not designed to be compatible with any existing broadcast standards, they have developed a special form of MAC for HDTV transmission. It's called MUSE, which is an acronym for *MU*ltiple *S*ub-Nyquist *E*ncoding." MUSE sub-samples the 1125-line picture, transmitting every other pixel of every other line in a first field. The missing samples of the line are transmitted next, followed by alternate samples of the missing lines and, finally, the samples previously omitted. MUSE has two resolution specifications. One resolution is for static pictures where the full information content of the 1125-line system is delivered via one 8.1-MHz baseband video signal. The other is the resolution that is provided when the picture contains motion; that is the resolution of current NTSC pictures. All forms of MAC, including MUSE, employ various amounts of pre-emphasis for the video signals, as shown in Fig. 9. In MAC systems, the 0-dB crossover frequency for the emphasis curve is much higher than for NTSC, and the low-frequency gain reduction is only about 3 dB for the B-MAC and D-2 MAC systems. MUSE employs a very elegant form of pre-emphasis that provides substantial improvement in signal-to-noise ratios. The MUSE pre-emphasis characteristic applies a large high-frequency gain boost for small-amplitude high-frequency components, and much less emphasis for large high-frequency components. That is possible only with a signal format that has no color subcarrier mixed in with it.

There are other variations on the MAC HDTV idea, but by now it should be clear that the path towards a standard is going to be a long and tortuous one. There seems to be an increasing tendency, in this country at least, to favor some sort of NTSC compatible approach to enhanced definition TV, so that millions of TV's don't become obsolete. It is entirely possible that the first delivery of HDTV may not be via broadcasting or cable TV at all. It could well be that we will see first examples of HDTV delivered to us in the form of software (new laser optical-disc formats or even new VCR formats based upon Super VHS or ED-Beta technology). Of course, such software will require new video monitor/receivers and other new hardware. Still, you should hold on to those NTSC receivers for the moment, since the current multiplicity of HDTV systems could well delay over-the-air HDTV for many years to come. **R-E**

HIGH-POWER HI-FI AUDIO AMP





FOR YOUR HOME OR CAR

With rock-n-roll power, here's a stereo amplifier that you can build.

L.K. ROSS and AMP WATTS

EVERY SO OFTEN A NEW IC COMES ONTO the market that excites the experimenter's imagination with all sorts of possibilities. One such IC is National Semiconductor's LM12 power op-amp: And when we say power, we mean power. That single IC can pump out 100-watts RMS of audio into 4-ohms; twice that amount of power is available if you use two LM12 IC's in a bridge configuration.

Today,—especially with compact-disc audio, and its wide dynamic range—even moderate levels of sound reproduction require a power amplifier that won't clip the peak inputs. The LM12 can supply those peak-power demands—and so the *Opto-Amp* idea took shape from that beginning. Two separate power supplies were also designed: one for 110-volt AC home operation, and another for 12-volt DC car operation.

The LM12 power-amp has many features that make it ideal as an audio amplifier. You'll first notice the extremely low parts count that permits compact size, reliability, and ease of assembly. All kinds of circuity are built right into the LM12 IC: controlled turn-on, thermal limiting, over-voltage shutdown, output-current limiting, and complete protection against overloads including shorts to the supplies!

Table 1 shows the complete *Opto-Amp* specifications. Notice the excellent distortion specification (THD less than .01%, slew rate as high as 9V/μs), which should appeal to serious audio buffs and sound professionals. Possible applications of our amplifier include just about whatever your imagination dreams up: car-stereo booster amp, sub-woofer amp, PA system, yacht-stereo amp, stage-monitor amp, or guitar-practice amp.

How it works

The *Opto-Amp* has two identical channels (for stereo), so we'll analyze in detail the right channel only. The LM381 (IC3) pre-amplifier has an input-voltage range of 0.75 to 1 volt, with a voltage gain of about 10; the LM12 (IC1 and IC2) power-amps will provide a voltage gain of about 4 each. In keeping with the design goal of low parts count, the LM381 is an ideal choice. It's easy to operate, and requires only a single positive supply with simple filtering provided by R9 and C9. Audio goes to the inverting input, while the non-inverting input is at AC ground through C10. Resistors R6 and R3 determine the gain, and R5 provides bias. Coupling-capacitor C11 isolates the audio input from the amplifier biasing.

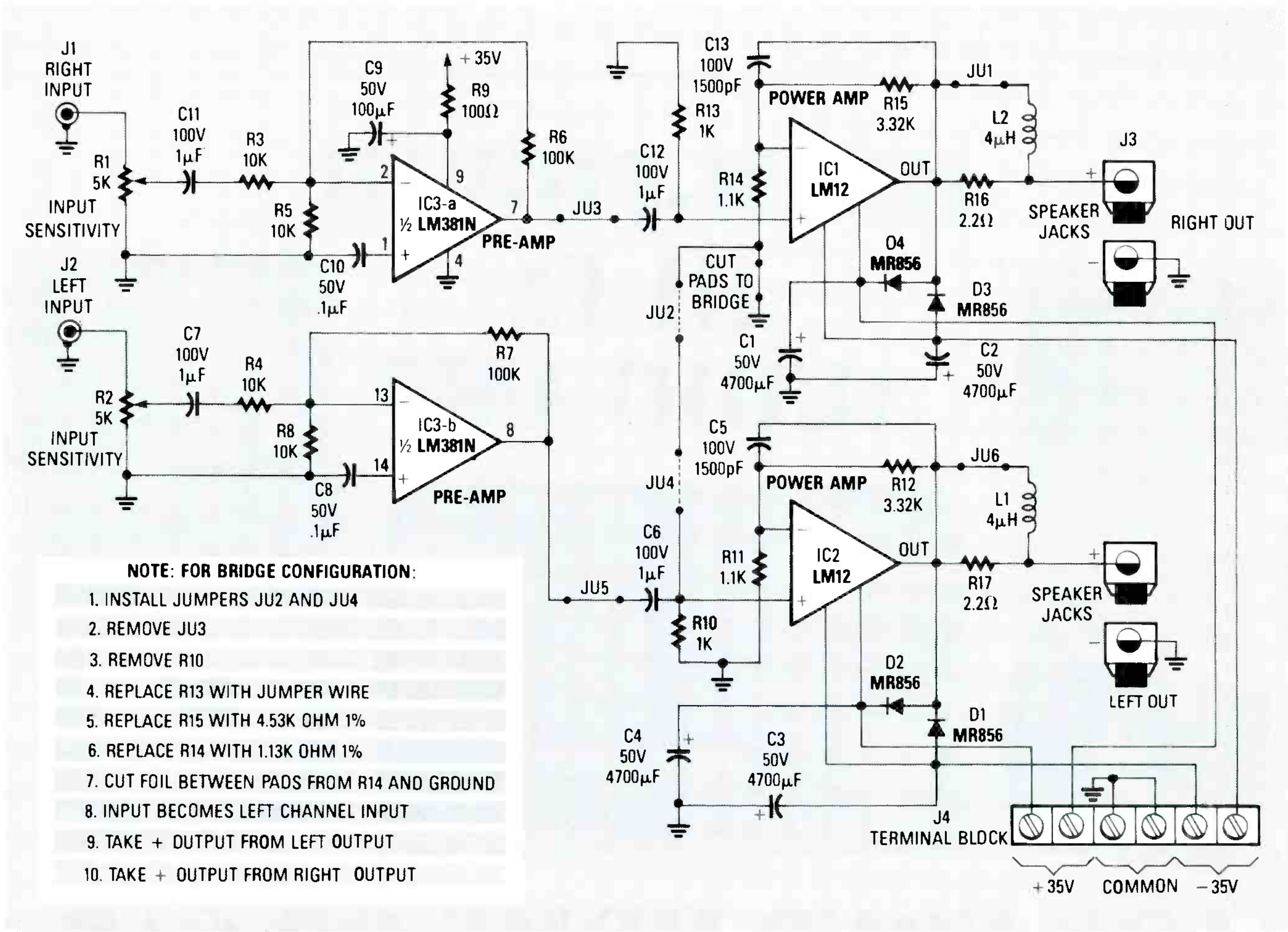


FIG. 1—THE *OPTO-AMP* IS NORMALLY SET UP FOR STEREO, but can be re-configured for monaural—with twice the output power.

TABLE 1: *OPTO-AMP* SPECIFICATIONS

POWER RATING: CONTINUOUS

STEREO: 60 WATTS RMS PER CHANNEL CONTINUOUS INTO 8 OHMS
100 WATTS RMS PER CHANNEL CONTINUOUS INTO 4 OHMS

BRIDGED: 120 WATTS RMS INTO 8 OHMS
200 WATTS RMS INTO 4 OHMS
WILL DRIVE 2 OHM LOAD LIMITED TO 150 WATTS PER CHANNEL
TOTAL POWER DISSIPATION IS 150 WATTS MAX EACH CHANNEL.

DISTORTION: THD IS LESS THAN .01%

SLEW RATE: 9V/μs

SIZE: 10.2" x 2.6" x 5"

INPUT: LINE LEVEL WITH INPUT SENSITIVITY ADJUSTMENTS

The pre-amp output is AC-coupled through C12 to IC2, which is set up as a non-inverting amplifier. The gain is equal to (R14 + R15)/R14. Diodes D3 and D4 are necessary to clamp the output to the supply rails in case the speakers (which are inductive loads) kick back. Inductor L2 and resistor R16 provide output isolation enabling the amplifier to drive capacitive loads, which audio power amplifiers must be able to do. Capacitor C13 is in the feed-back loop for frequency stability. Large supply-capacitors C1 and C2 are located close to the IC to prevent changes in load current from returning to the amplifier's input—a precaution that also reduces the power-supply filtering requirement.

Examine the PC-board layout and note some of the design features that are not seen in the schematic. For example, all grounds are returned to a single point for each amplifier, and the +V and −V supplies are kept separate for each IC amplifier.

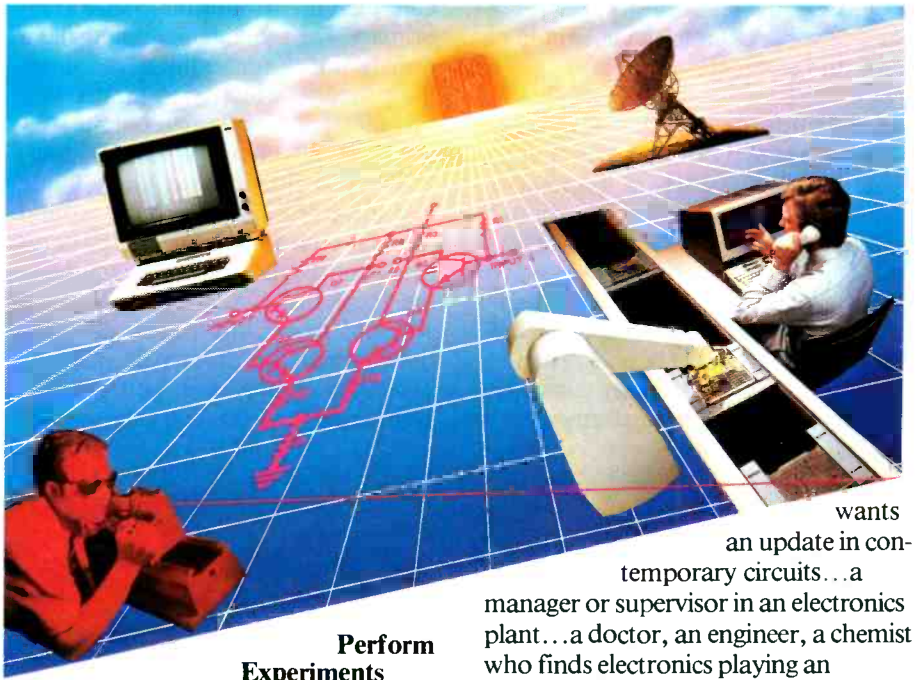
Bridging to mono

The *Opto-Amp* is capable of being bridged for twice the power, namely, for monaural applications. To convert the *opto-amp* from a stereo to monaural (bridge) operation, you'll have to perform some PC-board surgery like moving jumpers around and cutting copper lands. That's because IC2 stays in the non-inverting configuration, while IC3 is changed to an inverting amplifier. Both amplifier outputs are then equal in magnitude, but opposite in phase. Any speaker connected between the two outputs will have twice the signal amplitude of either amplifier referenced to ground. (When two amplifiers are bridged across a speaker, the output ground of

MASTER THE NEW ELECTRONICS WITH McGRAW-HILL'S

Contemporary Electronics Series

The fast, easy and low cost way to meet the challenges of today's electronic innovations. A unique learning series that's as innovative as the circuitry it explains, as fascinating as the experiments you build and explore.

