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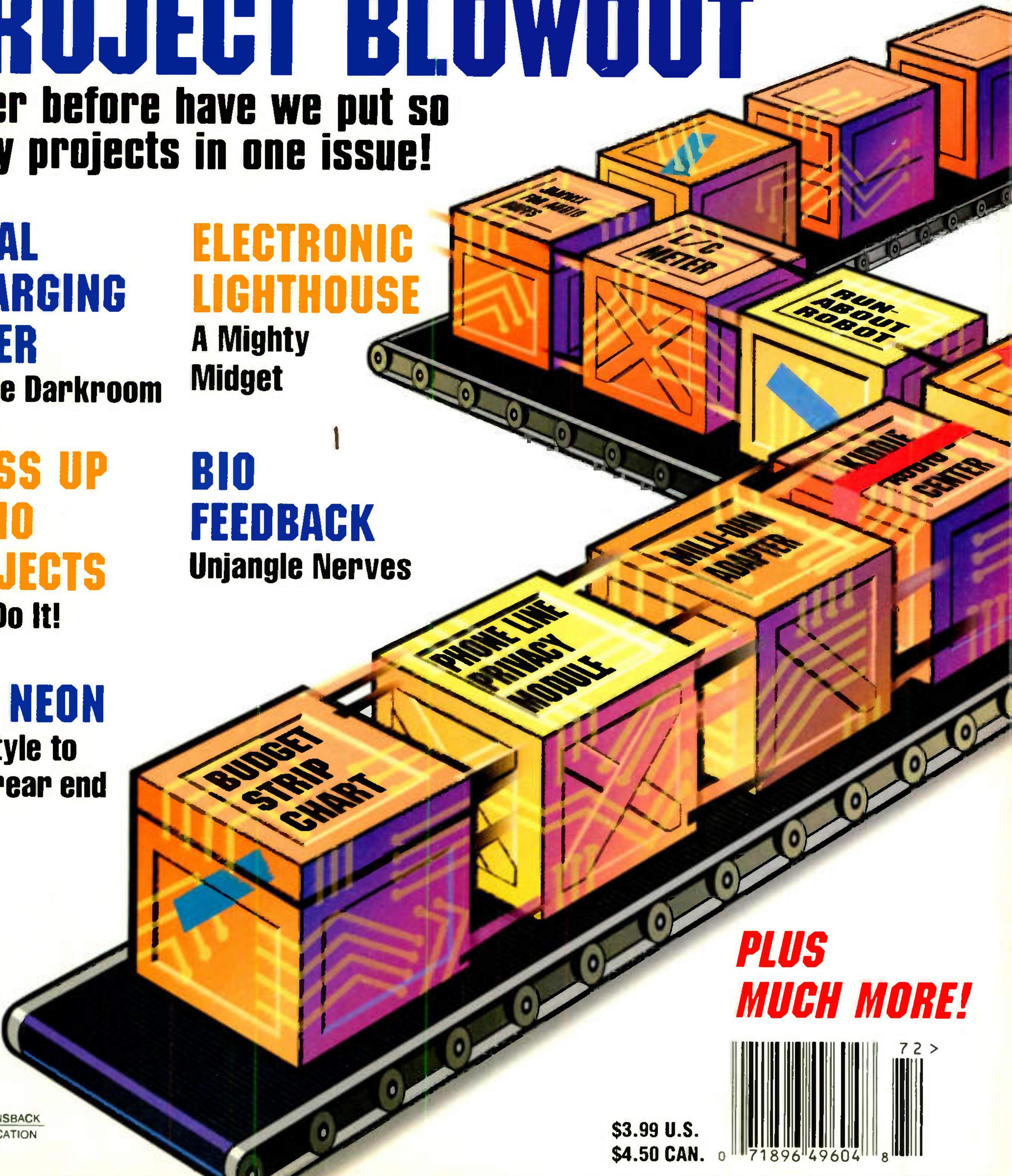

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POPTRONIX Experimenter Handbook

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POPTRONIX
Experimenter Handbook

SUMMER, 1997

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Editorial

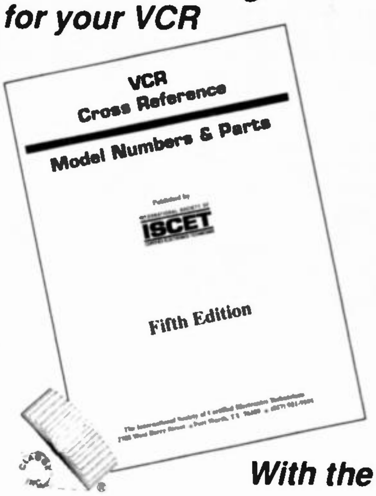
We hear of many kinds of disasters each day. Those that make the newspapers and TV are major ones, and they seriously affect the lives of many people. However, the minor tragedies that happen to all of us are usually overcome in a few hours or a day or two. Those that aren't subdued are usually imaginary incidents, pending tragedies, that are about to happen. For example, I fear the day when our publisher will come into my cubicle, smile, and say, "Julian, you're being promoted. You don't have to work on authors' project manuscripts anymore!"

Where did I go wrong? What greater fun can there be than tinkering with an electronic gadget? Some author, somewhere, dreamed up an exotic application from a common, available chip or component, and I get to play with it! I get to power it up, use it, and even talk to the author about the theory of operation and the design problems he faced. I get to edit the manuscript, take the photos, check the parts list. Why would anyone want to take all this away from me? Where did I go wrong?

I will overcome this imaginary, pending tragedy with a plan I now have working. I can't give you the details, but I ask you to forgive me for certain small errors that pop up from time to time in this magazine. For example: You will spot a misspelling, notice a misplaced comma, or even see the publisher's name omitted from the title page. I assure you that all the technical details, parts lists, diagrams, etc., will always be correct to the best of my ability. With this happening, I expect the publisher to burst into my office and say, "Julian, how do you expect to get ahead in this company when you produce sloppy text. Son, you are in a dead-end job!"

He will make my day!

Julian S. Martin
Editor



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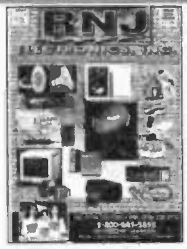

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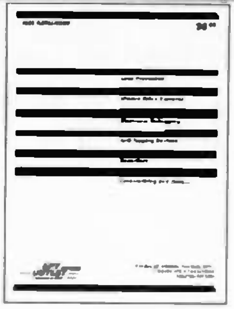

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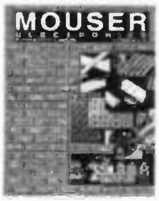

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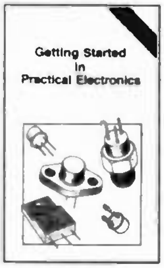

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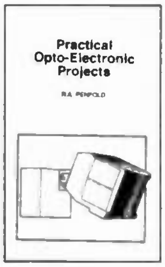

If you shun opto-electronic projects for lack of knowledge, this is the book for you. A bit of introductory theory comes first and then a number of practical projects which utilize a range of opto devices, from a filament bulb to modern infrared sensors and emitters—all are easy to build.

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PRODUCTS & BOOKS

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Sound Stage features the RS-929 Dolby Pro Logic A/V receiver, a Studio 60 CD changer, the FVH-4913 four-head hi-fi VCR, a six-speaker system with powered subwoofer, a 32-inch TV, and a unified A/V remote control. The customized black-and-wood-trim cabinet is designed to complement the system's components.

The A/V receiver provides 115 watts by three channels in the Pro-logic mode and 120 watts by two channels in the stereo mode. The Studio 60 safely stores up to 60 CDs. Preset or user-input categories and subcategories make it easy to find the disc you want. The 10-inch powered subwoofer features a 100-watt RMS power amplifier with level control, variable crossover, and auto power. The main two-way speakers handle up to 150 watts of power with 6.5-inch woofers and three-inch tweeters. For center-channel audio, a unique mirrored 6.5-inch, full-range speaker system is incorporated in a chambered configuration with the main speaker cabinets. All front speakers are magnetically shielded. The surround/rear two-way speakers have 4.5-inch woofers and three-inch tweeters for up to 120 watts of peak music handling.

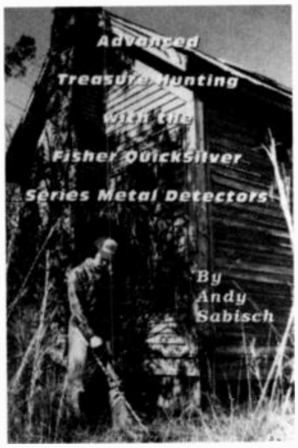
The complete HT-732AV1 Sound Stage home theater system has a suggested retail price of $2799.95. For those who already own a large-screen TV, the system is also available as model HT-732A1 without a television. For more information, contact Fisher, 21605 Plummer St., Chatsworth, CA 91311-2329; Tel: 818-998-7322; Fax: 818-701-4149.

CIRCLE 30 ON FREE INFORMATION CARD

ADVANCED TREASURE HUNTING WITH THE FISHER QUICKSILVER SERIES METAL DETECTORS

by Andy Sabisch

Although the focus of this book is upon Fisher QuickSilver metal detectors—the CZ-5, CZ-6, CZ-6a, and CZ-20, to be precise—most of the pointers it offers will be useful to any dedicated "detectorist." For instance, readers learn how to familiarize themselves with their metal detectors by creating a "test garden"—burying an assortment of coins, jewelry, and the types of trash (flip tops, aluminum foil, nails, screw tops) that give false signals.



The book explains how to search neighborhood parks for rare, old coins lost long ago and still awaiting discovery. It describes the techniques used to hunt for lost jewelry and coins in the shallow water of local swimming holes, lakes, rivers, and the ocean. The book also covers competitive treasure seeking, electronic prospecting, relic hunting, and bench-testing a detector.

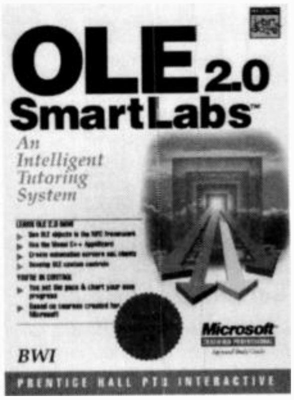
The CZ QuickSilver metal detectors are described in detail. The book explains how to use the target ID system to ignore coin signals and dramatically increase your gold-ring find rate. It examines the "two-frequency Fourier domain" technology behind the CZs, and provides in-depth coverage of each feature offered, including 3-tone target ID, meter ID, deep-target audio boost, and wet salt mode.

Advanced Treasure Hunting with the Fisher QuickSilver Series Metal Detectors is available for $7 plus $2 shipping and handling from Fisher Research Laboratory, Dept. PE, 200 West Willmott Road, Los Banos, CA 93635; Tel: 209-826-3292; Fax: 209-826-0416.

CIRCLE 31 ON FREE INFORMATION CARD

OLE 2.0 SMARTLABS FOR WINDOWS 95

At the heart of Microsoft's applications strategy, OLE technology is what makes Windows objects and programs work together. This tutoring system, designed by the developers of Microsoft's OLE Courseware, helps programmers learn to implement OLE, quickly and efficiently. The CD-ROM and accompanying booklet allow users to learn from their own, personalized OLE curriculum.



For those who are new to OLE, SmartLabs delivers a comprehensive, soup-to-nuts course. It covers every important element, including OLE components, containers, document behavior, the OLE registry, OLE controls and custom controls, and OLE servers. Pro-

(Continued on page 10)

PRODUCTS & BOOKS

(Continued from page 8)

grammers who already know the basics will be able to focus on just their own topics of interest for a quick refresher—SmartLabs even includes a pre-test that assesses how much the user already knows and creates a custom course based on that information. Topics covered include MFC encapsulation of OLE components and containers, OLE automation fundamentals, drag-and-drop, and integrating OLE controls into Windows programs.

SmartLabs provides hands-on training based on proven teaching principles. The course is organized into goals, tasks, and skills. The program makes sure that users understand each topic, and offers extra reviews for those who need them. Users create real, OLE-based applications. SmartLabs works from within the user's C++ compiler, just like a Help file, allowing code to be run at any time.