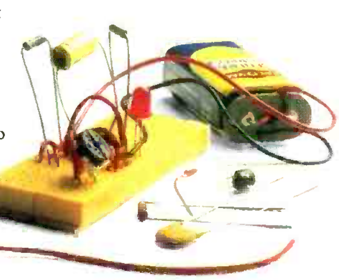


From digital logic to the latest 32-bit microprocessor, the McGraw-Hill Contemporary Electronics Series puts you into the electronic picture one easy step at a time. Fifteen unique Concept Modules, sent to you one every 4–6 weeks, give you a handle on subjects like optoelectronics, robotics, integrated circuits, lasers, fiber optics and more.

Each Concept Module goes right to the heart of the matter. You waste no time on extraneous material or outdated history. It's a fast, efficient, and lively learning experience...a non-traditional approach to the most modern of subject matter.

Unique Interactive Instruction

With each module, you receive a McGraw-Hill Action Audio Cassette. Each tape is a dynamic discussion that drives home the key facts about the subject. Your learning experience is reinforced through interaction with vividly illustrated text, audio cassettes, and actual electronic experiments. Indexed binders preserve backup material, notes, and tapes for convenient referral.



With your first module, you get this solderless breadboarding system. You'll use it throughout the series to build electronic circuits and bring concepts to life.

Perform Experiments in Contemporary Electronics

Throughout your series, laboratory experiments reinforce every significant point. This essential experience ...dynamic, hands-on demonstrations of theory in practice... will help you master principles that apply all the way up to tomorrow's latest VLSI (Very Large Scale Integrated) circuitry.

In your very first module, you'll use integrated circuits to build a digital oscillator, verifying its operation with a light emitting diode (LED). You'll learn to identify passive and active components, understand concepts common to all electronic circuits.

For Anyone Interested in Electronics

The Contemporary Electronics Series is designed for anyone from hobbyist to professional. It's for you if you're looking for new fields of interest...if you're a teacher who wants an update in contemporary circuits...a manager or supervisor in an electronics plant...a doctor, an engineer, a chemist who finds electronics playing an increasingly important role in your work. It's even for electronics engineers or technicians who feel their training needs freshening up. It's the quickest, most convenient, probably least expensive way to do it. And the only one that gives you hands-on experience.

15-Day No-Risk Trial

To order your first module without risk, send the card today. Examine it for 15 days under the terms of the order form and see how the Contemporary Electronics Series gets you into today's electronics. If card has been used, write us for ordering information.

McGraw-Hill
Continuing Education Center
4401 Connecticut Avenue NW
Washington, D.C. 20008

each amplifier is no longer used for the audio's return path through the speaker.)

But there's more: The values of the gain-setting resistors in IC2 must be changed, because the gain for an inverting amplifier is R15/R14 with R14 no longer connected to ground at one end. The right input pre-amplifier is no longer needed, so remove JU3. The input to IC2 is from the left input pre-amplifier, so install JU4 and JU2. The positive input of IC2 is connected to ground by replacing R13 with a jumper wire. Refer to the note in Fig. 1 for bridge conversion.

Power supplies

There are two different power-supplies depending on where you want to use the *opto-amp:* one for 110-volt AC home operation, and another for 12-volt DC car or boat operation.

Figure 2 shows a 12-volt power supply that you can use to operate the *Opto-Amp* in your car or boat. The 12-volt to 70-volt (± 35 volt) converter uses a toroidal-core transformer (T1) that has two center-tapped primary windings. Transistors Q1 and Q2 are hefty 30-amp transistors that switch 12 volts through the primary-windings No.1 and No.3. The center-tapped winding No.2 is connected to 12 volts, while windings No.4, No.5, and No.6 are the base-drive windings for Q1 and Q2. Power-resistors R1 and R2 provide bias. The base-drive windings are connected out of phase with the main primary windings, so Q1 and Q2 switch on and off to alternate the current into the transformer primary. The secondary winding has a turns ratio of approximately 5 times the primary, which yields after rectification and filtering an output voltage of ± 35 volts for a 12-volt input.

The 12-volt supply is ultra simple and ultra reliable. The tape-wound toroidal-core transformer is custom-made and available from the source in the Parts List. Other types of cores will not work; this is one of those times when the exact part must be used. The supply will pull about 2 amps under no load, and can supply 5 amps with the output voltage dropping down to ± 30 volts when heavily loaded.

Figure 3 shows the 110-volt AC power supply that uses a toroidal power transformer to supply 70 volts ($\pm$ 35 volts) at 5 amps; traditional laminated-core transformers can be used as well. The advantage of the toroid transformer is that it's self-shielding because the flux lines stay inside the core. The AC-line input uses an RFI/EMI filter, a power on/off switch, and line fuse. (A nice feature is the detachable AC line cord with standard plug that mates to the EMI-filter module.) The transformer secondary is rectified by diodes D1–D4 and filtered by C2 and C3 to provide two output voltages (± 35 volts) with a common ground. Each output is fused for 5-amps.

Notice that the supply outputs are unregulated. Bleeder resistors R2 and R3 serve two functions. First, the bleeders maintain a minimum load to prevent a large increase in output voltage when the amplifier is disconnected. Second, when the power is

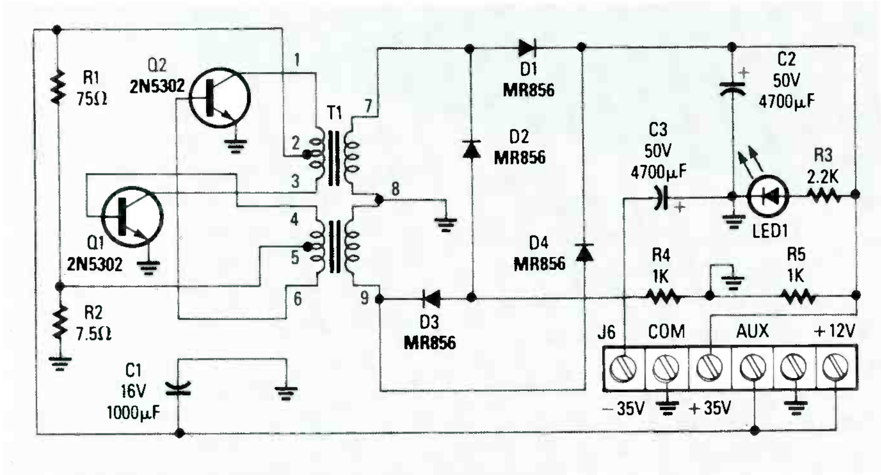


FIG. 2—THE 12-VOLT DC POWER SUPPLY is perfect for operating the *opto-amp* from a car or boat battery.

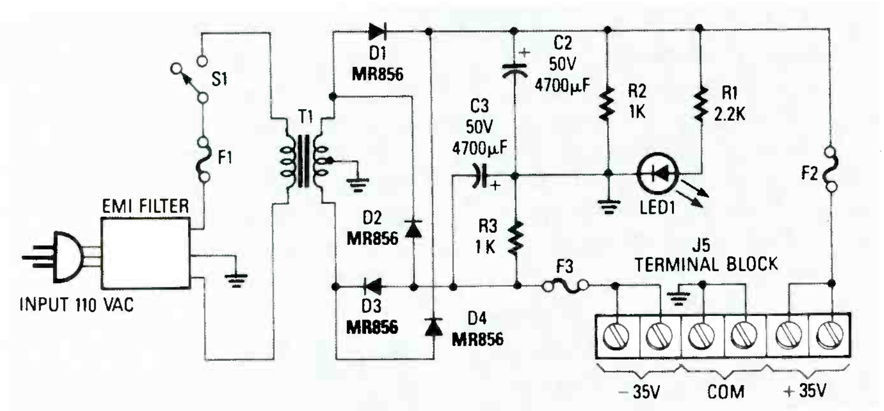


FIG. 3—THE 110-VOLT AC POWER SUPPLY is perfect for operating the *opto-amp* from your household AC current.

PARTS LIST OPTO-AMP

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

R1, R2—5000-ohms trimmer potentiometer
R3, R4, R5, R8—10,000 ohms
R6, R7—100,000 ohms
R10, R13—1000 ohms, 1%
R11, R14—1100 ohms, 1%
R12, R15—3320 ohms 1%
R16, R17—2.2 ohms, 2-watt

Capacitors

C1–C4—4700µF, 50 volts, axial electrolytic
C5, C13—1500 pF, 100 volts, polyester foil
C6, C7, C11, C12—1µF, 100 volts, ceramic monolithic
C8, C10—0.1µF, 50 volts, axial ceramic monolithic

Semiconductors

IC1, IC2—LM12CL, 150-watt power op-amp
IC3—LM381N, audio pre-amp
D1–D4—MR856, rectifier diode, 3-amp, 300-volts

Inductors

L1, L2—Inductor, 4µH

Miscellaneous: Thermalloy 6421B heat-sink, AW-12 PC board, enclosure, hardware, phono jacks, speaker terminals, power terminal strip, rubber feet, hookup wire, magnetic wire, 14-pin DIP socket.

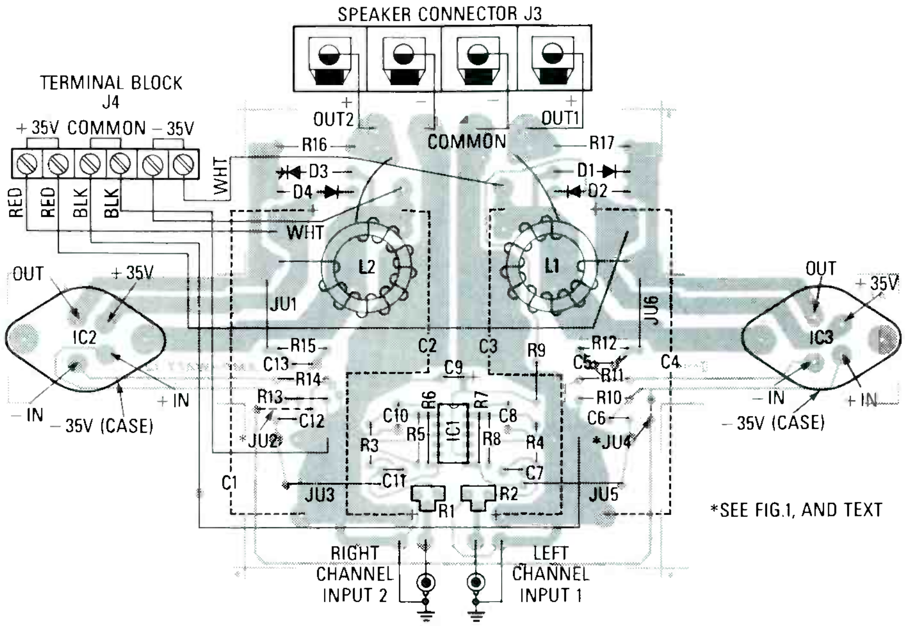


FIG. 4—PARTS PLACEMENT FOR THE *OPTO-AMP*. The inductors should be wound exactly as shown.

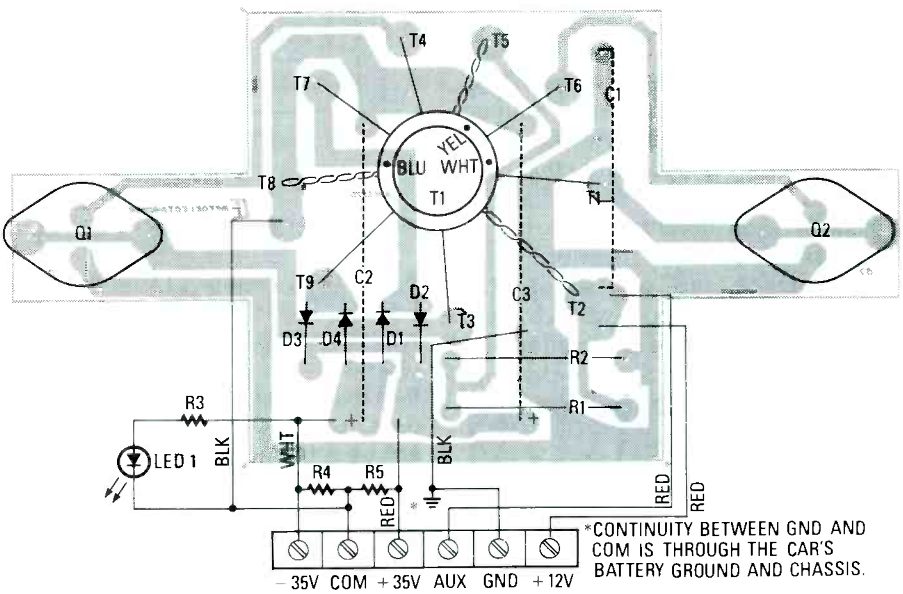


FIG. 5—PARTS PLACEMENT FOR THE 12-VOLT DC POWER SUPPLY. Notice the placement of the torodial transformer T1.

turned off, the resistors bleed the current off the filter capacitors, thereby eliminating the possibility of a shock hazard from a charged capacitor. LED1 functions as an on/off indicator that operates from secondary voltage.