OLE 2.0 SmartLabs for Windows 95 costs $69.95 and is published by Prentice Hall PTR Interactive, Upper Saddle River, NJ 07458; Web site: http://www.prenhall.com.

CIRCLE 32 ON FREE INFORMATION CARD

KEYBOARD/MOUSE STATION

Thinking of getting a new workstation to free your desktop of all your PC paraphernalia? Think again. *Rubbermaid's 625M Underdesk Keyboard & Mouse Superstation* can clear away some of the clutter—and reduce the risk of potential repetitive motion industries at the same time.

Most workstations are at a standard 30-inch height, yet ergonomists recommend that users position their keyboards and mouse pads at a lower level. Wrist supports are also recommended. The Superstation is unlike traditional keyboard drawers in that it features an oversized, adjustable mouse surface that can be positioned for right- or left-handed use. The mouse

(Continued on page 108)

POPTRONIX Experimenter Handbook
Summer 1997

Designed to lower the audio blasting that goes with TV-commercials, the unit also serves as a studio sound manipulator!

JULES RYCKEBUSCH

Stereo Compressor

An Audio Compressor is an essential tool for audio processing and it is commonly found in recording studios. Most recording studios have a selection of compressors, each chosen for some specialized feature or nuance. Your home may not be a professional recording studio, but you do need our Stereo Compressor, so read on.

As the device's name implies, the Stereo Compressor compresses or limits the dynamic range of an audio signal. (Make sure you read the sidebar How Compressors Work.) In a recording studio, compressed audio prevents tape-recorder overload during loud passages without losing quiet passages in the noise floor (hiss). Before compressors were invented, the recording engineer would ride the gain by manually adjusting the signal level. Compressors are commonly used to record vocalists and acoustic instruments, especially those that have large dynamic ranges. Compressed audio can also be used to create artificial effects while recording, such as increasing the apparent sustain of an instrument or completely squashing the level of a signal. We will learn how to accomplish these audio effects later.

Compressors can also be abused. Have you ever wondered why TV commercials sound louder than regular TV programming? Well, the producer of the offending TV commercial has used a large amount of compression on the audio tracks and then boosts the gain to just below distortion level. The end result is an apparent increase in loudness to the listener. This works because modern TVs and home theaters have a large dynamic range for the audio signal.

Film and TV producers take advantage of the dynamic range available to them by recording normal conversation and background sounds 6 to 12 dB below the maximum signal level. Then for dramatic effect, music and sound effects such as explosions can be that much louder than the dialogue track. This is very noticeable when watching a movie on a high-fidelity video tape recorder. In fact, for late-night viewing, when you are *trying* to be quiet, you have to turn the TV up just to hear the dialogue and then quickly turn it down when the car chase scene comes crashing into your living room. But, with the Stereo Compressor, you don't need to constantly ride the gain. It will automatically do that for you!

When you patch the Stereo Compressor between your hi-fi VCR and your stereo sound system, you can enjoy listening to movies late at night in full fidelity, at low volume, without being blasted out of your chair when Rambo raids your living room. You can also use the unit to prevent tape (recording) overload while making home audio recordings.

How it is done

The block diagram of the Stereo Compressor is shown in Fig

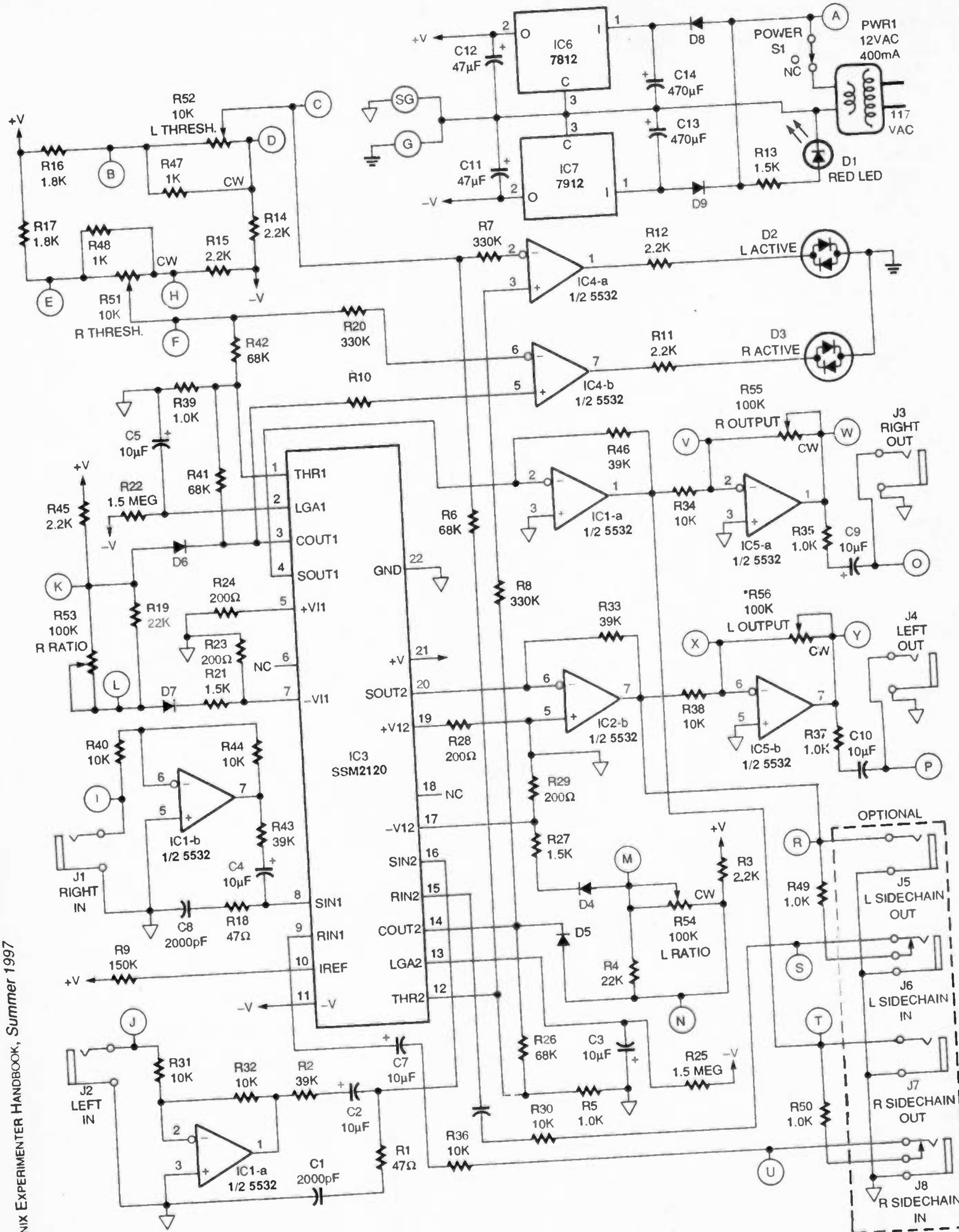


FIG. 2—SCHEMATIC DIAGRAM for the Stereo Compressor. When the sidechain jacks are included, the unit is designated as the Stereo version by PAiA. The Home Theatre version eliminates the jacks.

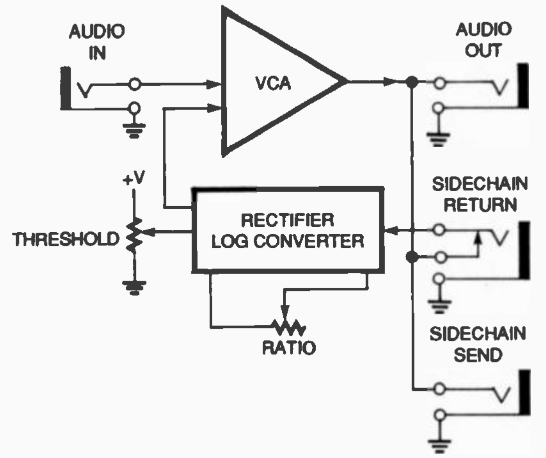


FIG. 1—FUNCTIONAL BLOCK DIAGRAM of the Stereo Compressor. Side-chain portions of the diagram may be omitted from the unit's construction.

1. The input signal is fed to a voltage-controlled amplifier (VCA) that has a nominal gain of unity. Some of the output signal is fed to a precision rectifier followed by a logarithmic converter circuit. The output of this block is a DC voltage proportional to the log of the average level of the input signal. By sending some of this DC control voltage to the VCA we automatically reduce the gain of the VCA when the input signal exceeds a user-determined threshold level. It is important to note that we determine the signal level after the VCA and not before. This allows the output level to increase and sound normal, but not increase as much as the input signal does. By varying the amount of feedback we adjust the compression ratio, which in conjunction with the THRESH control, determines the operating characteristics of the compressor.

The optional *sidechain* jacks permit external processing of the audio signal or substituting a completely different audio signal as the control signal. This add-on circuitry lets the user experiment and achieve some useful audio effects.

How it works

Figure 2 is the schematic diagram of the Stereo Compressor. The device has two independent channels of compression, right and left. The heart of the circuit is the SSM2120 dual dynamic range processor integrated circuit IC3. The SSM2120 features two complete dynamic range processors. Each one consists of a voltage-control amplifier, a logarithmic converter, and a precision rectifier. The chip also features a dynamic range of 100 dB at only .01-percent total harmonic distortion at +10 dB input. The remainder of the Stereo Compressor circuit consists of input and output buffers, the control circuitry and the comparator.

Since the electronics for both channels is identical, we will look at the right channel in detail. The input audio signal from J1 goes to an inverting buffer circuit consisting of R40 and R44 and IC1-b. Its output signal (IC1-b, pin 7) is coupled to the signal input on IC3, pin 8, via C4, which blocks any DC component of the input signal. The SSM2120 chip is actually looking for a current input source, and R43 provides the proper amount of current to the chip. The RC filter formed by C8 and R18 eliminates any stray RF interference.

The output signal from the internal VCA of IC3 (pin 4) is actually a current signal. It is restored to a voltage signal by current-to-voltage converter IC1-a and its feedback resistor R46. The signal from IC1-a, pin 1 is routed to output stage amplifier IC5-a via R34. The output signal from IC5-a, pin 1, is coupled via R35 and C9 to jack J3. OUTPUT potentiometer R55 lets you adjust the unit's gain.

The output signal is also sent to the rectifier input (IC3, pin 9) via R36 and C7 either directly, or via the optional side-chain jack circuitry including R50. The side-chain jacks consist of a standard 1/4-inch open-circuit OUT phone jack (J7) and a 1/4-inch IN phone jack (J8) with a normally-closed switch built into them. These jacks form a normalized patch point for additional audio processing. With nothing plugged into J8, the signal path is uninterrupted. By inserting a phone plug into the side-chain IN jack (J8), the normal signal path is broken and either the processed original signal is sent to the rectifier input, or a completely different (new) signal is sent to the rectifier input. We will later see how to use this feature for some really powerful audio processing.

But first, the control side of the house. Resistor R22 provides a reference current to the log-averaging circuit within IC3 via pin 2. It also forms an RC timing circuit with C5. This RC circuit determines the response time for the compressor. The time constant is set so that the compressor will respond rapidly without distorting.