The PC board for each power supply is single-sided and available from the source in the Parts List, or you can etch your own using the PC Service layout. Component polarity is critical for the electrolytic capacitors and the diodes, so make sure that you double-check them prior to soldering.

Construction tips

As shown in Fig. 4, inductors L1 and L2 are simple to wind by hand with 10 turns of magnet wire on a ferrite core. The core type is not critical; indeed, any 1″-diameter ferrite-core will work just fine. Use 4″ tie-wraps to secure the wound inductors to the PC board. Before you solder magnet wire to the PC board, scrape off the varnish and tin the bare copper with a hot soldering iron.

Take extra care when installing the IC amps on the large heat sinks. Modify the IC insulator with a knife to accommodate the two extra pins on the LM12, and remove any burrs from the heat-sink. Make sure that you use tubing on the four IC leads to prevent shorts to the heat-sink. Apply heat-sink compound on both sides of the insulator to facilitate heat transfer. When you install the LM12 on the heat sink, tighten the mounting screws before soldering the IC pins to the PC board. **CAUTION: Note that the heat-sink will ultimately be at ground potential, that the case of the LM12 is the −35-volt supply, and that none of the pins are at ground potential—so be careful and double-check your work with an ohmmeter.**

The amplifier inputs and outputs are clearly labeled on the artwork. Use No.16-gauge bus wires on the outputs. The power supply and ground wires are brought out to a terminal strip JU4. Lastly, install capacitors C1–C4 about ¼″ above the board on the solder side, with the polarity as indicated on the artwork.

Figure 5 shows the Parts Placement for the 12-volt DC supply. Mounting the 2N5301 power transistors using insulated heat sinks, and heat-sink compound is a must. The transformer leads must be formed until they line up with the holes in the PC board, or else they might pull up the copper foil. The LED power indicator is connected between 12 volts and ground using a 2000-ohm current-limiting resistor R3. The terminal strip JU4 has outputs for the +V, −V, and COM connections. The AUX terminal is wired to +12 volts to power a cooling fan, and the remaining two terminals are 12-volt DC input and GND.

Figure 6 shows the custom transformer (T1) for the 12-volt DC power supply. Anyone wishing to build it

PARTS LIST—12-VOLT POWER-SUPPLY

Q1, Q2—2N5301, NPN transistor
LED1—(*L*ight *E*mitting *D*iode) green with panel mount
D1–4—MR856, rectifier diode, fast, 3-amp, 300 volts.
R1—75 ohms, 10-watt, 5%
R2—7.5 ohms 5-watt, 5%
R3—2000 ohms, ¼-watt, 5%
R4—1000 ohms, ¼-watt, 5%
R5—1000 ohms, ¼-watt, 5%
C1—1000µF, 16 volts, axial electrolytic
C2, C3—4700µf, 50 volts, axial electrolytic
T1—T1270, custom transformer
Miscellaneous
PS-1270 PC board, chassis assembly, hardware, 6-terminal power strip, hookup wire.

PARTS LIST—AC POWER-SUPPLY

D1–D4—MR856, rectifier diode, fast, 3-amp, 300 volts
LED1—(*L*ight *E*mitting *D*iode) green with panel mount
C1–C4—4700µF, 500 volts, radial electrolytic
R1—2200 ohms, ¼-watt, 5%
R2, R3—1000 ohms, ¼-watt, 5%
T1—Toroidal transformer, 110-volts primary, 70-volts, center-tapped secondary
Miscellaneous: EMI line-filter (Standex, LR57454, 3-amp 250-volt), 3-prong AC line-cord, SPDT switch, PS110/70 PC-board, PC-mount fuse clips, 5-amp fuses, chassis-mount fuse-holder with 3-amp 250-volt fuse, chassis assembly, hardware, 6-terminal strip, and hookup wire.

will want detailed information about the transformer that uses a standard tape-wound core. As you might have already guessed, tape-wound cores are not very common, and it is unlikely that you will find an equivalent core—except from the manufacturer, Magnetics, Inc., and their minimum order is $100. In addition to that hurdle, the transformer is somewhat difficult to wind because of the large-wire sizes involved; therefore, Optoelectronics, Inc. will supply the complete *T1270* custom-wound transformer. (For ordering information, refer to the Parts List.) Should you want

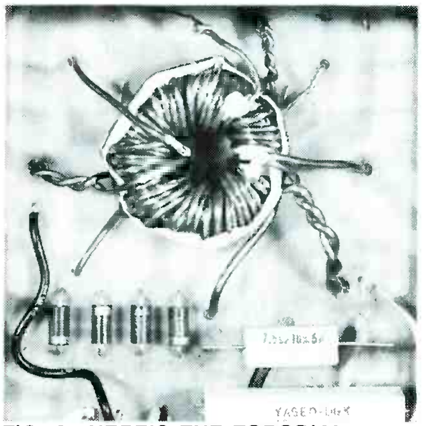


FIG. 6—HERE'S THE TORODIAL transformer used in the 12-VOLT DC to ±35-VOLT DC power supply.

to build your own transformer, here are the specifications you'll need:

- Description: 12-volt input, 64-volt center-tap output, with 6.8-volt center-tap base-drive winding.
- Core: 1 mil tape-wound with case dimension of 1.460" × 0.915" × 0.345". Magnetics, Inc. part number 52029-1D.

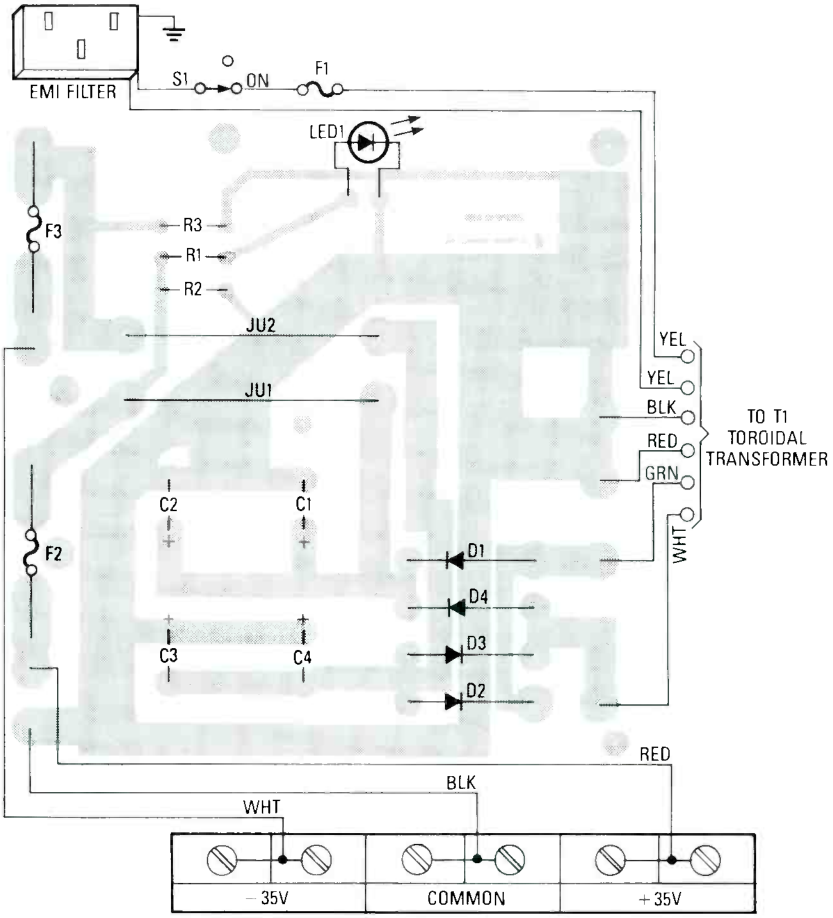


FIG. 7—PARTS PLACEMENT FOR THE 110-VOLT AC power supply.

- Windngs: Preimary 14-turns center-tapped, base-drive 6-turns center-tapped, secondary 38-turns center-tapped.
- Wire: Primary uses 12-gauge, base-drive uses 16-gauge, and the secondary uses 14-gauge.

Mount the transformer to the chassis using plastic ties with the transformer resting on plastic tie downs. Mount the PC board to the chassis on 1/4" spacers and No. 4 hardware. Check to make sure that nothing is shorted to the chassis under the PC board. The output terminal strip is wired as indicated on the chassis artwork with two terminals for +V, two for −V, and two for ground. Use a 3-amp 250-volt fuse in the line-fuse holder, and 5 A fuses in the outputs.

Figure 7 shows the 110-volt to ±35-volt power supply. Assemble the PC board and make sure that the polarity of the diodes and filter capacitors is correct. Install all hardware in the chassis and wire the transformer secondary to the PC board as indicated in the schematic. Solder one transformer-primary lead directly to one of the insulated terminals on the EMI filter. (Use heat shrink tubing over all primary connections to prevent electrical shock when servicing.) Connect the other transformer-primary lead to the center terminal of the toggle switch. The bottom terminal of the toggle switch gets wired to the chassis-mount fuse holder, while the fuse holder's center terminal gets wired to the other insulated terminal on the EMI filter.

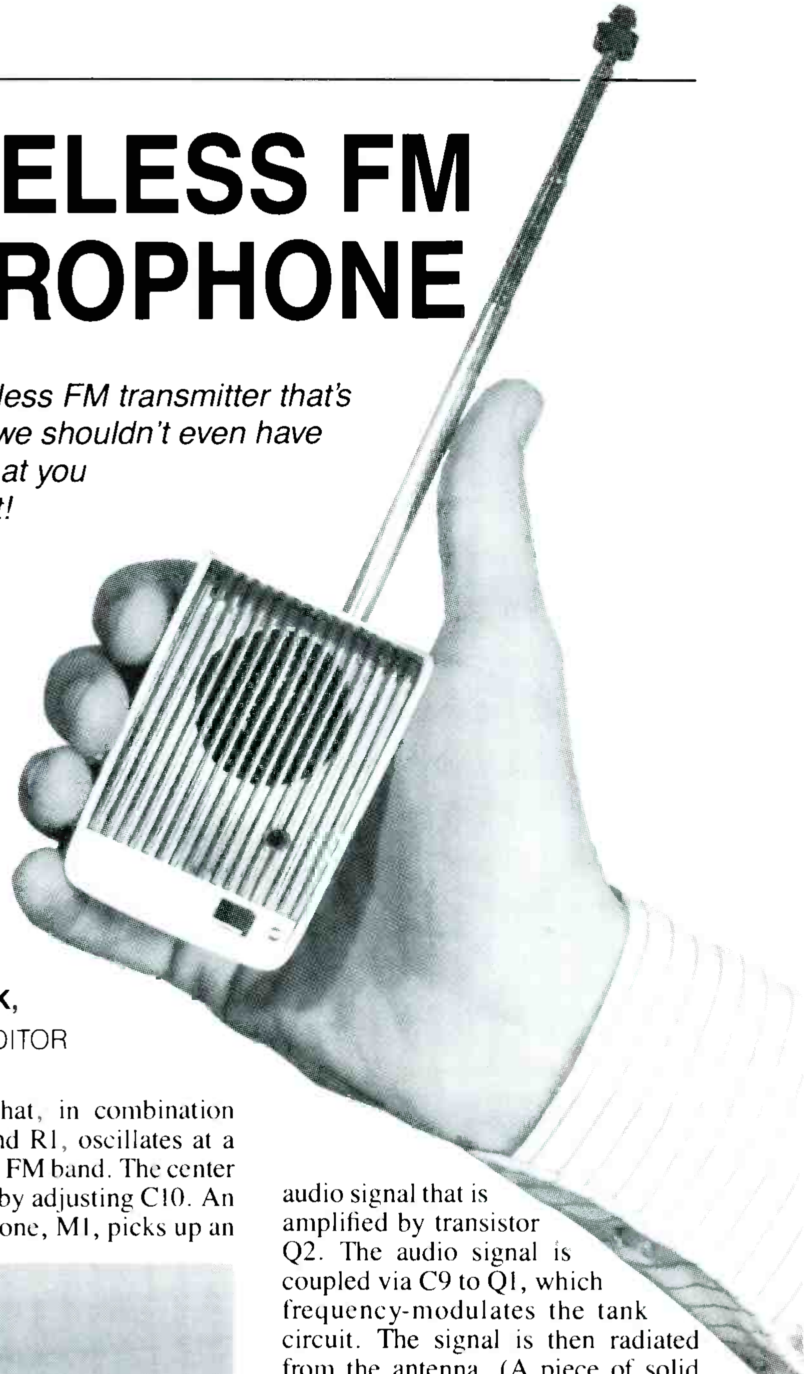
continued on page 157

ORDERING INFORMATION

The following are available from Optoelectronics, Inc. 58821 N.E. 14th Ave., Ft. Lauderdale, FL 33334; phone (800) 327-5912, FL residents phone (305) 771-2050; include 5% shipping and handling; FL residents add 6% sales tax. Master Card and Visa OK for orders over $200. *Opto-Amp amplifier* complete kit $149; 12-volts power supply model *1270* for $99.95; AC power supply model *110/70* for $119. Individual parts: any PC board $25; LM12CLK $29 each; heat-sinks $9.95 each; *T1270* tape-wound power transformer for 12-volt DC supply $30; send self addressed stamped envelope for a complete price list of all parts.

WIRELESS FM MICROPHONE

Here's a wireless FM transmitter that's so versatile, we shouldn't even have to tell you what you can do with it!



MARC SPIWAK, ASSOCIATE EDITOR

OUR BATTERY-POWERED WIRELESS FM transmitter that can transmit an audio signal over a short distance (about a hundred feet), to any frequency in the standard FM band. The transmitter itself is assembled on a PC board that measures less than 4 square inches (34 × 46 millimeters). The fully assembled unit is shown in Fig. 1.

The transmitter conforms to the FCC's regulations regarding wireless microphones. Its emissions stay within a band of 200-kHz, and its output is between 88 and 108 MHz. The field strength of the radiated emissions do not exceed 50 μV/m at a distance of 15 meters from the device.

The small size of the transmitter is what gives it its versatility. The transmitter can be used as a wireless microphone, it can be concealed in a room and used a "bug" for a good practical joke, or perhaps placed near a baby's crib and used as a child monitor. The wireless microphone in Fig. 2 used the case of an old microphone that was found in a junkbox. A small on/off switch was added to the circuit. It can be used to talk to someone in another car on a long road trip, or to anyone wearing a walkman-type radio.

The circuit

The schematic for the transmitter circuit is shown in Fig. 3. Adjustable-capacitor, C10, and the coil, L1, form a tank circuit that, in combination with Q1, C2, and R1, oscillates at a frequency on the FM band. The center frequency is set by adjusting C10. An electret microphone, M1, picks up an audio signal that is amplified by transistor Q2. The audio signal is coupled via C9 to Q1, which frequency-modulates the tank circuit. The signal is then radiated from the antenna. (A piece of solid wire can be used as an antenna if you don't want to use a telescopic one.)

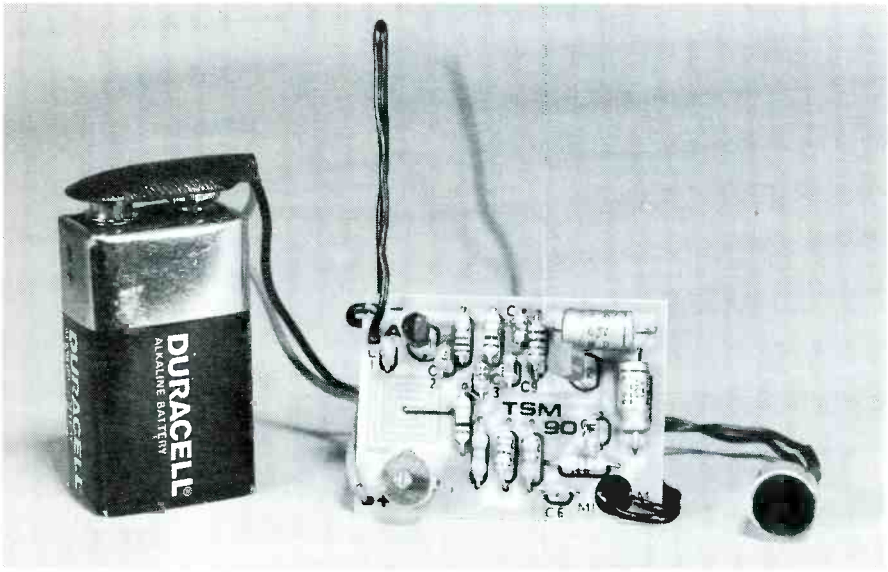


FIG. 1—THE FULLY ASSEMBLED PC BOARD. This FM transmitter board is so small, measuring 1⁵⁄₁₆ × 1¹³⁄₁₆ inches, that it will fit inside almost anything.

The circuit can operate from 9–12 volts DC. It's easiest to use an ordinary 9-volt transistor battery, but if you have to conserve space in a small case, you may prefer to use small 12-volt batteries that are about half the size of a AA cell. If you are going to use the transmitter as a child monitor or for some other similar application, you may want to use an AC adapter as a power source.

Parts

All of the parts, including an etched, drilled, and silk-screened PC

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—100 ohms
R2, R4—10,000 ohms
R3—1000 ohms
R5, R7—47,000 ohms
R6—2.2 megohms
R8—4700 ohms
Capacitors
C1—1.5 pF, ceramic disc
C2—100 pF, NPO
C3, C4—330 pF, NPO
C5, C9—0.1 µF, NPO
C6—0.001 µF, NPO
C7—22 µF, electrolytic
C8—6.8 µF, electrolytic
C10—10–40 pF trimmer capacitor
Semiconductors
Q1—BF199 or NTE229, or equivalent NPN transistor
Q2—BC183C or NTE199, or equivalent NPN transistor
Other components
L1—coil, approximately 1 µH (see text)
M1—electret microphone
S1—SPST switch
Miscellaneous: 9-volt battery and connector, wire, project case, solder, etc.
Note: The complete TSM kit for the FM transmitter is available for $13.85. Contact Prospect Electronics, PO Box 9144, Allentown, PA 18105.

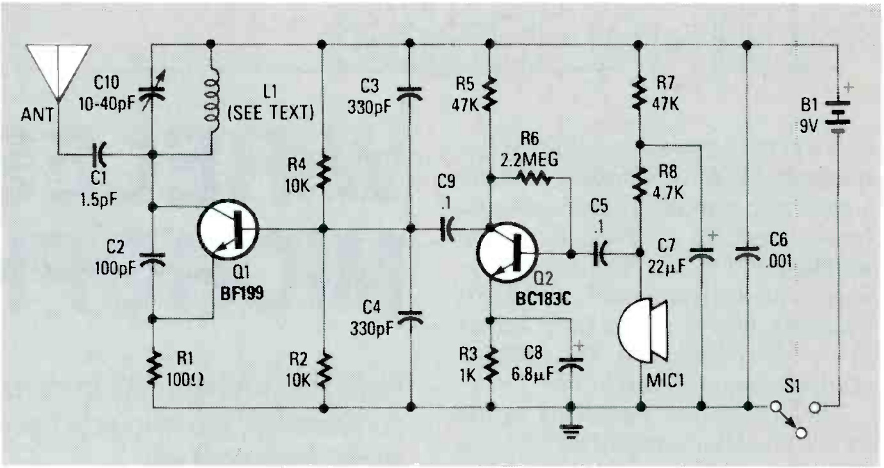


FIG. 3—THE FM-TRANSMITTER circuit has few components, but it can still transmit a clear audio signal up to a hundred feet.

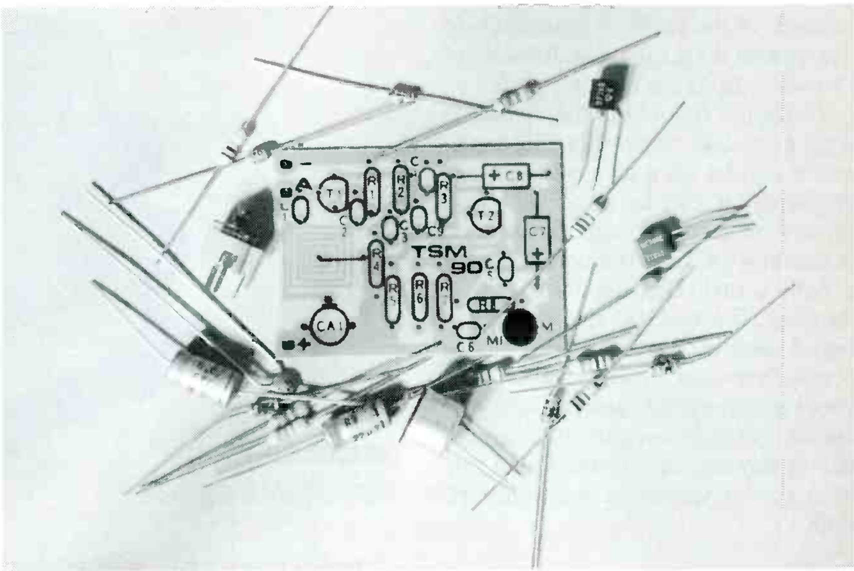


FIG. 4—HERE IS THE COMPLETE PARTS KIT. You shouldn't have any trouble building this one, and it's sure to work when finished.

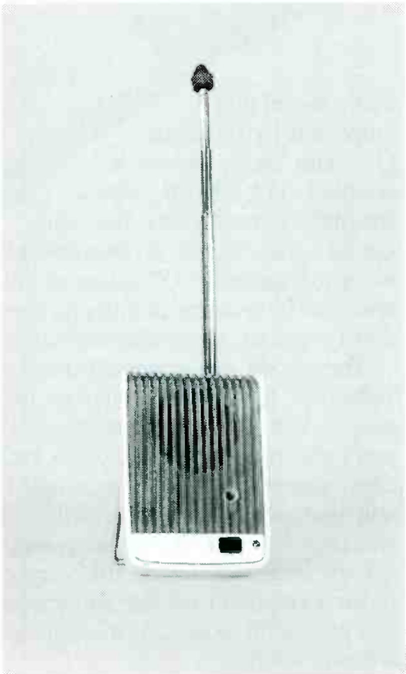


FIG. 2—THIS WIRELESS MICROPHONE was made out of an old, gutted microphone. A transmitter and a 9-volt battery fit inside.

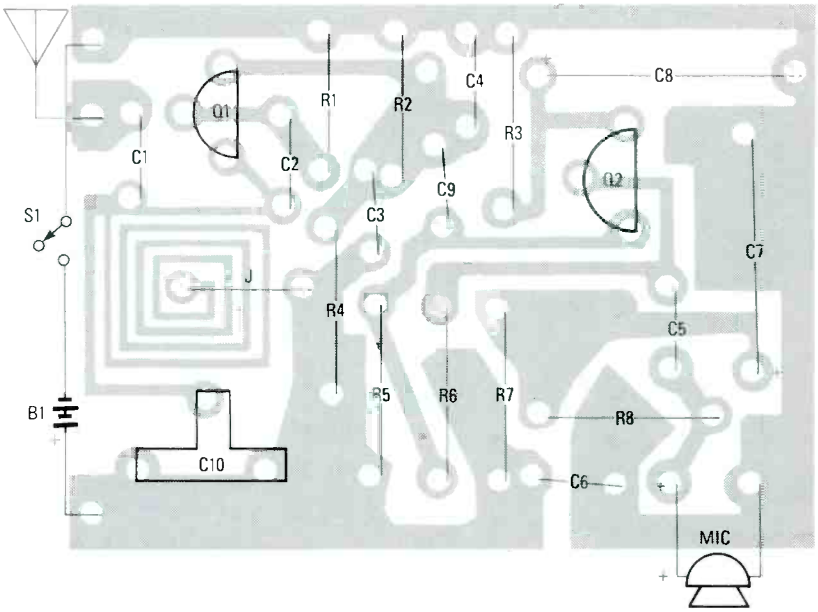


FIG. 5—PARTS-PLACEMENT DIAGRAM. Solder the components to the board in the order of the Parts List.

board are available as a kit from TSM (see Fig. 4). If you look at the PC board's foil pattern in PC Service, you'll notice that there's a small square-shaped spiral-like trace on the board. That is actually the coil, L1. So, whether you buy the kit, or if you can find all the parts in your junkbox and make your own PC board, you'll already have L1. But if you want to build the circuit on a breadboard, you might be able to get away with an adjustable coil centered around 1 μH. The only other things you'll need is a battery and battery clip, a small case, and a piece of wire for the antenna.

Construction

Building this kit is no different than building any other, once you have the PC board. A Parts-Placement diagram is shown in Fig. 5. The components should be soldered to the board in the order that they're listed in the Parts List. To avoid damaging the electret microphone, make sure that the lead connected to the microphone's case is the one that you connect to ground on the PC board. And of course, as always, make sure that

FIG. 6—AN EMPTY CIGARETTE PACK makes a good home for the FM transmitter.

there are no bad solder joints or bridges before connecting power.

Get it working

After you apply power to the board, all you have to do is set an ordinary FM radio on an unused station on the lower portion of the dial—around 88 MHz. Then just speak into the electret microphone while adjusting C10 using a plastic trimmer tool. at some point you should hear your voice on the radio. Once you find the approximate setting of C10, fine tuning it should be no problem. It might be easier to receive a clear signal on a dial-tuned radio, rather than a digitally tuned one.