Potentiometer R51 along with other resistors, develops the threshold level signal. The voltage from the wiper of R51 is sent to the threshold input of IC3 (pin 1) via R42. Another resistor R41 across the threshold pin 1 and the control output pin 3 establishes the internal gain of the control stage. The control output signal from pin 3 goes to a voltage-divider network centered around potentiometer R53 then to the inverting VCA input of IC3 (pin 7). A positive voltage on this input reduces the VCA gain, which is what we need to make the compressor work. Note that both the inverting and non-inverting control inputs (pins 5 and 7) are tied to ground via R5 and R7. The control inputs must remain close to ground potential for proper operation. A 6-millivolt change in voltage at these control pins causes a 1 dB change in VCA output. Diodes D6 and D7 ensure a unipolar control voltage. Potentiometer R53 is the compression RATIO control. It gives

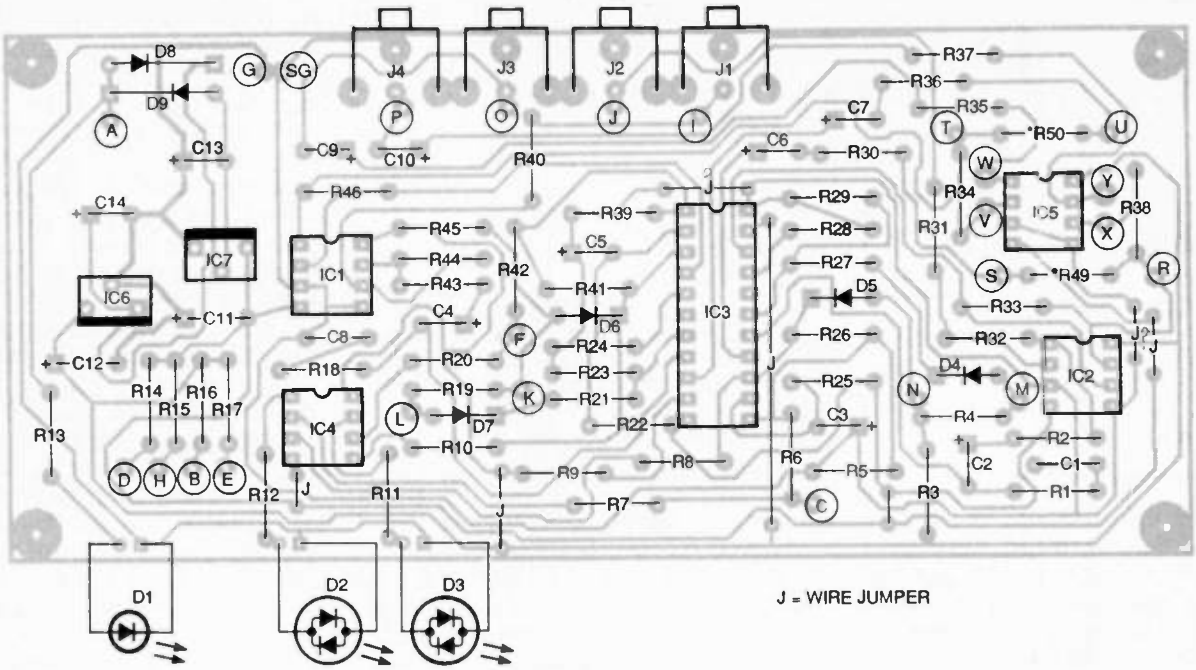
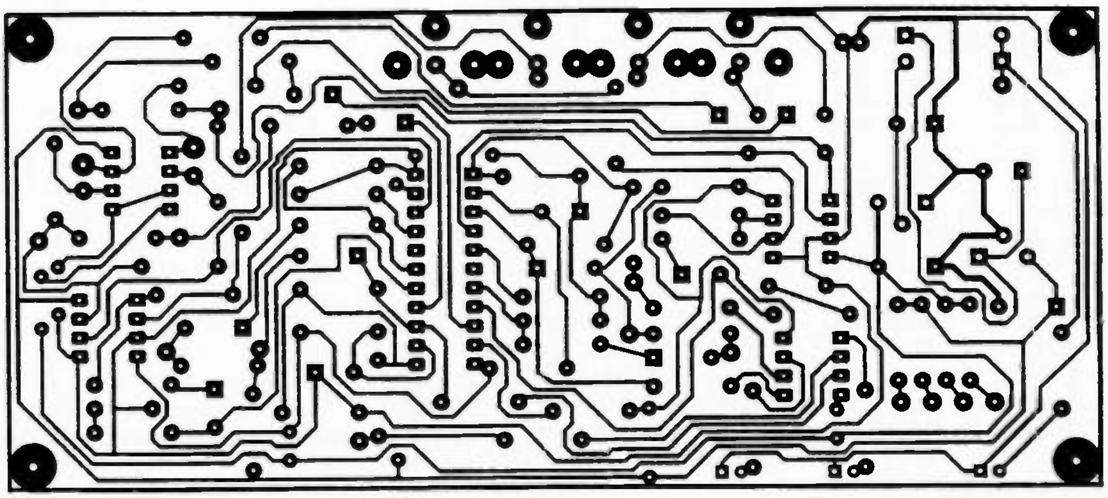


FIG. 3—PARTS PLACEMENT on the PAiA PC board. The silk-screen markings on the board provide an additional assist for the assembler. Resistors R49 and R50 are shown in place for the Home Theatre version. The studio version of the Stereo Compressor has these resistors mounted on jack terminals.



BOTTOM VIEW of the PC board, shown same size, details the foil pattern home-brew experimenters must assemble.

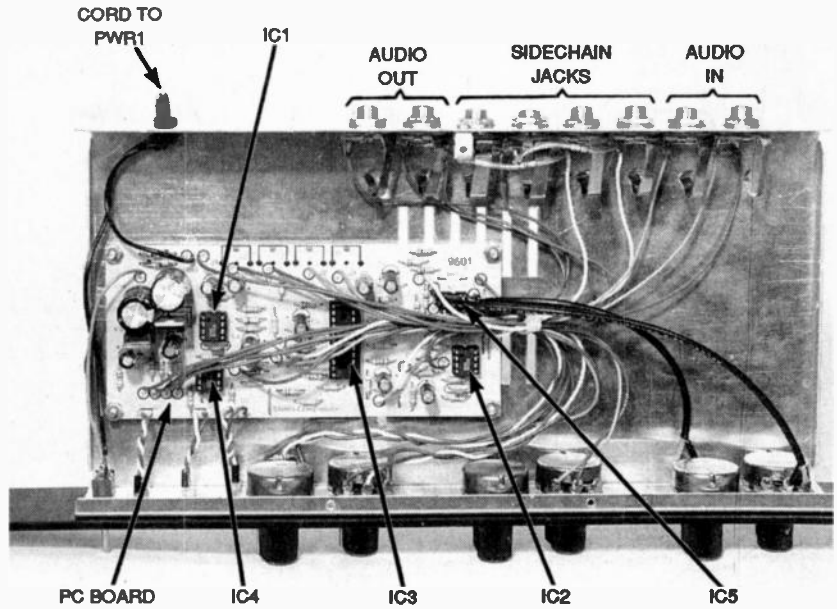
an adjustable compression ratio of 2 to 1, all the way to about 25 to 1.

The last portion of the circuit is the comparator formed by IC4-b, two input resistors R10 and R20, a bicolor light-emitting diode LED3, and current limiting R11 for the light-emitting diode D1. Notice that op-amp IC4-b is a comparator. Normally it is unwise to use an op-amp for this purpose because the output stage saturates, which will slow down the comparator's response time. (Note: D1 through D3 are light-emitting diodes or LEDs. This symbol identification code was used in this story in order to agree with PAiAs kit symbolism.) In this instance, we need to get an output that changes from one supply rail to the other. This makes dual-LED interfacing very simple. Along with being an excellent audio op-amp, the NE5532 functions well as a comparator in this application.

The power supply circuit consists of an externally connected Wall-Wart 12-volt AC transformer PWR1 and associated diodes and capacitors. (See top-right corner of Fig. 2.) One side of the 12-volt AC line is tied to ground and the hot side goes to half-wave rectifiers D8 and D9. These diodes deliver bipolar, unfiltered DC, and each supply is filtered by electrolytic capacitors C13 and C14. Even though

PWR1 is rated at 12-volts AC, the filter capacitors charge closer to the peak value of the 12-volt AC, and just about 15-volts DC is delivered to the +12-volt DC regulator IC6 and −12-volt DC regulator IC7. The output of each voltage regulator section is filtered for decoupling purposes by electrolytic capacitors C11 and C12.

Two ground systems are used in the Stereo Compressor, one for power return and the other for signal return. This design practice reduces the possibilities of ground loops that introduce unwanted AC hum to the audio signals.

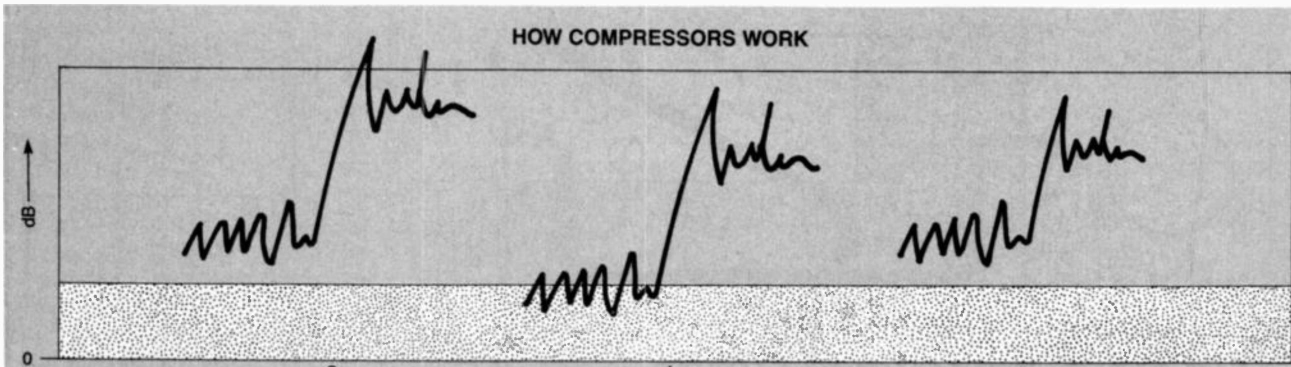


BIRD'S EYE VIEW of the Stereo Compressor before the chassis cover is secured in place. Note the neat interconnection between the PC board and front and rear panels.

Construction

Assembly of the Stereo Compressor is relatively straightforward. PAiA Electronics has complete kit of parts available for the Home Theatre version (no sidechain jacks) and the Studio version (includes sidechain jacks). If you want to roll your own, the circuit can be built on a Radio Shack experimenter's PC board or you could copy the same-size drawing of the circuit board provided in these pages and make your own board. The SSM2120 chip (IC3) is available from several sources including PAiA, Newark and Allied. The other parts are common garden variety types available from local and mail-order parts suppliers. If you do breadboard the circuit, make certain you use good grounding techniques. Return all signal and power grounds to one common point to eliminate any ground loops. Should you elect to use the PAiA circuit board, the circled letters in Fig. 2 are termination-point identifiers for hookup wires that run from the front and rear panel-mounted parts to the PC board. These interconnections are shown in Figs. 3 and 4.

The three light-emitting diodes D1 through D3 require lead extensions made from #22 insulated hookup wire. Mark the leads so that you can readily identify the anode and cathode terminals. Twist the leads of the LEDs and cut their length so that the LEDs will fit into the



The gray band is the usable dynamic range of a quality audio tape. The dotted band below the gray band is the inherent tape noise (hiss) common to all tapes. The range (height) of these bands varies with tape quality. The audio signal in (a) shows a loud passage that is too loud for the listener, so the volume was turned down (b) to lower the loud passage in the tape's dynamic range. However, the quiet passage was lowered into the noise band common to all tapes. The quiet passage is either lost in the hiss or will sound appalling when played back. A compressed audio signal of the same passage (c) permits the quiet passages to be recorded above the hiss in the tape's usable dynamic range while the loud passage is reduced in volume for the listener's pleasure.