The case

You can really go wild on the case for this one. You can install the board and battery in practically anything. The microphone is very sensitive, so it will pick up an audio signal from inside an empty cigarette pack, as shown in Fig. 6. You can put the transmitter in any small box that will blend into the particular surroundings—it can be from cough drops, paper clips, sugar, or inside an empty vitamin jar! There's probably enough room inside most portable radios to install a transmitter, and you might be able to tap power from the existing batteries. Then you'll have a portable radio/transmitter, that can easily be moved to any room in your home.

Another idea is to hollow out the center of an old book and put a transmitter and battery in there. The wireless transmitter is so versatile, that you'll surely want to build one—or two! **R-E**

HI-FI AMPLIFIER

continued from page 154

Checkout

Use an ohmmeter to check for shorts from the LM12 to the heatsink. Check all diodes, capacitors, and IC's for correct polarity. Stuffing components in backwards is the most frequent mistake in construction, and can be a fatal error—so check thoroughly. The next step is to check the power supply for correct output voltages. Keep in mind that, unloaded, the voltage can be 100–150% higher than the nominal voltage.

Now let's connect the *Opto-Amp* to the power supply, but with no output speakers or audio inputs connected. Nothing should get very hot and fuses should not blow. Center the sensitivity potentiometers (R1 and R2) on the PC board and then connect the speakers. Use a source input with a volume control to prevent damaging your speakers and ears.

For 12-volt operation, the wire size going to the battery must be a minimum of 12-gauge for up to 8-foot lengths, and larger gauge for longer distances. A 30-amp in-line fuse must be placed near the source of the power (battery); after all, we're dealing with significant amounts of power that could cause severe damage to the car's electrical system, the *Opto-Amp* power supply, or worse. Even a fire could occur if the 12-volt supply line is not properly fused.

Use a 30-amp relay to switch the power off and on. You can mount a switch under the dash, or use the power antenna output from the car radio to enable the *Opto-Amp*. You will want to make sure that the relay can not be energized unless the key is turned on to prevent draining your car battery to death. At full power, the load on the car electrical system is the same as leaving the headlights on.

Both the *Opto-Amp* and power supply are compact enough to mount wherever space is available. If there is no air flow—such as in the vehicle's trunk—then use a 12-volt fan to move air over the heat-sink fins in the power supply and *Opto-Amp*. One final note about bridging: If you are planning to bridge two amps in your car then you'll need at least two power supplies.

The 110-volt AC power-supply operation is straight forward. Keep in mind that there should be nothing to hinder air movement over the *Opto-Amp*. If there is any question about overheating, then add a quiet fan. The *Opto-Amp* can be mounted apart from it's power supply or right next to it. Several *Opto-Amps* can be bolted and stacked into a rack mount. You can operate the *Opto-Amp* bridged from one power supply, but the fuses will blow if the 5-amp limit is exceeded; to prevent that from happening, use two power supplies for extra power. **R-E**

BUILD A PAIR OF LINE-CARRIER MODEMS

Build a pair of modems that communicate over the AC lines!

KEITH NICHOLS, CRC ELECTRONICS

How do you connect two PC's together? Solutions range from "Sneaker Net" (wherein the user carries a diskette from one machine to the other) to complex and expensive proprietary network systems. For occasional use, Sneaker Net is easy and reliable, but as usage increases, a more efficient means of data transfer becomes necessary. The problem is that a full networking system requires dedicated wiring, expensive network servers, and lots of user training. Clearly, a midrange solution is required.

The line-carrier modem presented here is one such solution. The LCM100 is inexpensive (about $100 for a pair of modems), easy to build and use, and uses existing AC wiring to transmit and receive signals. The LCM100 can operate at any baud rate up to 9600, and relies on your communications software to transmit and receive data.

For example, you could use a pair of modems to transmit files between two PC's in an office. You'd use your normal communications software (Crosstalk or ProComm, for example) to send files in Xmodem or Kermit format. Another possibility would be to transmit manufacturing data from a factory floor back to the central office for processing. At home, you might use the LCM100 to transmit files from the PC in your study to the kids' PC in the basement. You might also use a pair of LCM100's to transfer data between dissimilar machines—an IBM PC and a Macintosh, for example.

Background

The LCM100 operates in much the same manner as the familiar telephone modem, but sends its signals via electric-power wiring instead of telephone lines. Each module translates serial asynchronous data between RS-232C and frequency-shift-keying data formats.

A normal telephone modem translates the voltage levels of the digital input signals into two distinct audible tones, one of which represents a logic 0, and the other, a logic 1. The process of shifting the frequency of the output tone as the logic levels change is called *F*requency *S*hift *K*eying, or FSK. The pair of frequencies representing the two logic states are conventionally called "mark" and "space".

The LCM100 converts RS-232C signals into FSK form, but the mark and space frequencies are above 100 kHz, which is well above the audible range. To permit communication in two directions simultaneously (full duplex mode), two pairs of frequencies are used, one called

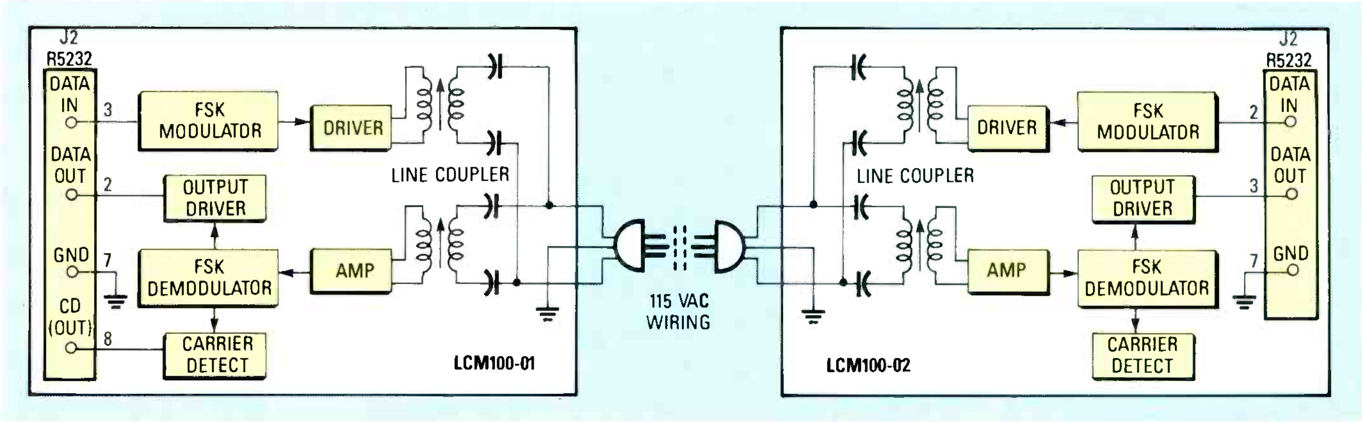


FIG. 1—BLOCK DIAGRAM of the LCM100 data-communication system. The AC-power wiring of the building is used to carry the FSK transmission.

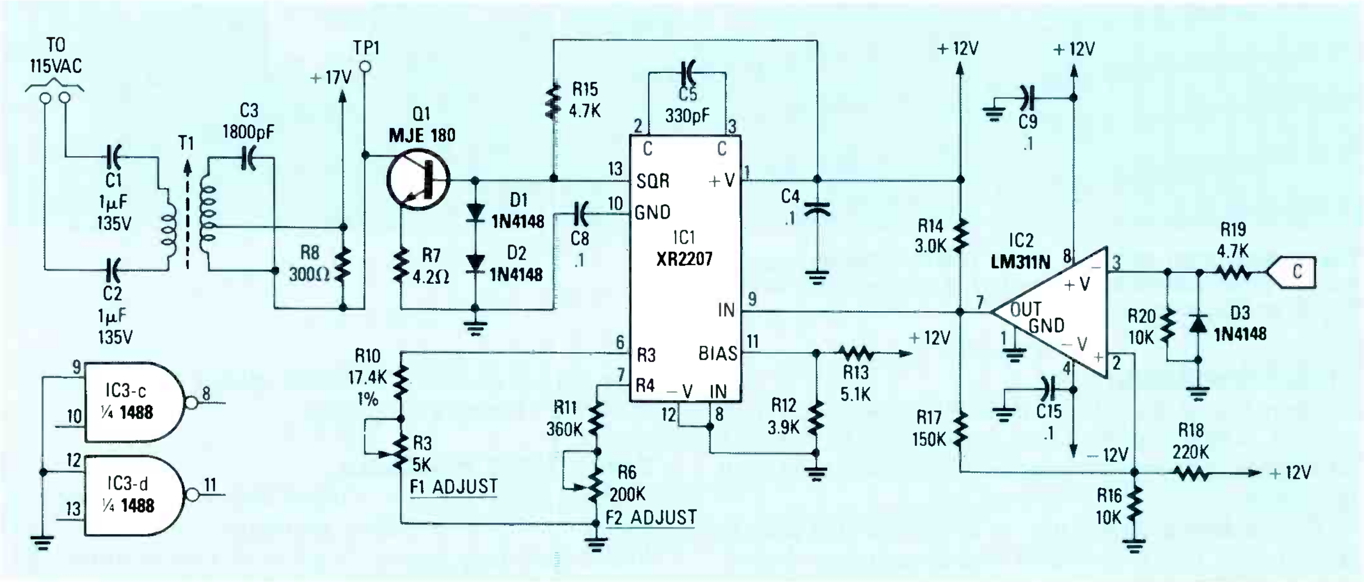


FIG. 2—TRANSMITTER SECTION of the LCM100. Op-amp IC2 shapes RS232 data and presents it to the FSK modulator, IC1. After amplification, the signal is coupled to the AC line by T1.

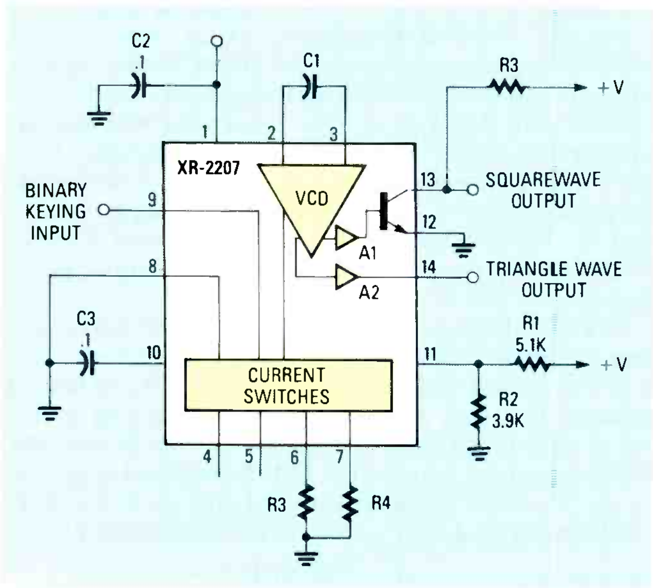


FIG. 3—BLOCK DIAGRAM AND PIN-OUT of the XR2207. The binary keying inputs (pins 8 and 9) determine output frequency.

highband, and the other, lowband. (The two frequency pairs are also known as the originate set and the answer set. Those terms designate only the frequencies that each unit is using and do not imply the source or content of the data itself.)

The LCM100 system consists of two modules, the LCM100-01 module, and the LCM100-02. The designation is arbitrary, but it shall be assumed herein that the LCM100-01 module transmits on the highband and receives on the lowband, and the LCM100-02 module transmits on the lowband and receives on the highband. The frequencies that are used by each of the modules are shown in Table 1.

The AC-power line is similar in some respects to the telephone line. However, although the telephone line has well-defined characteristics (a nominal impedance of 600 ohms, relatively little noise, etc.), the AC line can be a harsh environment for data signals. With an impedance as low as 2 ohms and occasional thousand-volt noise spikes, it is less than an optimum communications medium. The LCM100 system must be able to impose an FSK carrier of sufficient strength onto the low-impedance power line, as well as filter out the 60-Hz signal and any other noise components that may be present, thus demodulating only the transmitted signal.

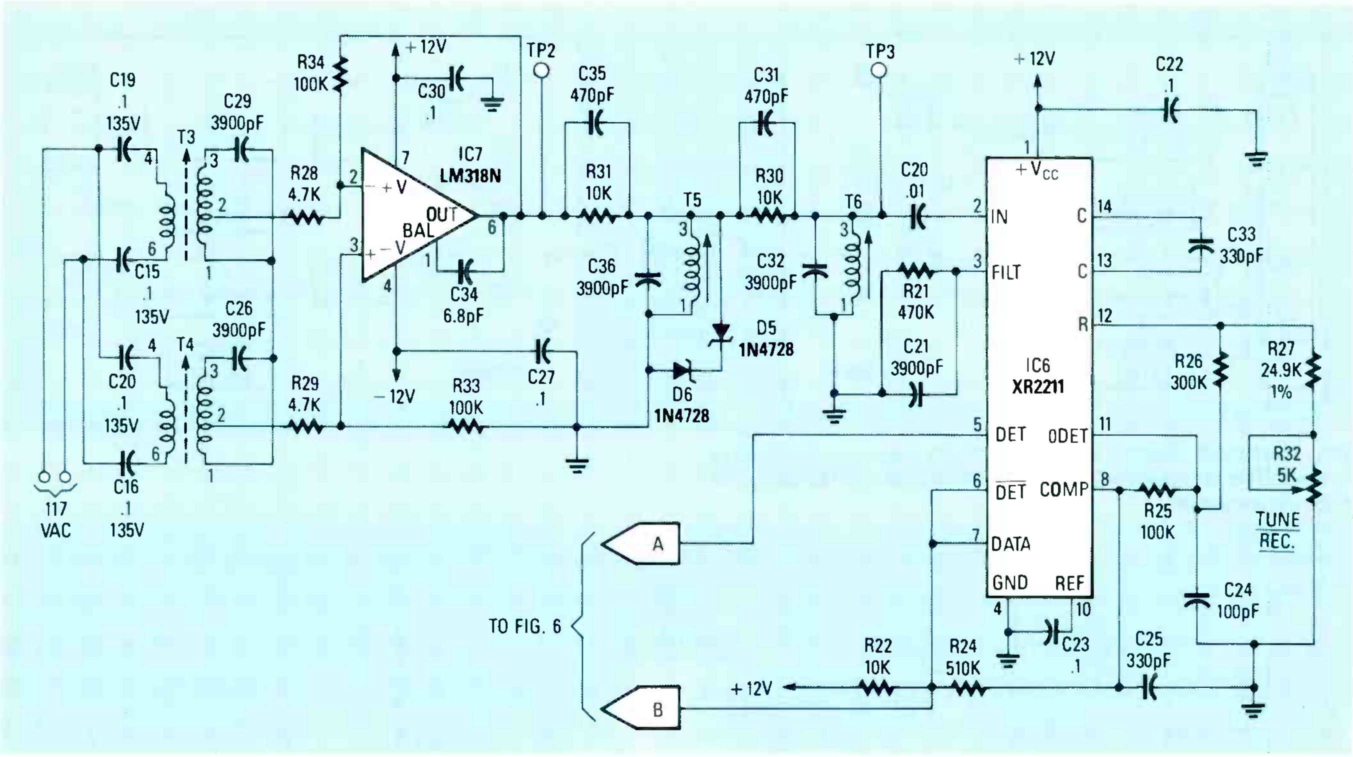


FIG. 4—RECEIVER SECTION of the LCM100. Signals coupled from the power line are conditioned by IC7 and then demodulated by IC6, an FSK demodulator.

Circuit description

Figure 1 is the block diagram of the LCM100 line-carrier modem, which consists of four basic functions: modulator/driver, line coupler, amplifier/demodulator, and output driver.

The modulator/driver and its associated line coupler comprise the transmitter stage, and the amplifier/demodulator, together with its line coupler, defines the receiver stage of the modem circuitry. Each stage is discussed in detail as we continue.

Transmitter stage

Serial input signals are fed via RS-232C port (J2) to the input-conditioning circuit surrounding IC2 (See Fig. 2). Negative-going pulses are clipped by D3, and positive-going pulses are conditioned by voltage-comparator IC2. That signal shaping ensures that the input signals to modulator IC1 are above the threshold voltage required by the oscillator's binary keying input.

TABLE 1—LCM FREQUENCIES

	LCM100-01	LCM100-02
f1 (mark)	150.00	100.00
f2 (space)	156.50	106.50

TABLE 2—TIMING RESISTORS

Frequency (kHz)	R3 (K)	R4 (K)
150	20.20	
100	30.30	
156.5		466.2
106.5		466.2

Exar XR2207 modulator

The XR2207 (IC1) is a monolithic voltage-controlled oscillator. It can produce simultaneous triangle- and square-wave outputs over frequencies ranging from 0.01 Hz to 1 MHz. It is ideally suited for FSK applications because it can be set for two (or four) different time bases and digitally switched among them. A block diagram of the XR2207 and a typical hookup are shown in Fig. 3.

Four main functional blocks comprise the XR2207: A *V*oltage-*C*ontrolled *O*scillator (VCO), four current switches (which are activated by binary keying inputs), and two buffer amplifiers for the triangle- and square-wave outputs. The VCO is actually a current-controlled oscillator that gets its input from the current switches. Output frequency is proportional to input current; four discrete frequencies may be selected by two binary inputs (pins 8 and 9). Those input currents are set by timing resistors connected to pin 4–pin 7. The values for those resistors can be seen in Table 2.

The LCM100 uses only two of the four FSK levels. The unused timing inputs (pins 4 and 5) are left unconnected, and the second binary-keying input, pin 8, is tied to ground. The mark and space frequencies are set by the values of timing-resistors R3 and R4 and timing-capacitor C1 between pins 2 and 3. The FSK input signal is applied to pin 9. A low applied to pin 9 (with pin 8 tied low) produces a signal with a frequency *f1* determined by:

$$f1 = 1/(R3 \times C1)$$

A high applied to pin 9 produces a signal *f2* with a frequency determined by:

PARTS LIST

Note: Component values in parentheses are for the LCM100-02 board; other values are for the LCM100-01 board.
All resistors are ¼-watt, 5% unless otherwise noted.

R1, R2, R4, R5, R15, R19, R28, R29—4700 ohms
R3—5000 ohms, PC-mount trimmer potentiometer
R6—200,000 ohms, PC-mount trimmer potentiometer
R7—4.2 ohms
R8—300 ohms
R9—not used
R10—17,400 ohms, 1% (24,900 ohms, 1%)
R11—360,000 ohms
R12—3900 ohms
R13—5100 ohms
R14—3000 ohms
R16, R20, R22, R30, R31—10,000 ohms
R17—150,000 ohms
R18—220,000 ohms
R21—470,000 ohms
R23—620 ohms
R24—510,000 ohms
R25—100,000 ohms
R26—300,000 ohms
R27—24,900 ohms, 1% (16,200 ohms, 1%)
R32—5000 ohms, PC-mount trimmer potentiometer
R33, R34—100,000 ohms (47,000 ohms)
R35—820 ohms

Capacitors

C1, C2—1 μF, 135 volts
C3—1800 pF (3900 pF)
C5—330 pF
C6—1000 μF, 35 volts, electrolytic
C4, C7–C10, C13, C18, C22, C23, C27, C30—0.1 μF, 25 volts, monolithic
C11—100 μF, 25 volts, electrolytic
C12, C17—10 μF, 25 volts, tantalum
C14, C25, C33—330 pF
C15, C16, C19, C20—0.1 μF, 135 volts
C21—3900 pF
C24—100 pF
C26, C29, C32, C36—3900 pF (1800 pF)
C28—0.01 μF, disk
C31, C35—470 pF
C34—6.8 pF

Semiconductors

BR1—50 volts, 1 amp
D1, D2, D3, D6—1N4148
D4, D5—1N4728 (3.3-volt Zener)
LED1—standard red
LED2—standard green
IC1—XR2207, FSK modulator
IC2—LM311N, op-amp
IC3—1488, RS-232 line driver
IC4—78L12ACZ, precision +12-volt regulator
IC5—79L12ACZ, precision −12-volt regulator
IC6—XR2211, FSK demodulator
IC7—LM318N, op-amp
Q1—MJE180, NPN power transistor
Q2—PN2222, NPN switching transistor
Q3—2N3906, PNP switching transistor

Other components

J1—115-volt AC receptacle J2—25-pin D connector P1, P2—3-pin header strip P3—2-pin header strip MOV1—150-volt varistor T1—RF coil, TOKO RAN10A6729HK
T2—24-volts, 180 mA, PC mount (Dale PL-13-07)
T3-T6—RF coil, TOKO RAN10A6729

Miscellaneous

Note: The following are available from CRC Electronics, 13547 S. E. 27th Place, Suite 3D, Bellevue, WA 98005, (206) 747-9636: Etched and drilled PC boards with plated-through holes, $34.95/pair; Partial kit (includes PC boards, all transformers, coils, jacks, and high-voltage capacitors) $69.95/pair; Complete kit excluding case and power cords, $129.00/pair; Assembled and tested PC-board assembly without cases and power cords, $179.95/pair; Complete assembled and tested system, $159.95/pair. Individual components are also available.

$$f2 = f1 + \Delta f1$$

where $\Delta f1 = 1/(R4 \times C1)$. In both equations, f is specified in Hz, R3 and R4 are in ohms, and C1 is in farads.

In an actual circuit, R3 and R4 can have values between 2K and 2 megohms, and the timing capacitor should be polycarbonate, polystyrene, or mylar, for optimum temperature stability. Table 2 shows the resistor values used to obtain the highband and lowband frequencies, in both cases using a 330-pf timing capacitor. Note that the value of R4 is the same for both the frequency bands. That is because the difference between the mark and space frequencies is the same for both frequency pairs. Because non-standard values are obtained, a series combination of a fixed resistor and a potentiometer permit fine tuning the mark and space frequencies.

The square wave output of the XR2207 (pin 13) is an open-collector stage that drives power transistor Q1. Resistor R15 is a pull-up resistor for the IC's output.

Power transistor Q1 drives the tuned line coupler (T1 and C3) that effects the impedance transformation necessary to impose the FSK carrier onto the 60-Hz power line. Protective capacitors C1 and C2 isolate the modulation circuitry from the power-line voltage.

Receiver Stage

As shown in Fig. 4, the parallel line couplers, T3/C29 and T4/C26, are capacitively isolated from the AC line by protective capacitors C15, C16, C19 and C20. One of the LC circuits is tuned to the "mark" frequency of the line-carrier signal, and the other is tuned to the "space" frequency. The line couplers effectively present a high impedance to the 60-Hz power-line signal while presenting a low-impedance path to the tuned frequencies.

Next, the received signals are amplified by IC7, an LM318N high-slew-rate op-amp. The output of IC7 is fed through a bandpass filter network composed of C35 and R31, T5 and C36, C31 and R30, and T6 and C32. Those components shape the signal and reject noise; Zener-diodes D5 and D6 clip the peak-to-peak signal voltage to 6.6 volts to avoid damaging the demodulator (IC6).

Exar XR2211 Demodulator

The XR2211 is a *P*hase-*L*ocked-*L*oop (PLL) IC designed especially for data communication and particularly suited for FSK-modem applications. It operates over a frequency range from 0.01 Hz to 300 kHz and can accommodate analog input signals between 2 millivolts and 3 volts. A block diagram of the XR2211 and a typical FSK-demodulator hookup are shown in Fig. 5.

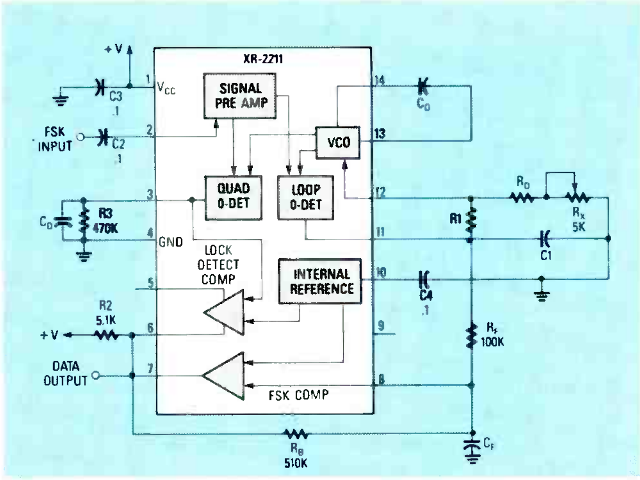


FIG. 5—BLOCK DIAGRAM and basic hookup of the XR2211 FSK demodulator. See the text for information on calculating resistor and capacitor values.

Frequency-shift-keyed input signals are fed to pin 2 of the IC through a 0.1-µF coupling capacitor. The internal impedance is 20 kilohms and the minimum recommended input signal is 10 mV.

The center frequency of the demodulator's passband must be set at the center of the frequency band that is to be detected. In the LCM100 the passband is set halfway between the frequency pairs: (106.5 + 100)/2 = 103.25 kHz for the LCM100-01 demodulator, and (156.5 + 150)/2 = 153.25 kHz for the LCM100-02.