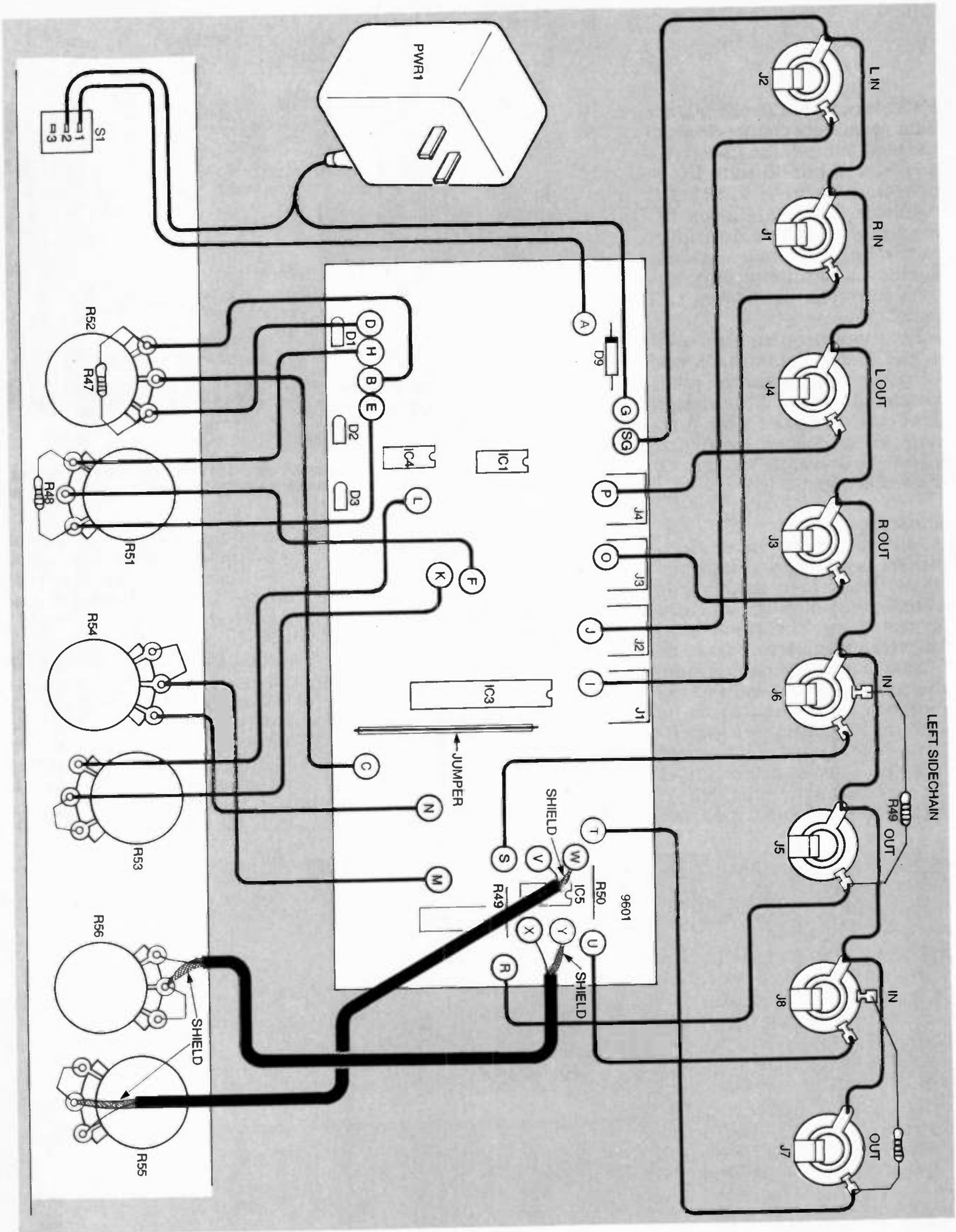


FIG. 4—**INTERCONNECTING THE PC BOARD** with the front and rear panel parts is simplified by PC board circled markings. The long cable runs from the board's output stage to two front-panel controls, which requires using thin, flexible, audio, coaxial cables such as the RG-174/U type. The unit's step-down power transformer PWR1 is contained in a wall-plug casing that plugs into a power outlet.

three holes provided for them on the front panel. These holes are between the POWER switch S1 and the THRESH potentiometer R52 (See Fig. 4).

If you choose to omit the sidechain option (*A big mistake—Editor*), eliminate jacks J5 through J8. Resistors R49 and R50 normally mount on the terminals of jacks J5 and J7. When the sidechain jacks are omitted, these 1000-ohm resistors are connected to terminals R and S and S and T, respectively, on the PC board.

The light-emitting diodes (D2 and D 3) combined ground path must return straight to the power supply common. The LED's comparatively high current that is switching on and off in this ground return could cause popping sounds in the audio output when connected to signal or even power grounds.

Testing

After you have wired the Stereo Compressor, check for solder bridges, cold-solder joints, incorrect component polarities and all the other nasty errors that prevent a circuit from functioning normally and sometimes result in self-destruction. Do this before applying power!

The best way to test the Stereo Compressor is to connect it between a CD or cassette deck and your hi-fi audio system. Set the RATIO control (R53) fully counter clockwise and the THRESH control fully clockwise. Set the OUTPUT control to about ten o'clock. These are the minimum settings. You should hear undistorted, noise-free audio. Both LEDs (D2 and D3) should be green. If there is distortion or noise, you need to go back and check your wiring and component polarities. If everything sounds good and you have green LEDs, then everything should be working fine. Note: with no input signal the LEDs may drift slightly and not track the THRESH control.

Once everything is working, slowly rotate the THRESH control. At some point around mid-rotation, the LEDs should start to indicate red. This means compression is starting to occur. Rotate the RATIO control clockwise. You should hear a decrease in volume as the compressor squashes the signal. At full counterclockwise rotation there might be some distortion. This is to be expected.

Using the compressor

The main use for a compressor is to keep levels from getting out of control while recording vocals and acoustic instruments. This takes a little experimentation. For a vocalist I usually start out around a 4-to-1 compression ratio with the THRESH set so the LED indicates red when the singers reach their nominal level. This way if they hit a note 20 dB higher than nominal (which would definitely clip most tape decks) the signal out of the compressor only increases by about 5 dB.

The Stereo Compressor can increase the apparent sustain of a sound. By using a large amount of compression and restoring the level with the OUTPUT control, the compressor will initially reduce the output signal by a large amount. As the input signal level decreases, the amount of compression will decrease and the output level will

PARTS LIST

All fixed resistors are ¼-watt, 5%.
R1, R8—47-ohms
R2, R33, R43, R46—39,000-ohms
R3, R11, R12, R14, R15, R45—2200-ohms
R4, R9—150,000-ohms
R5, R35, R37, R39, R47-R50—1000-ohms
R6, R26, R41, R42—68,000-ohms
R7, R8, R10, R20—330,000-ohms
R9—150,000-ohms
R13, R21, R27—1500-ohms
R16, R17—1800-ohms
R22, R25—1.5-Megohm
R23, R24, R28, R29—200-ohms
R30-R34, R36, R38, R40, R44—10,000-ohms
R51, R52—10,000-ohm panel-mount potentiometrer
R53-R56—100,000-ohm, panel-mount potentiometer

Capacitors

C1, C8—2000-pF, ceramic disk
C2-C7, C9, C10—10-µF, 16-volt, electrolytic
C11, C12—47-µF, 16-volt, electrolytic
C13, C14—470-µF, 25-volt, electrolytic

Semiconductors

IC1, IC2, IC4, IC5—5532 dual low-noise op-amp
IC3—SSM2120 dynamic range processor
IC6—7812 +12-volt regulator
IC7—7912 –12-volt regulator
D1—Light-emitting diode, red
D2, D3— Light-emitting diode, bi-color, red and green
D4-D7—1N4148 silicon signal diode
D8, D9—1N4001 silicon power diode

Miscellaneous

J1-J4—Jack, RCA-phono, PC-mount (Home Theatre version only)
J1-J5, J7— Jack, ¼-in., monophone, panel-mount (Studio version only)
J6, J8—Jack, ¼-in., mono-phone, closed-circuit, panel-mount (Studio version only)
PWR1—Wall-Wart 12-volt AC transformer
PC board, wire, audio coaxial cable (see text), knobs, hardware, case, solder, etc.

The following are available from PAiA Electronics, 3200 Teakwood Lane, Edmond, OK 73013. Tel: 405-340-6300. FAX: 405-340-6378. Email: http://www.paia.com.

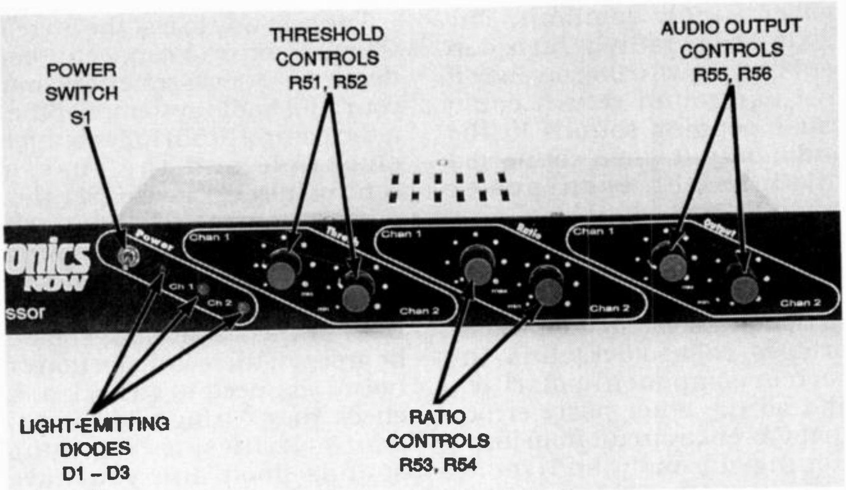
Complete kit of electronic components including circuit board, knobs, wall-plug transformer, phone jacks, etc., but less case—US$74.75 #9601K

Home Theatre desk-top case, punched, anodized, legended, with wood end caps and hardware—US$19.25 #9601DTC

Studio rack-mount case, standard 19-in. wide, 1-¾-in. high, punched, anodized, legended front panel. Includes 1/4-in. jacks and all hardware—US$29.50 #9601RMC

Please add US$7.00 for shipping and handling for kit orders in the USA.

PC board only—$22.50 #9601PC (shipping prepaid)



FRONT PANEL view of the Stereo Compressor. Since the unit can be used in the recording studio, channel reference is made to 1 and 2 instead of LEFT and RIGHT, respectively.

remain relatively constant. The Beatles used this on the final piano chord in A Day In The Life to make the sound linger on.

To use the compressor as a limiter while recording, set the RATIO to about 20 to 1 and set the THRESH control so that the LEDs momentarily change from green to red on peak signals. This will preserve as much dynamic range as possible.

When the Stereo Compressor is connected to a hi-fi VCR for late night viewing, set the RATIO control as high as possible without distorting and set the THRESH control to change the LED's color during quiet spoken passages. This will allow you to preserve the fidelity and stereo spread of the movie sound track, hear all the dialog, but not get blown out of your seat when the F-114 does a strafing run in your living room. The above settings are intended to be starting points, so feel free to experiment.

Using the sidechain jacks

Along with regaining control of your hi-fi VCR, there are all sorts of useful functions available via the side chain jacks. By patching an audio processor in the sidechain jacks, all sorts of cool thing are possible. One of the most useful is creating a *de-esser*. This is a device used to remove sibilance from vocals. Sibilance is that nasty Shhhh sound that occurs when S words are spoken or sung, because of the way S sounds are formed in the human vocal track.

When we form an S sound, air passes between the teeth and tongue forming a burst of white noise and a short blast of air. If the speaker or vocalist is close to the microphone, this is picked up as a brief overload and noise burst. This burst of sound mostly contains high frequencies. By setting an equalizer to boost high frequencies and patching it into the side chain, the compressor will drastically compress the signal when the high frequencies are present, but act normally when they are not.