In Fig. 5, the oscillator's center frequency is calculated as follows:

$$f_O = 1/(R_O \cdot C_O)$$

where R_O is in ohms and C_O is in farads. Using a 330-pf capacitor for C_O, the computed values for R_O are 29.35K and 19.77K for the LCM100-01 and LCM100-02 modules respectively. With a 5K trimmer wired in series, 1% resistors with values of 24.9K and 16.2K are used. Capacitor C_O should be mylar, polycarbonate, or polystyrene.

System bandwidth is set by R1, and C1 sets the loop-filter time constant and damping factor. The value of R1 is determined by the mark/space frequency difference:

$$R1 = (R_O \cdot f_O)/(f1 - f2)$$

The calculated values for R1 are 395 kilohms (f_O = 103.25 kHz) and 382 kilohms (f_O = 153.25 kHz). However, in order to increase the detectable bandwidth, both LCM100 modules use a 300K value for R1.

The equation for computing the loop-damping factor associated with C1 is complex, but there is a convenient rule of thumb. The damping factor should be approximately 1/2, and a value of C1 = C_O/4 will produce that. With C_O equal to 330 pf, C1 equals 82.5 pf. Because the loop low-pass filter time constant T equals R1 × C1, the LCM100 uses a 100-pf value for C1 in order to compensate for the lower value of R1.

Resistor R_B provides positive feedback across the FSK comparator and facilitates a rapid transition between output states. A value of 510K is normally used.

Components C_F and R_F form a single-pole post-detection filter for the FSK data output (R_F generally = 100K). Capacitor C_F smoothes the data output; its value is calculated roughly as:

$$C_F = 3/\text{data rate in bits per second}$$

where C_F is in microfarads. Since the LCM100 is designed for operation up to 9600 bps (bits per second), a value of 330 pf is acceptable.

The final area requiring calculation is the lock-detect section of the XR2211, which is used in a carrier-detect function. The open-collector lock-detect output (pin 6) is connected to the data output (pin 7). That disables any output created by noise, unless a carrier signal is present within the detection passband of the PLL. Presuming a parallel resistance of 470 kilohms, the minimum value of the lock-detect filter capacitor, C_D, is:

$$C_D = 16/(f1 - f2)/2$$

The LCM100 uses a 3900-pf capacitor for C_D.

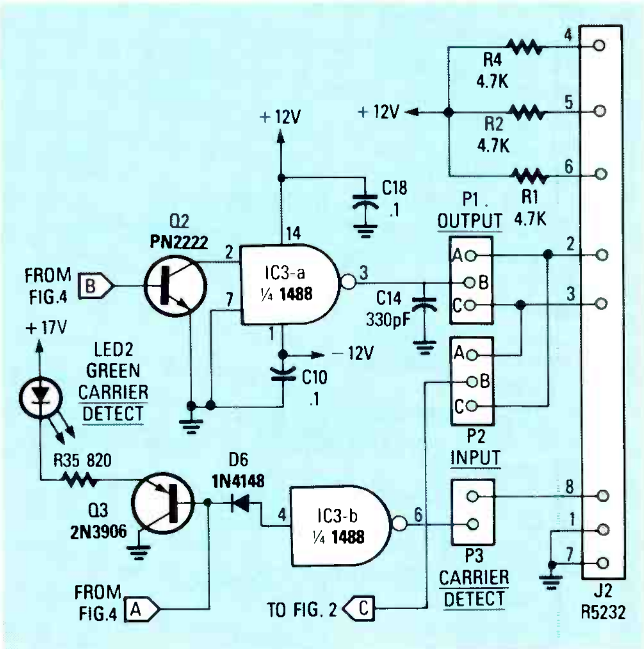


FIG. 6—OUTPUT AMPLIFIER AND CONNECTORS. Transistor Q2 amplifies the output of the XR2211. Line buffer IC3-a then converts the signal to RS-232C form.

Output driver

Referring to Fig. 6, the data output of the XR2211 (pin 7) is amplified by NPN-transistor Q2, which drives IC3-a, one section of a 1488 quad RS-232C line driver. It produces the positive- and negative-voltage levels required by the RS-232C interface.

The carrier-detect output of the XR2211 (pin 5) drives the base of transistor Q3, which controls LED2, the carrier-detect LED. The LED provides a convenient means of verifying that the two modems are "talking" to each other.

Power supply

The LCM100's power supply, shown in Fig. 7, consists of power-transformer T2, bridge-rectifier BR1, precision-voltage-regulators IC4 and IC5, and other associated filter capacitors. Regulators IC4 and IC5 produce the ±12-volt supplies required by the various IC's. In addition, fuse F1 and MOV1, a 150-volt varistor, provide protection from short circuits and voltage surges.

Construction

The line-carrier modem system is built on two identical

PC boards, one of which is designated as the LCM100-01 module and the other, the LCM100-02 module. Each circuit board contains a power-supply, a transmitter, a receiver, an output driver, an RS-232C interface, and carrier-detect circuitry. All components on the two boards except C3, C26, C29, C32, C36, R10, R27, R33, and R34 are identical.

Begin assembly by installing the resistors, including the variable potentiometers. Use the parts-placement diagram shown in Fig. 8. Keep in mind that R10, R27, R33, and R34 have different values on the two boards. Note that R9 is not used.

Next, install all jumper headers, test pins, J1, J2, and the fuse clips. Note that the fuse clips must be oriented with the indented ends away from the fuse. Connectors J1 and J2 should be secured to the board with 4-40 hardware before soldering.

The capacitors and diodes are installed next, except the electrolytic capacitors, C6 and C11. Be sure to observe the polarity of the diodes and the tantalum capacitors, C12 and C17. Again, note that capacitors C3, C26, C29, C32 and C36 have different values on the two boards.

Next, install IC1, IC2, IC3, IC6, and IC7. The use of IC sockets is recommended to minimize the possibility of damage to the IC's from excess heat.

Transistors Q1, Q2, and Q3, varistor MOV1, and IC4 and IC5 are installed next. Use care not to interchange IC4 (78L12A) and IC5 (79L12A), the +12- and −12-volt regulators. Note that transistor Q1 should not be secured to the PC board with a screw and nut. Use extreme care not to overheat the transistors and IC's when soldering.

The tunable RF coils are installed next. Note that T1 (TOKO RAN 10A6729HK) has a different part number than T3, T4, T5 and T6 (TOKO RAN 10A6729). When installing the RF coils, be sure to solder all 5 pins plus the two housing tabs to the PC board.

Next, install the power transformer (T2), bridge-rectifier BR1, electrolytic capacitors C6 and C11, and the LED's. Be sure that the correct polarity is observed when installing the electrolytic capacitors and LED's. The cathode (or flat side) of the LED's goes toward the center of the PC board. Transformer T2 must be installed with leads 1 and 2 (120 V) toward the AC receptacle (J1). Bend the mounting tabs against the board and solder them, as well as the six transformer leads, to the board. Also, be sure that bridge-rectifier BR1 is installed with the (+) lead closest to pin 2 of T2.

Last, carefully insert the IC's in their respective sockets. Figure 9 shows the final assembly.

Testing and tuning

1) Begin testing by thoroughly inspecting both boards for missed or inadequate solder joints, solder bridges, etc.

Caution! Working directly with AC power is dangerous, so be careful! Before applying power to the circuit, be sure to place the board on a non-conductive surface, and do not touch any exposed leads or traces on the line-voltage side of the circuit!

2) With the assembled board on a non-conductive surface, install F1 (½ amp) in the fuse clips, then connect a three-wire power cord to receptacle J1 and apply power to the circuit. **Keep your hands away from the high-voltage components and traces on the board!** The red LED (D9) should light, indicating that power is on. The green LED may flicker momentarily; however, it should not remain lit.

3) Now connect a temporary switched jumper between the data-input pin of J2 (the DB25P connector) and one of the +12-volt sources (pin 4, 5, 6, or 20 of J2). A convenient way to do that is to use a spare DB25P male connector with an SPST switch wired across the pins to be jumpered. If you haven't already done it, install the jumpers on headers P1, P2, and P3 as follows. On the LCM100-01 board: P1, P2—A and B jumpered; P3—not jumpered. On the LCM100-02 board: P1, P2—B and C jumpered; P3—jumpered.

4) The next step is to adjust the mark and space frequencies of modulator IC1. Begin with the LCM100-01 board. Attach the input lead of a frequency counter to TP1 (the collector of Q1), and the ground lead to pin 1 or pin 7 of the DB25P jumper. With the jumper switch on, adjust R3 until the meter reads 150 kHz. That is the "space" frequency (*f1*) of the FSK modulator. Next, turn the jumper switch off and adjust R6 to get a reading of 156.5 kHz. That represents the "mark" frequency (*f2*). Switch between *f1* and *f2* several times while fine tuning R3 and R6 until both frequencies are correct.

5) The transmitter line coupler can now be tuned to the modulator's FSK band as follows: Attach a high-impedance oscilloscope probe (×10 setting) to TP1, and clip the ground lead to pin 1 or pin 7 of J2. Set the sweep time and amplitude controls to display a sine wave. Adjust the tuning slug of RF-transformer T1 until maximum amplitude is obtained. Now flip the DB25P jumper switch to the other position and observe the change in amplitude as the frequency changes. Adjust T1's tuning slug until the amplitudes of *f1* and *f2* are equal. Repeat steps 2 through 5 with the LCM100-02 board, using 100 kHz and 106.5 kHz as the *f1* and *f2* settings respectively.

6) The receiver-stage line couplers are similar to the one used in the transmitter except that two of them are configured in a parallel arrangement. That permits precise tuning to the mark and space frequencies individually, rather than using an average of the two. The result is greater receiver sensitivity and superior noise rejection.

Tune the receiver line couplers as follows: Attach a scope probe (×10 setting) to TP2 (pin 6 of IC7) on the LCM100-01 board. Be sure to clip the ground lead to the signal ground, as before. Connect the power cords to both boards and plug both cords into the same 115-volt outlet box. The volts/division setting of the scope should be increased a couple of notches from where it was set for TP1. Adjust the tuning slug of T3 or T4 until an increase in amplitude of the waveform is seen on the display. Continue adjusting the slug until maximum amplitude is obtained. You may need to adjust both T3 and T4 in order to do that. When the amplitude exceeds a certain point you will see the peaks of the sine wave flatten out as the Zener diodes (D6 and D7) chop the voltage at ±3.3 volts. Flip the DB25P jumper switch on the LCM100-02 board to shift the frequency, then readjust T3 or T4 (on the LCM100-01 board) until the maximum amplitude is seen on the scope. Now, toggle the LCM100-01 jumper switch several times while fine tuning T3 and T4 until both *f1* and *f2* frequencies appear to have equal amplitude on the scope display. The waveform should look like a symmetrical sine wave with flattened peaks. Repeat step 6 for the LCM100-02 board

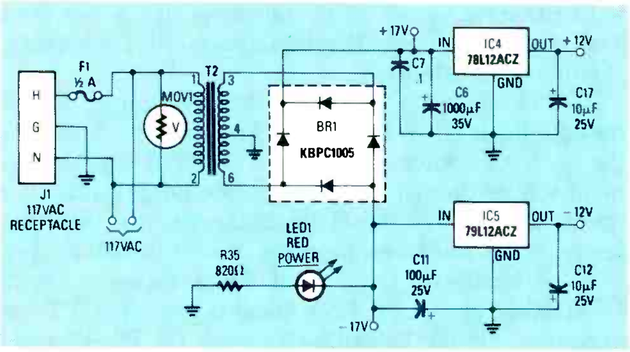


FIG. 7—THE LCM100's POWER SUPPLY. Regulators IC4 and IC5 are precision types; don't interchange them!

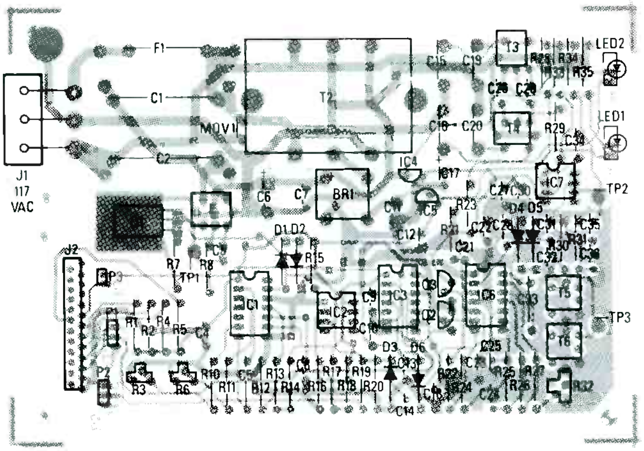


FIG. 8—INSTALL ALL COMPONENTS as shown here.