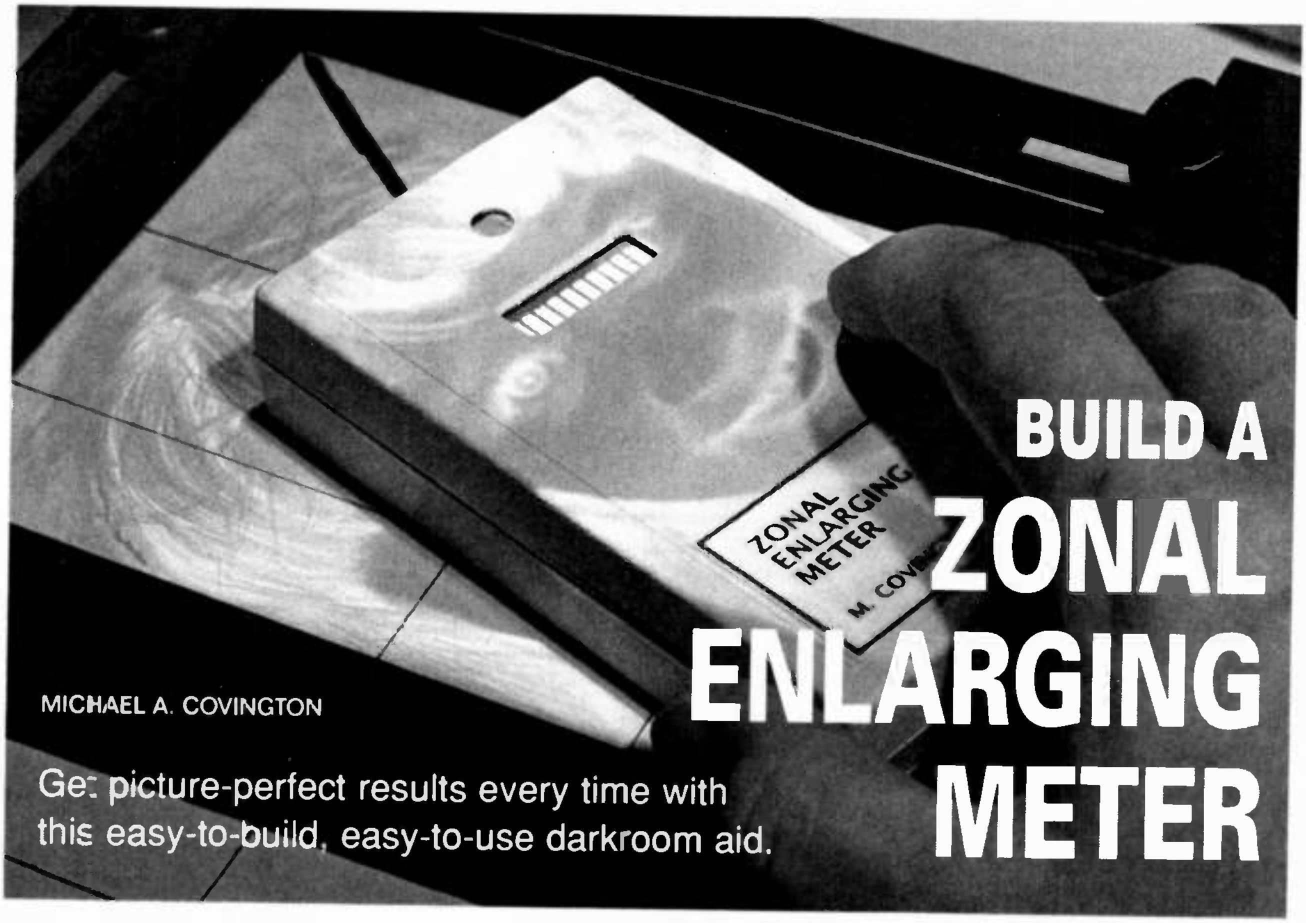
You cannot eliminate sibilance, but it can be minimized with a de-esser. Any equalizer will work. The best way to figure out what frequencies to boost is to listen to the audio through the equalizer. Start boosting until you have noticeably increased the sibilance. Anything above 3 kHz usually works; you may have to experiment. A similar problem, although at the other end of the audio spectrum, relates to P and B thump sounds. These can be minimized the same way by boosting the offending bass frequencies (less than 300 Hz) via the sidechain.

Another abuse of a compressor is to totally squash an individual instrument signal, then restore its level. This is done with vocals, snare drums, kick drums, etc. U2 does this on a lot of their recordings. By squashing instruments that have a percussive quality (such as drums or slap bass) the amount of percussive attack is increased. This occurs because the compressor does not respond instantly. The initial attack transient portion of the signal gets through the compressor unaffected while the remainder of the signal is compressed normally. The end result is overall increase in the percussive quality of the processed sound.

The Stereo Compressor can also be used as a *ducker*. A ducker is a device that reduces one signal's level based on a different signal. This effect gets used a lot on radio commercials. In this case, a different audio signal is fed into the side chain such as an announcer's voice. When the announcer speaks, the output of the compressor is reduced. This is useful for keeping background music at maximum volume, but letting the announcer's voice cut through the background music by reducing the music level when the announcer speaks. Listen closely to any radio commercial and you will notice this effect. Duckers are also great for DJs or a presentation with background music.

This ducker effect is also used in the studio to allow one instrument to cut through on a mix. If you want a particular instrument to be more noticeable, such as a snare drum, send the snare signal into the sidechain and have the rest of the mix feeding the compressor normally. When ever the snare drum plays, it will reduce the level of the main mix, increasing the presence of the snare drum without increasing its level. Just by adding a few jacks, we have increased the power of an already useful tool.

The Stereo Compressor is a state-of-the-art audio processor. It can be used to upgrade your home recordings, as an addition to a professional recording studio, or it can just allow you to enjoy late-night movies without riding the gain. Enjoy! Ω



BUILD A ZONAL ENLARGING METER

MICHAEL A. COVINGTON

Get picture-perfect results every time with this easy-to-build, easy-to-use darkroom aid.

Most enlarging exposure meters tell you how many seconds to expose print paper. The Zonal Enlarging Meter described here does not! Instead, it tells you how light or dark each area of the picture will turn out, based on a selected standard exposure time for your enlarger.

When in the photo darkroom, you position the Zonal Enlarging Meter with one hand and adjust the lens opening of the enlarger with the other hand. The exposure setting technique using the Zonal Enlarging Meter is much faster than twisting the dials on a conventional enlarging meter and it assists in obtaining a correctly exposed enlargement that fits all the brightness zones of the negative into the response range of print paper, from stark white to jet black. Ordinary enlarging meters measure only one zone which is usually a highlight or skin tone, and just guess where the other zones will fall. The Zonal Enlarging Meter lets you measure any area of the enlarger's project image on the paper surface and adjust the lens opening until that area is as light or as dark as you want it to be.

How it Works. The heart of the Zonal Enlarging Meter circuit (Fig. 1) is a National Semiconductor LM3915 LED bargraph driver IC, which lights any-

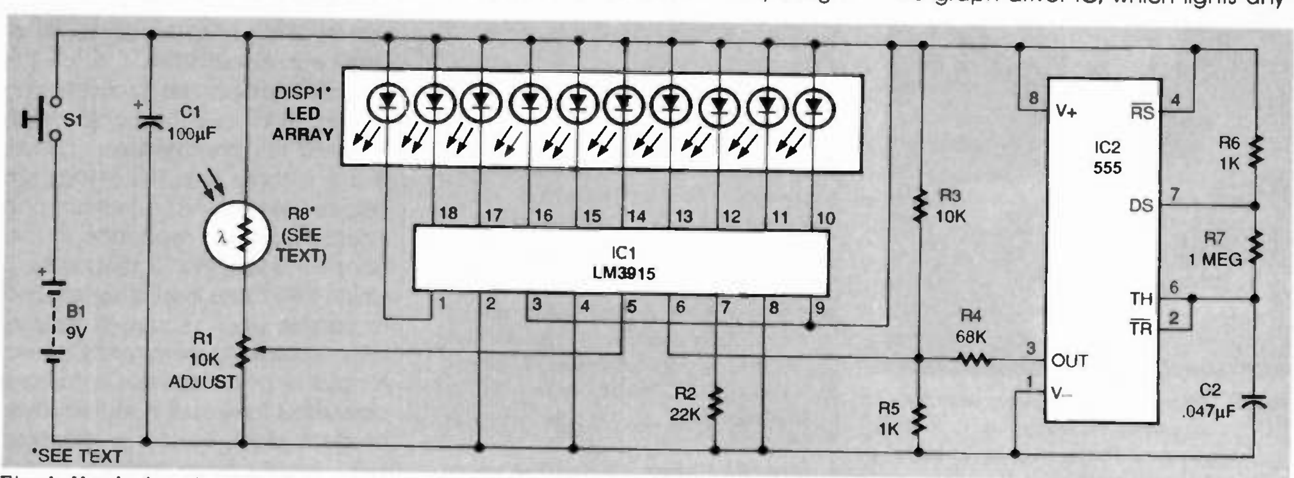
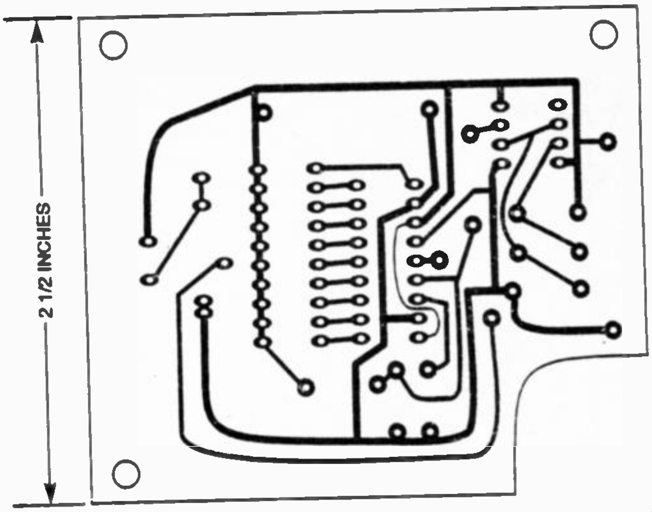


Fig. 1. Here's the schematic diagram for the Zonal Enlarging Meter. Light falling on photoresistor R8 causes LEDs in the bar-graph display DISP1 to illuminate. The number of LEDs that come on is logarithmically proportional to the light intensity.

where from 0 to 10 LEDs depending on the ratio of the input voltage on pin 5 to the reference voltage on pin 6.

The trigger voltages for the LEDs in bar-graph display (DISP1) are arranged along a logarithmic scale, just like photographic exposures, and the total voltage range is 10 to 1. Because of some nonlinearity in the photo resistor's response to light-intensity change, the range of light levels that the meter actually covers is more like 30 to 1, which is ideal because it slightly exceeds the density range of a properly exposed negative.

Each LED in DISP1's bargraph display has three states, off, flashing, and fully on; that feature lets you read a total of 20 steps rather than just 10. The flashing effect is produced by the 555 oscillator (IC2), which makes the reference voltage at pin 6 of IC1 fluctuate so that an LED that is just on the verge of turning on will flash. To simplify the circuit, you can leave out this flashing feature by omitting IC2, R4, R6, R7, and C2.



Same-size foil-pattern diagram for the meter's PC board. Carefully drill holes so that integrated-circuit chips and display chip mount quickly.

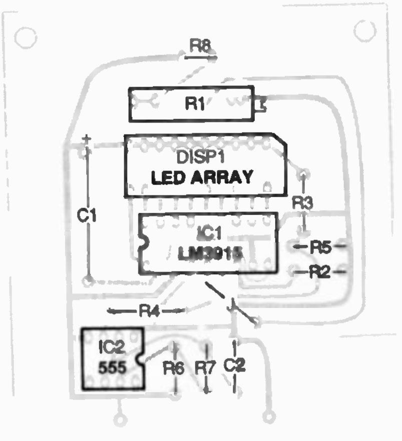


Fig. 2. Parts location diagram shows that the PC board is uncluttered and easy to assemble. Mounting holes align with the screws used to close the plastic case.

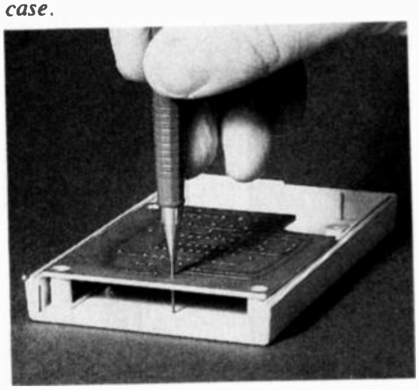


Fig. 3. Prior to inserting parts onto the PC board, extend the lead of an automatic pencil through the holes in the case cover for the LED bar-graph display DISP1 and photoresistor R8.

PARTS LIST FOR THE ZONAL ENLARGING METER

SEMICONDUCTORS

DISP1—10-LED bar-graph display, red (Mouser 351-2402 or equiv.)
IC1—LM3915 LED logarithmic-bargraph driver integrated circuit (National Semiconductor)
IC2—555 timer-oscillator integrated circuit

RESISTORS

(All fixed resistors are ⅛-watt, 5% units.)
R1—10,000-ohm, 10-turn, ¾- to 1-inch long, trimmer potentiometer
R2—22,000-ohm
R3—10,000-ohm
R4—68,000-ohm
R5, R6—1,000-ohm
R7—1-megohm
R8—Cadmium sulfide photoresistor (see text and note below).

ADDITIONAL PARTS AND MATERIALS

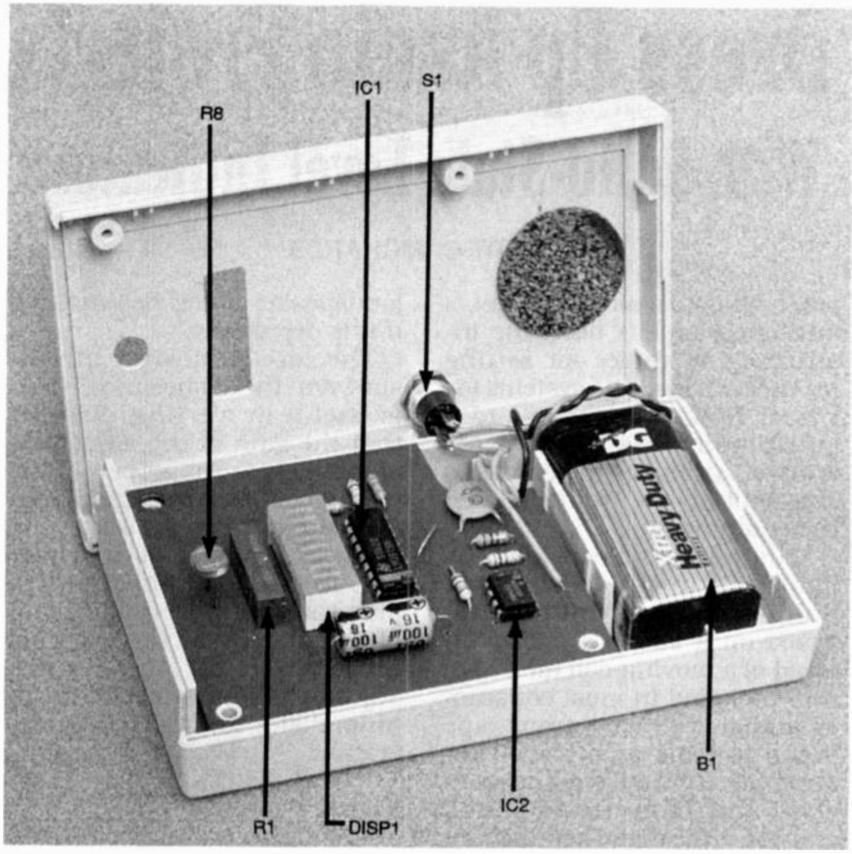
B1—9-volt transistor-radio battery
C1—100-µF, 16-WVDC, electrolytic capacitor
C2—0.047-µF, ceramic capacitor
S1—Normally-open, momentary-contact, push-button switch
Plastic-case enclosure (includes battery connector; Pac-Tec HML-9VB, RadioShack 270-211, or equiv.), PC circuit-board material as needed (see text), wire, solder, etc.

NOTE: A suitable photoresistor, type 76C59, is available from Mouser Electronics, 2401 Highway 287 North, Mansfield, TX 76063, phone 800-346-6873.

Choosing a Photoresistor. The choice of cadmium sulfide photoresistor (R8) used in the meter depends on what is available and what kind of paper and exposure time you like to use. You'll need one whose resistance is somewhere between 50K and 500K at the light level corresponding to a mid-gray tone in a picture printed on your paper with your exposure time.

One commercially available photoresistor that works well is the type 76C59 available from Mouser Electronics (see the Parts List). It's rated for a resistance of 20K to 50K ohms at a light intensity of 10 lux (1 foot-candle), and 20 megohms in total darkness. The light level for a mid-gray tone in a 5-second exposure on most fast enlarging papers is about 1 lux; at that light level, this photoresistor has a resistance of about 300K.

Another way to get a suitable photoresistor is to buy a surplus assortment and test the photoresistors until you find a suitable one. The testing procedure is simple. First, reject any photoresistors whose resistance in total darkness is less than 2 megohms, or which take more than a few seconds to stabilize when placed in darkness after exposure to room light. One way to put a photoresistor into total darkness is to wrap it in several layers of black cloth, plastic, or electrical tape. Avoid aluminum foil; it reflects light and tends to develop cracks that will throw your readings awry.



The Zonal Enlarging Meter with PC circuit board and battery B1 in position just prior to closing the plastic case. Note the holes cut for the photoresistor R8 and LED bar-graph display DISP1. The photoresistor is mounted above the PC board to be flush with the inside surface of the case's cover.

Next, set up your enlarger to make a properly exposed print on your usual paper with your usual exposure time. Then put the photoresistor on a mid-gray area of the projected image, turn off the safelight, and measure the resistance. If it's between 50K and 500K, and the resistance in total darkness is at least 10 times higher, you have a workable photoresistor. If the photoresistor's test measurements are outside that range specified above, you can still use the photoresistor by substituting a different value for R1. The resistance of R1 should be about 1/50 to 1/2 that of the photoresistor.

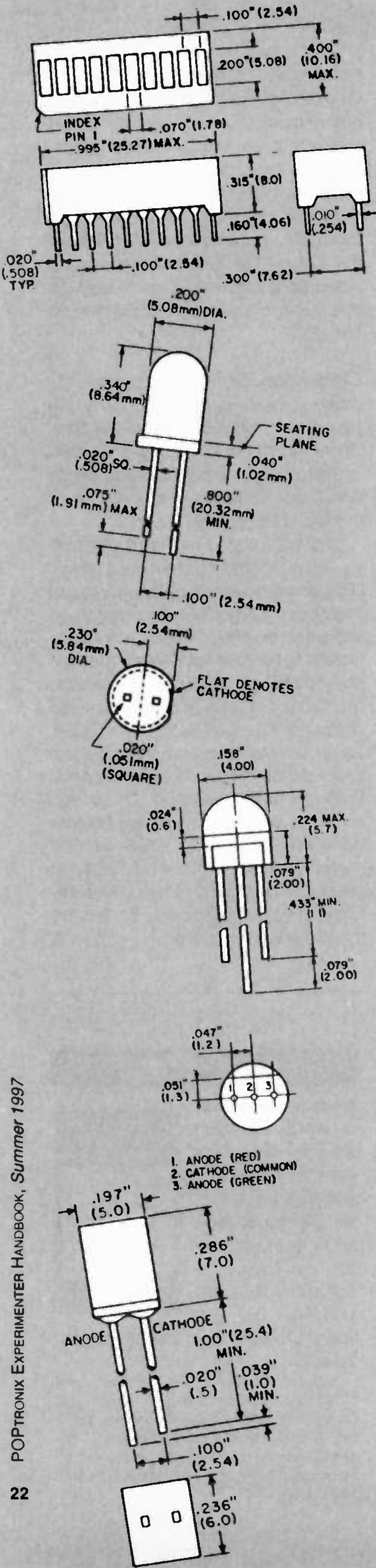
Here's the Zonal Enlarging Meter all closed up and ready for use.

Putting it Together. The Zonal Enlarging Meter is housed in a Pac-Tec HML-9VB plastic enclosure (see Parts List). The illustration of the foil-side pattern of the printed-circuit board provided is same-size and can be used to produce a PC board using any of the photographic techniques available. You can assemble the project equally well on perfboard or a universal, pre-drilled circuit board. The parts location diagram in Fig. 2 should be followed closely no matter what circuit board you use.

The photograph in Fig. 3 shows how to locate the holes for the photoresistor and the LED display in the plastic case cover once you've made the circuit board. To cut the rectangular opening for the LED bar-graph display (DISP1) in the case, drill holes in the corners directly over the display, then join them with a jeweler's saw if you have one. If you don't have a jeweler's saw, simply drill more holes until you have an approximately rectangular opening. Either way, finish the hole carefully with a file. Even though it is not attached to the hole in the cover, the photoresistor should stand up high enough on its leads so that it doesn't pick up stray light from the LEDs.

Calibration. Set up your enlarger to make a properly exposed print with your usual paper and exposure time. Place the meter on a mid-gray area of the image, turn off the safelight, and press S1. Adjust R1 so that five of the ten LEDs are on.

Now explore the rest of the picture. You will probably find that two or three LEDs come on in the densest areas of the negative that will show detail on the print, and eight LEDs are illuminated in the thinnest areas that will show detail. You may find it useful to make a set of strips of paper exposed at the light level of one LED, two LEDs, up to ten, so that you can see the exact shade of gray that corresponds to each meter reading. Once you have the desired adjustment for your darkroom operation, close up the meter's case. You are now ready to produce quality, full-tonality photographs at a rapid pace on the first try with each negative. Ω



Dress Up Audio Projects With Solid-State Level Indicators

ROBERT C. RICHARDS

THE D'ARSONVAL (MOVING NEEDLE) analog meter has been the instrument of choice for setting input levels in audio systems for years. Now that most audio equipment has been miniaturized an analog meter will no longer fit on the front panel of the equipment.

This role has been filled by light-emitting diode circuitry. Solid-state level indicators-based on a string of LEDs instead of a moving-coil meter are now included in most consumer audio products: from tape decks to baby monitors. They are small, lightweight, inexpensive, and immune to shock damage that could damage an analog meter's delicate meter movement.

This article describes three different methods for adding solid-state LED level indicators to your audio projects. In each, the level indicator selected gives the equipment a more professional appearance than in the original project while providing a useful function.

Typical amplifier

Figure 1 is a block diagram of a typical audio amplifier. The input signal is applied to an adjustable-gain amplifier stage. This first stage raises the voltage of the input signal to a higher audio level for the power amplifier stage, and the amplifier's gain is controlled by the operator with a front-panel knob. The output of this first stage is fed to a power amplifier that drives a loudspeaker. The gain in the adjustable amplifier stage must be high enough to allow the signal from the loudspeaker to be heard after the power amplifier has been amplified. However, this gain must not be so high that the signal becomes clipped and distorted. There is also the possibility that the loudspeaker could be damaged if it is overdriven.

The level indicator circuit shown in the dashed box (Fig. 1) is useful in alerting the user that the gain of the adjustable amplifier is set improperly. This circuit consists of a signal-averager stage that clips audio signal peaks for a smooth display and an LED level indicator display consisting of from one to ten LEDs. By observing this LED display, the operator can adjust the amplifier for minimum distortion and proper operation.

Signal averager

The signal averager circuit in Fig. 2 will be shared by all of the LED level indicators described in this article. The operational amplifiers are general purpose types. The TL072 dual operational amplifier will save PC board space, and it is a reliable, inexpensive, medium-quality device. The first operational amplifier, IC1-a, is an inverting amplifier whose gain can be adjusted up to 5. Adjustable feedback resistor, R2, sets the circuit gain. It is a PC- board-mounted trimmer that is set once and never adjusted again.

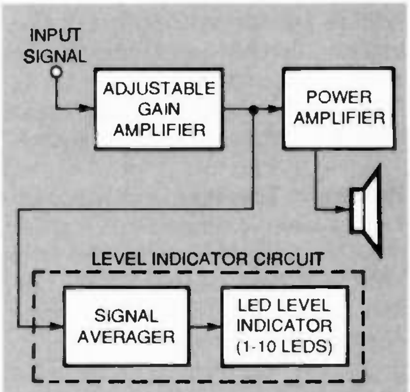


FIG. 1—A TYPICAL AUDIO AMPLIFIER block diagram with a LED level indicator circuit added.