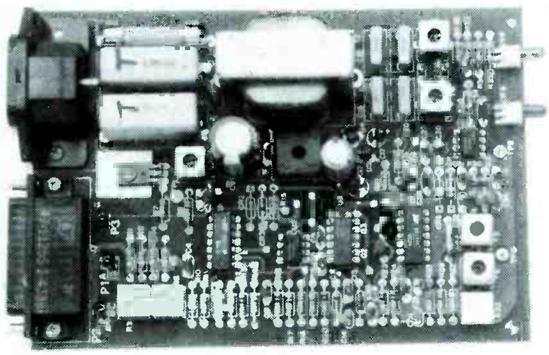


FIG. 9—THE FINAL ASSEMBLY looks like this.

(using the DB25P jumper switch on the LCM100-01 board to shift the frequencies).

7) The next step is to align the bandpass-filter network. The procedure is the same for each board. Attach the scope probe (× 10 setting) to TP3 (the ungrounded end of T6). Adjust the tuning slug of T6 until maximum amplitude of the sine wave is displayed. Toggle the jumper switch (on the opposite board) and fine tune T6 until an equal amplitude is obtained for both frequencies. Next, adjust T5 in the same manner as T6; note that T5 affects the amplitude very little.

8) The final tuning step is to adjust the free-running frequency of the VCO in the XR2211. The simplest way to do that is to adjust R32 while observing the green LED (D8) on the board (the opposite board, of course, must be plugged in and transmitting). Turn the adjustment screw of R32 until the green LED lights, then continue turning in the same direction until it turns off again. Set the adjustment screw of R32 halfway between the two points and mark the position of the screw slot with a pencil. Now flip the jumper switch on the opposite board to change the frequency, and repeat the previous step. You should have two pencil marks on R32 a few degrees apart. Turning the adjustment screw halfway between the two marks should result in the correct setting. Repeat for the other board.

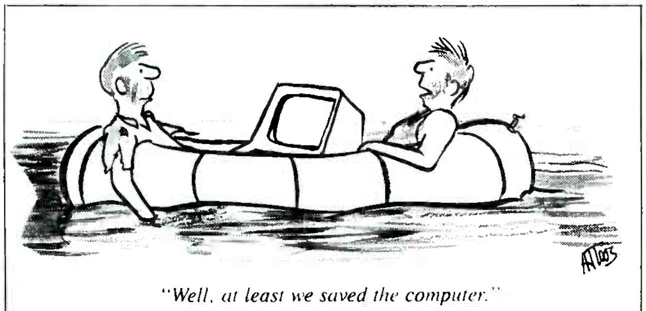
8-a) A more accurate method of setting the VCO of the XR2211 is as follows: Configure a function generator to produce a 4800-Hz square wave with a voltage swing of zero to +6 volts. Use that signal to adjust your oscilloscope to display a symmetrical square wave. Next, attach the function-generator output lead to the DATA-IN pin of J2 on the LCM100-01 board. Make sure the jumper switch is in the off position. Attach the scope probe to the DATA-OUT pin of J2 on the LCM100-02 board. With the power on to both boards, adjust R32 (on the LCM100-02) until a symmetrical square wave is displayed. That indicates the correct setting of the oscillator at the "center frequency," the midpoint between the detector mark and space frequencies. The green LED will, of course, be on at that setting.

Repeat the previous step, reversing the two boards, to complete the "tuning" process. The final step is to test the modems by transmitting actual data.

9) To do so, you'll need a serial-data output source. A video terminal, in full-duplex configuration, will do nicely. A simple loop-back circuit is the easiest test. The terminal is connected to the LCM100-01 modem that is plugged into the power line. The LCM100-02 modem, with pins 2 and 3 of J2 jumpered together, is plugged in some distance away. As you type on the keyboard, the data is transmitted to the LCM100-02 modem, looped back through the jumper, and re-transmitted to the LCM100-01 modem where it appears on the terminal's screen. Depending on your terminal's configuration (DTE/DCE), you may need to transpose the two modems or switch the internal jumpers on the LCM100-01 modem board to get things working properly.

The LCM100 will successfully transmit data over distances of several hundred feet, or more, at rates up to 9600 bps. In general, the greater the distance, the lower the baud rate should be for error-free transmission.

The ultimate range is limited by the power company's step-down transformer and the cross-coupling between the 115 V legs of a 230-volt distribution system. You can arrange communication between the latter by attaching a fused capacitor (a 1-µF, 400-volt capacitor in series with a ½-amp fuse) between the two 115-volt legs in your electrical panel box.



"Well, at least we saved the computer."

KIRLIAN

continued from page 59

terminal is lying underneath the copper-clad board on top. A single-sided copper-clad board measuring 4 × 5–inches is mounted on top of the unit (see photo), copper side down. Before gluing the board in place, solder a wire to the copper side, and then drill a hole through the top of the chassis for the high-voltage terminal on the ignition coil.

Three-terminal ignition coils can be obtained from any automotive supplier or an automotive junkyard. Just about any 12-volt, three-terminal coil will work.

The most-costly component in the assembly is the plastic chassis. The overall dimensions are 3.25 inches high, 6.25 inches deep, and 8.0 inches wide. If you wish, the chassis, as well as wired and tested units, can be purchased from the supplier mentioned in the Parts List.

The setup used in making a Kirlian photograph is shown in Fig. 4. The film is placed on the board mounted to the top of the unit, and the specimen is placed on top of the film. If the specimen to be "photographed" is inanimate, such as a leaf or a piece of metal, it should be grounded for best results. Any earth ground that you can connect a wire to will work fine. In any event, the specimen is placed between two sheets of thin (0.010-inch) transparent plastic, and the "sandwich" is then placed on the film.

Never ground a living creature, including yourself. Doing so can subject the "specimen" to a very nasty shock. When dealing with living creatures, take special care to prevent any contact with a ground.

One note about the ignition coils high voltage terminal: To the uninitiated, the location of that terminal may not be apparent at first glance. It is located within the tube-like protuberance at the top of the housing. When the coil is used in it's normal application, a spark-plug wire is placed in the opening at the top of the tube so that it makes contact with the terminal inside; the wire is held in place by friction. For our application, the lead from the copper-clad board must make good contact with the high-voltage terminal.

You will note from Fig. 1, that the circuit uses two ON/OFF switches, S1 and S2. Switch S1 is the unit's main power switch; when it is in the ON position, power is supplied to the neon lamp, NE1, and the circuit is placed in standby mode. The neon lamp does more than give a visual indication of the state of the unit. Since we are working with photographic film, the circuit must be used in a relatively dark, light-tight room. Obviously, that can present problems in using the unit. If the controls are clustered around the lamp (as shown in Fig. 5), the lamps gives off just enough light to make identification of the controls possible in a dark room without adversely affecting the Kodalith film. When you use color film, you should block the light from the film. Switch S2, the discharge switch, is a normally open momentary. It is used to control the balance of the circuit.

To make a Kirlian photograph, turn on the unit using S1, turn out the lights, place the film and specimen on the top plate as discussed previously, and make the exposure using S2. As a guideline, start with an exposure time of 10 to 15 seconds. It is likely that you will do a lot of trial-and-error experimentation with both the exposure time and frequency (which is adjusted using R1) before you will obtain satisfactory results.

The author has had good results with two types of film: Kodak 6118 Ektachrome and Kodalith 2556. The Ektachrome film will give you spectacular color transparencies, such as the one accompanying this article. However, it can be difficult to work with and to develop. Unless you have a photographic darkroom and are equipped for developing that type of film, you will probably want to take it to your local photo-developing store.

Kodalith 2556 ortho film type-3 is a high-contrast, black-and-white graphics-art film that may be familiar to those who make their own PC boards. The results are less spectacular, as shown in Fig. 6, but that film's light requirements are less exacting (a photographic safelight or the red neon lamp on the unit can be left on when handling the film), and the processing is much simpler, requiring just three basic chemicals. The author found the right exposure using the Kodalith first, and Ektachrome for the final exposure. **R-E**

ADVERTISING INDEX

EXPERIMENTERS ELECTRONICS HANDBOOK does not assume any responsibility for errors that may appear in the index below.

Gernsback Publications, Inc.
500-B Bi-County Blvd.
Farmingdale, NY 11735
1-516-293-3000
Fax 1-516-293-3115
President: **Larry Steckler**
Vice President: **Cathy Steckler**

For Advertising ONLY
1-516-293-3000
Fax 1-516-293-3115

Larry Steckler
publisher
Arline Fishman
advertising director
Shelli Weinman
advertising associate
Lisa Strassman
credit manager
Christina Estrada
advertising assistant

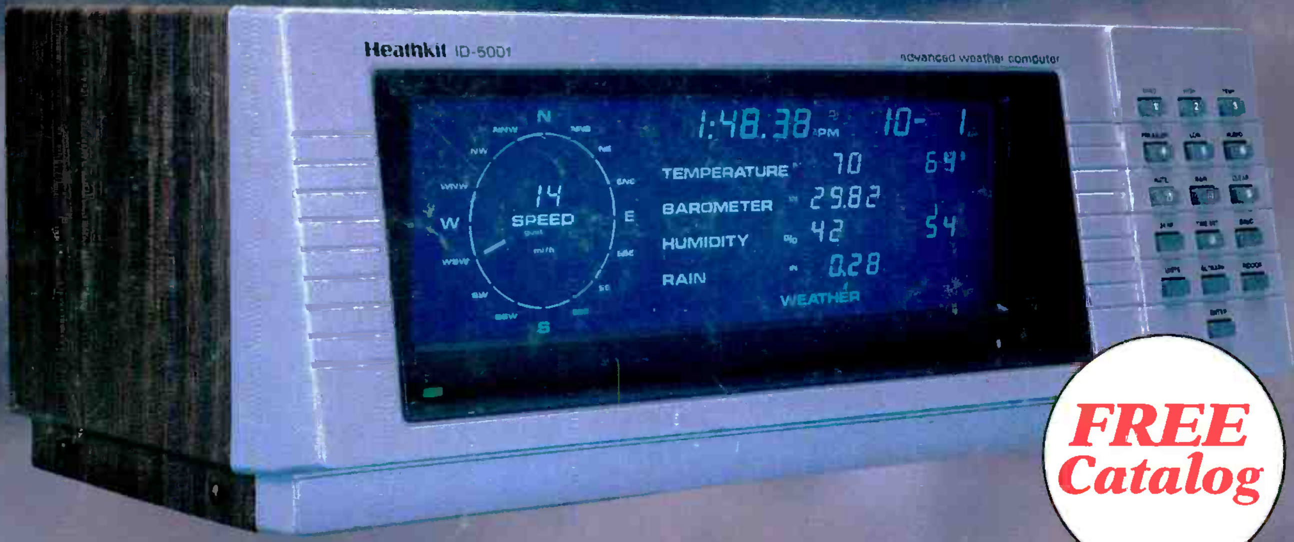
SALES OFFICES

EAST/SOUTHEAST
Stanley Levitan
Eastern Sales Manager
Radio-Electronics
259-23 57th Avenue
Little Neck, NY 11362
1-718-428-6037, 1-516-293-3000

MIDWEST/Texas/Arkansas/Okla.
Ralph Bergen
Midwest Sales Manager
Radio-Electronics
540 Frontage Road—Suite 339
Northfield, IL 60093
1-312-446-1444
Fax 1-312-446-8451

PACIFIC COAST/ Mountain States
Marvin Green
Pacific Sales Manager
Radio-Electronics
5430 Van Nuys Blvd. Suite 316
Van Nuys, CA 91401
1-818-986-2001
Fax 1-818-986-2009

Heathkit®



FREE Catalog

Track The Weather With Your Own Personal Weather Station

Don't let the weather catch you off guard. Plan your activities using the precision-crafted Heathkit® ID-5001 Advanced Weather Computer.

Powerful enough for commercial use, the ID-5001's striking cobalt blue liquid crystal display indicates wind speed, humidity, rainfall, high and low temperatures, and more. You'll find at your fingertips everything you need to keep you up-to-date on changing climate conditions.

The Advanced Weather Computer is an intelligent system, sounding alarms whenever threatening weather approaches. In addition, the ID-5001 is the only weather instrument known which automatically averages wind speed and direction to FAA/NWS standards and gives true values for wind speed and wind direction.

Includes precision wind sensor assembly.

The ID-5001 features: • High accuracy digital barometer • Display of indoor and outdoor temperatures • Push-button display of minimum and maximum readings • 32-point wind direction resolution • Display of indoor and outdoor relative humidity • Digital clock/calendar and much more!

Attractive enough to display in your home, the Advanced Weather Computer is just one of many exciting products in the Heathkit catalog. You'll discover 108 color pages packed full of electronic products in kit and assembled form including TVs, VCRs, computers, test instruments, as well as our new high-tech audio line.

The ID-5001 and all our other fine electronic products can be found in our *FREE* Heathkit catalog. For your copy, call 24 hours a day TOLL FREE:

1-800-44-HEATH

(1-800-444-3284)

Heath Company

CL-797R1 A subsidiary of Zenith Electronics Corporation

CIRCLE 14 ON FREE INFORMATION CARD