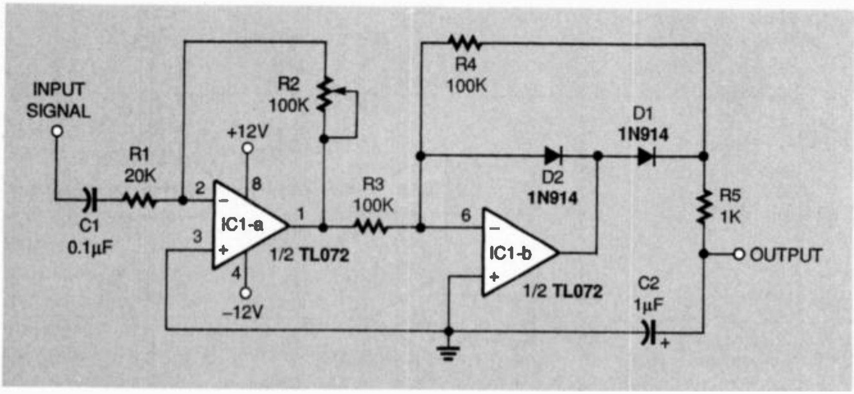


FIG. 2—A SIGNAL-AVERAGER circuit for use with the LED level indicator circuits discussed in the text.

This gain stage links a specific input voltage level to a specific LED indicator.

The second operational amplifier, IC1-b, forms a half-wave rectifier and signal averager that clips the brief peaks and displays them over a longer period of time. By stretching out and smoothing those peaks, as seen on the LED-level display, it will be easier to set the input adjustable-gain amplifier, IC1-a.

One-color LED peak indicator

The simplest solid-state level indicator is a single LED that flashes ON when the input level is high enough to drive the remaining audio stages. However, if you install only one LED, it is more important that it be used to alert the operator to an overload condition. The input level can then be reduced to avoid signal clipping and distortion. It can also reduce the possibility of damage due to excessive heat in the power amplifier and speaker. Most commercial amplifiers have indicators that will signal an overload before the level is high enough to cause an overload. This margin of safety is called *headroom* and it protects the equipment from the consumer who isn't satisfied unless the peak LED flashes occasionally.

The single-color, peak LED circuit is shown in Fig. 3. Unlike the TL072 operational amplifier discussed previously, the LM339 is a comparator. As shown in Table 1, whenever the voltage at the inverting input (labeled "−") of the LM339 is higher than the voltage at the

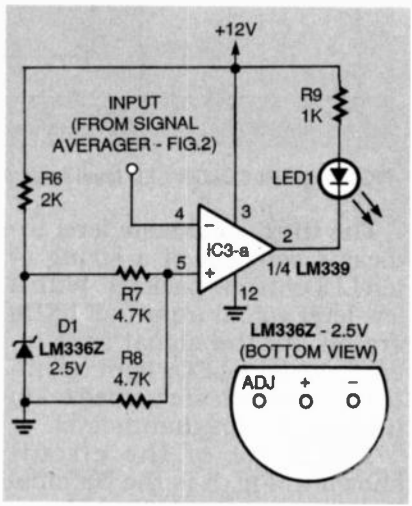


FIG. 3—A SINGLE-COLOR LED peak indicator circuit.

TABLE 1—COMPARATOR OUTPUT STATES

Inverting Input (–)	Noninverting Input (+)	Output
3 Volts	1 Volt	Ground
1	3	Float

noninverting input (labeled "+"), the output of the comparator is internally grounded. However, whenever the voltage at the inverting input is lower than the voltage at the noninverting input, the output of the comparator floats (effectively an open circuit) and no current flows.

The voltage divider consisting of resistor R6 and 2.5-volt precision voltage reference IC2 form a precision voltage reference whose voltage is divided in half at the junction of resistors R7 and R8. This places a reference voltage of 1.25 volts at the comparator noninverting input. Whenever the inverting input voltage exceeds the reference voltage, the output will be connected to ground internally and LED1 will light. By connecting the input of this circuit to the output of the averager circuit, the LED will flash on whenever the audio input exceeds the level set with gain potentiometer R2 in Fig. 2. Adjust R2 by applying a maximum level signal to the input of the averager, and then reduce the level slightly to allow for headroom. With the input level now set, adjust R2 until the peak LED just turns on.

Usually the maximum audio level can be determined by listening carefully to the loudspeaker's output. If this method is not sensitive enough for proper calibration, connect an audio signal generator to the input and an oscilloscope across the loudspeaker's terminals. Examine the overload effects on sinewave, squarewave and sawtooth-waveforms as you adjust the setting of R2.

Tri-color LED level indicator

Some LEDs will light in three colors. Tri-color LEDs have two LED dies in one package (generally one red and one green) which are controlled independently. By applying a voltage greater than about 2 volts to the separate pins, the LED can glow red, green, or yellow (when both dies are on). Figure 4 is a tricolor LED circuit. With a low input level, LED2 is off. As the input voltage increases, LED2 turns on and first glows green, then yellow, and finally red.

Resistor R10 and 2.5-volt precision voltage reference IC4 provide a precision voltage reference that is further subdivided by resistors R11, R12, R13, and R14. This chain of resistors creates three different reference voltages that set the voltage thresholds for the three LED

continued on page 148

colors. These reference voltages are fed to the three comparators along with the input signal. Notice that the input signal is connected to the inverting (-) input of one comparator (IC3-b) and to the noninverting (+) input of the other two comparators (IC3-c, IC3-d).

The output of these comparators is then connected to LED2. If the output of all of the comparators is floating, the red and green dies in the tri-color LED are biased on by R15 and R16, causing LED2 to glow yellow. However, if the output of a comparator is internally grounded, the connected color element will be pulled below 2 volts, and the element will turn off. Table 2 lists how the various comparators turn on and off to control the separate color dies in LED2 as the input voltage increases.

The comparator reference voltages are set so that reference V_Y is twice as large as V_G and reference V_R is twice as large as V_Y. This power-of-two relationship is commonly found in audio electronics. The reference voltages are: $V_R = 1.26$, $V_Y = 0.63$ and $V_G = 0.32$.

To set the gain level of the amplifier, connect the input of Fig. 4 to the output of the averager circuit in Fig. 2. As with the previous level indicator, apply a maximum-level signal to the input of the averager, and reduce the level to allow for headroom. Then, adjust R2 in Fig. 2 until LED2 just turns red. Now slowly reduce the audio input-signal level at the input to the amplifier. LED2 should change in sequence from red to yellow, then to green, and finally to off.

10-LED bargraph

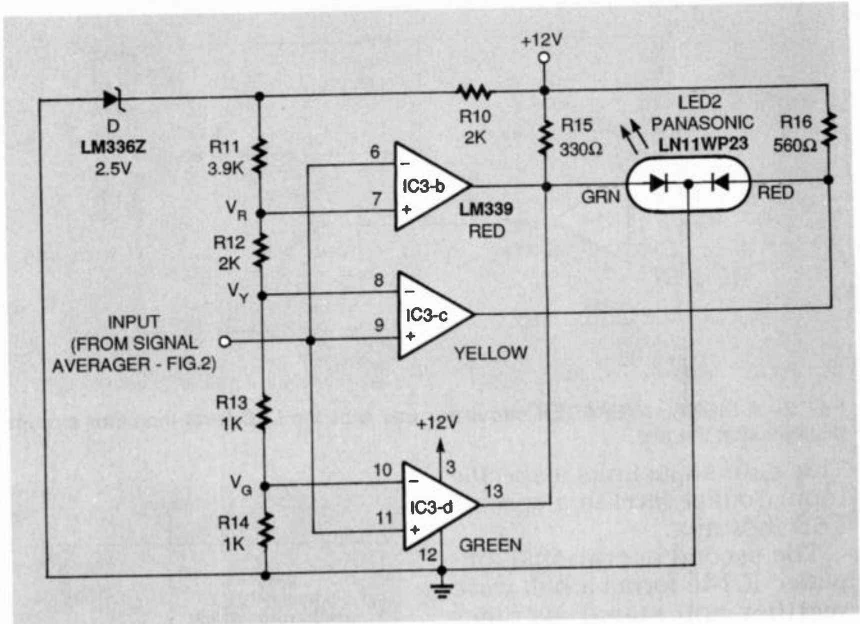


FIG. 4—A TRI-COLOR LED level indicator circuit.

The third solid-state level indicator consists of a string of ten LEDs in one package. With a low-level signal input, all LEDs are off. As the signal level increases, more LEDs light up until finally all ten are turned on to indicate the maximum level.

The heart of the circuit shown in Fig. 5 is the National Semiconductor LM3915. Internally, this IC is similar to the tri-color LED circuit *in toto*. The LM3915 contains a precision voltage reference, resistor divider chain, and ten comparators to drive the LEDs. This IC also contains current-limiting circuitry that limits the brightness of the LEDs without the need for separate resistors, and logic to select either a bargraph or a moving-dot display. In Fig. 5, the bargraph display is selected because pin 9 of IC5 is tied to the same voltage point as pin 3 of IC5. If pin 9 is allowed to float, the IC would program one LED

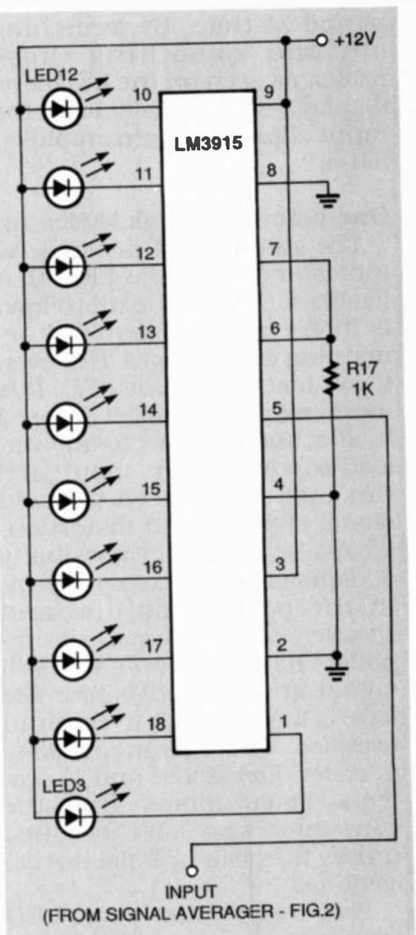


FIG. 5—A TEN-LED BARGRAPH level indicator.

to turn on at a time to provide a moving-dot display. The voltage references are set to the standard step increments used in

(*Continued on page 111*)

TABLE 2—TRICOLOR LED COMPARATOR OUTPUT

Input Level	IC3-b Output	IC3-d Output	Green Element	IC3-c Output	Red Element	LED2 Color
Less Than V_G	Float	Ground	Off	Ground	Off	Off
V_G to V_R	Float	Float	On	Ground	Off	Green
V_Y to V_R	Float	Float	On	Float	On	Yellow
More Than V_R	Ground	Float	Off	Float	On	Red

BUILD THE FAST PULSER SCOPE CALIBRATOR

You're looking for a used oscilloscope at a ham fair and wonder if that \$150 gem is really as good as the person at the table says it is. The trace lights up and the seller assures you it is "like new." What you need is something that will allow you to do a quick check of amplitude accuracy, sweep accuracy, and bandwidth. The Fast Pulser Scope Calibrator described here is a small, portable, battery-powered scope calibrator that meets those needs perfectly and costs less than one bad deal.

Testing a scope. Amplitude accuracy and calibration are both relatively simple to test. Any signal of a known amplitude will work well, including something as unsophisticated as a battery. Just apply the signal to the scope and count the number of divisions. If you have a way to generate one, a squarewave is even more useful as you get a direct indication of peak-to-peak amplitude that allows testing of AC-coupled circuits.

Time (or sweep) accuracy is easily tested by using a signal derived from a crystal oscillator, which will give better than 0.1% resolution and typically closer to 0.01%, depending on the crystal.

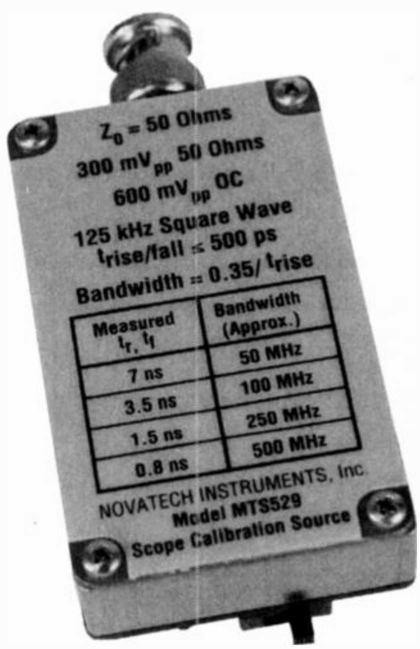
The most difficult parameter to measure is bandwidth. If you had a variable-frequency generator with a calibrated output, you could measure bandwidth by sweeping the input frequency until you reached the −3-dB point. Unfortunately, those instruments are not very portable. However, there is an easier way to determine bandwidth that is close enough for most purposes: apply a fast rise time pulse to the oscilloscope and observe the rise time of the displayed waveform.

To see how that works, let's say that a scope under test has the response curve of Fig. 1-a. Figure 1-b is a simple resistor-capacitor circuit that models that response curve.

If V_{in} is a fast pulse, V_{out} can be found with:

$$V_{out} = V_{in}(1 - e^{-t/RC})$$

where e is the exponential function, R is the resistance in ohms, C is the capacitance in farads, and t is the time in seconds after the pulse is applied. That output looks like the curve shown in Fig. 2. Figures 1-a and 2 were calculated using values of R and C to simulate an oscilloscope with a −3-dB rolloff at 100 MHz.



Psst! Wanna buy a used oscilloscope? Checking out that bargin before you buy is now a snap with this handy, portable device.

STEVEN D. SWIFT

Rise time is the time for a signal to go from 10% of its final value to 90% of its final value. Those points are labeled as 10% and 90% in Fig. 2, with the final value of V_{in} normalized to one.

We need to find the rise time, so by using:

$$0.1 = (1 - e^{-t_{10}/RC})$$
$$\text{and } 0.9 = (1 - e^{-t_{90}/RC})$$

we solve for t_{10} and t_{90} using:

$$t_{10} = 0.1054\ RC$$
$$\text{and } t_{90} = 2.303\ RC$$

The final formula for the rise time becomes:

$$t_r = t_{90} - t_{10} = 2.198\ RC$$

Since the −3-dB bandwidth (BW) of a simple RC circuit is given by:

$$BW = 1/(2\pi RC)$$
$$\text{or } RC = 2\pi BW$$

With $\pi = 3.1416$, we substitute into the formula for t_r:

$$t_r = 0.35/BW$$
$$\text{or } BW = 0.35/t_r$$

That formula can also be used to approximate other circuits with a smooth rolloff that are more than just the simple RC type, as long as they do not suffer from excess peaking, which causes ringing. Figure 3 is a plot of the bandwidth versus rise time using that formula.

If the rise time of the pulse is not fast compared to the rise time of the oscilloscope being tested, the scope's true rise time can be calculated by:

$$t_r(\text{scope}) = \sqrt{t_r(\text{observed})^2 - t_r(\text{pulse})^2}$$

For bandwidths up to 250 MHz, a pulse with a rise time t_r of < 640 picoseconds (0.64 nanoseconds) will cause less than a 10% error in the scope's bandwidth prediction. Figure 4 shows observed rise times on the scope's display versus actual rise times of the scope's circuitry as a function of the output rise time of the applied pulse.

Those calculations and figures apply to oscilloscopes with well-behaved responses as in Fig. 1-a. Poorly designed, misadjusted, or defective oscilloscopes will have overshoot,

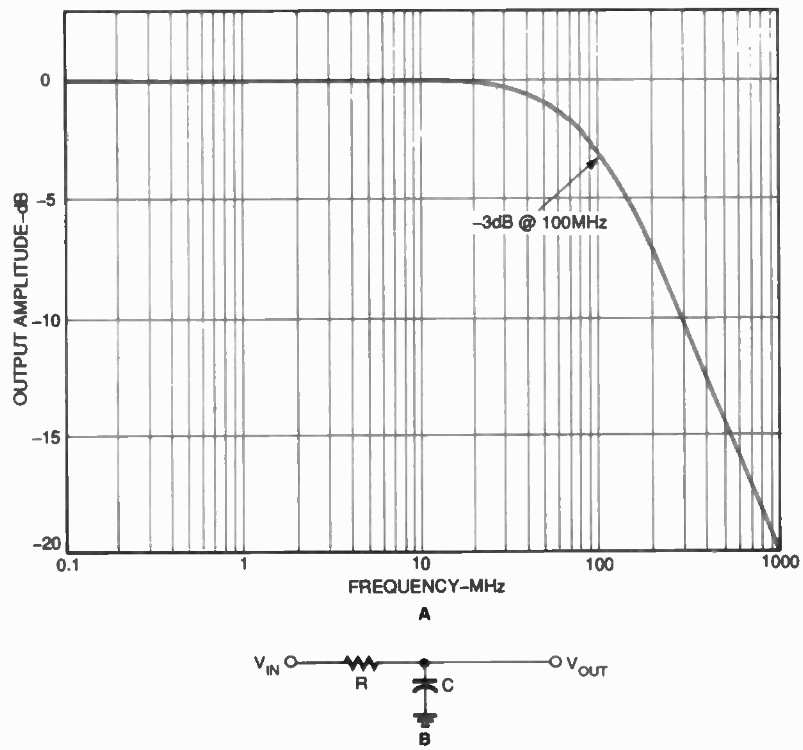


Fig. 1. The response curve of a typical oscilloscope (a) and a simple R-C circuit that simulates that response (b).

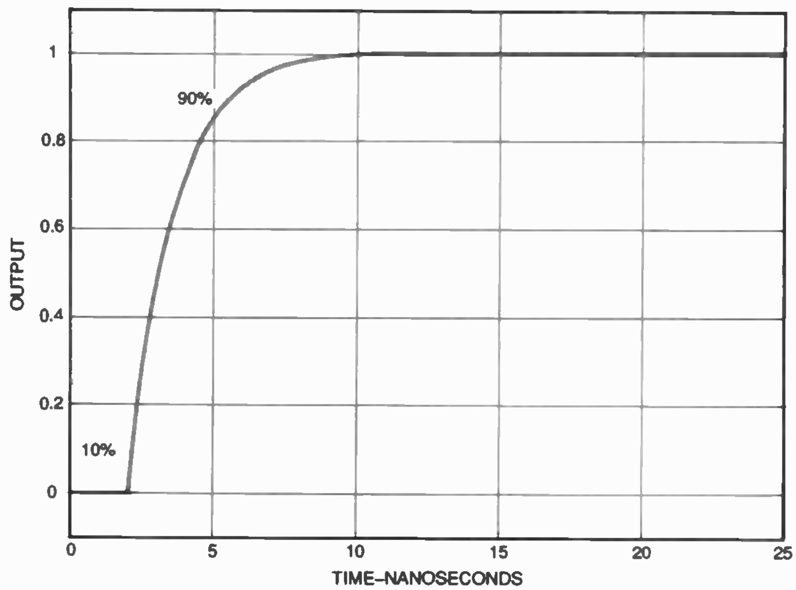


Fig. 2. The output of the R-C circuit when a fast pulse is applied to its input. Like oscilloscopes, a lower bandwidth will take longer for the output to reach 100%.

ringing, or undershoot. If overshoot or ringing is present and is, for example, greater than 15% of the final value, the apparent bandwidth will be incorrect. That is generally a sign of a peaked response and indicates an oscilloscope that may have some problems or be unsuitable for precision work.

Circuit design. With that background information, we can now design a circuit that will give us the correct signal to measure the amplitude, frequency, and bandwidth of an oscilloscope. We also want a unit that is small, battery-powered, and portable.

Since the bandwidth specification is going to be the most challenging, let's start there. We need to generate a fast pulse. In the past, the fastest devices available were tunnel diodes. Tektronix at one time made many different tunnel-diode pulsers, but those diodes are almost impossible to find. Fortunately, the need for high-speed digital circuitry has forced semiconductor manufacturers to generate special fast-logic families. One of those is Motorola's ECLips (*E*mitter *C*oupled *L*ogic *i*n *p*icoseconds). The devices specified have a maximum output rise time of 350 ps (0.35 ns): more than adequate for our purposes. We'll choose one of those devices for the fast part of the circuit.

A crystal-oscillator circuit ensures frequency accuracy, while the amplitude is set by choosing a version of the

PARTS LIST FOR THE FAST

RESISTORS

(All resistors are 1/10-watt, 1%, metal film, type 0805 surface mount, unless otherwise noted.)
R1, R2—82.5-ohm
R3, R4, R5, R9—124.0-ohm
R6, R7, R14—681.0-ohm
R8—1-megohm
R10, R11—100-ohms, 1 turn variable, surface mount (Panasonic EVM-1GSX30BXX or similar)
R12, R15, R18—27.4-ohm
R13—63.4-ohm
R16—49.9-ohm
R17, R19—0.0-ohm

CAPACITORS

C1, C2, C3, C4, C14, C16—10-µF, 6.3WVDC, tantalum, surface mount (3216 SM)
C5, C6, C7—.022-pF ceramic, surface mount (0805 SM)
C8, C9—470-µF, 6.3WVDC, high-frequency aluminum electrolytic (Panasonic ECA-0JFQ471 or similar)
C10, C11, C13, C15—22-pF ceramic, surface mount (0805 SM)
C12—220-pF ceramic, surface mount (0805 SM)

SEMICONDUCTORS

IC1—74HC4060M HCMOS oscillator/divider, SO-16 integrated circuit
IC2—MC100EL32D ECLips divide-by-2, SO-8 integrated circuit (Motorola)
IC3—MAX777CSA switching regulator, SO-8 integrated circuit (Maxim)
LED1—High brightness light-emitting diode, red

device for the fast part of the circuit whose output levels are both temperature and power-supply stable. The final overall block diagram is shown in Fig. 5.

Design details. Figure 6 shows the complete schematic. Refer to it and the block diagram during the discussion that follows.

A 74HC4060 HCMOS oscillator/divider integrated circuit (IC1) was chosen for generating the master clock because it includes the oscillator circuitry and dividers necessary for a precision crystal-controlled clock with a minimum of external components. Choosing that part lets us use an inexpensive 4-MHz crystal rather than a larger and more costly low-frequency crystal.

PULSER SCOPE CALIBRATOR

ADDITIONAL PARTS AND MATERIALS

J1—BNC male connector (Kings KC-79-59 or similar)
L1—100μH, 0.41-amp rated coil, surface mount (TOKO 636CY-101M or similar)
S1—SPDT miniature switch (Mouser 10SP018 or similar)
XTAL1—4-MHz AT-strip crystal, surface mount
B1—Batteries, 3-volts, see text
Printed-circuit board, case, cover, battery holder (Digi-Key BH2AA), 4-40 x ¼-inch Phillips pan head screws

Note: The following items are available from: Novatech Instruments, Inc., 1530 Eastlake Avenue East, Suite 303, Seattle, WA 98102; e-mail: novatech@eskimo.com, URL: http://www.eskimo.com/~ntsales: Key Parts kit (includes J1, IC1, IC2, IC3, printed circuit board, case, and cover) (order MTS529-K), $50. Circuit Board only (order MTS529-B), $10. Completely assembled and tested Scope Calibrator (order MTS529), $125. Please add $5 for USA shipping and $10 for overseas shipping by U.S. Postal Service. These are special prices and are valid only for six months. Please mention this article when you mail payment. WA residents must add 8.2% sales tax. Please mail a check drawn on a bank with a branch in the U.S. or a money order. Sorry, phone orders and charge cards are not accepted.

The divide-by-16 output of IC1, at 250 kHz, is applied to a Motorola MC100EL32 divide-by-2 ECLips flip-flop (IC2), through level-shift and decoupling components C7, C15, and R6. Resistor R3 sets the input impedance seen by IC2 and divides the amplitude of IC1's output down to the ECLips input levels. The MC100EL32 has transition times of both outputs specified at less than 350 ps (0.35 ns) and temperature-compensated output levels. The divide-by-2 action of the device provides 125 kHz at approximately 800-mV p-p to the amplitude adjustment circuit and output stage.

The output of IC2 is terminated with loads consisting of resistor pairs R1/R4 and R2/R5. The values shown provide an equivalent load voltage of about −2 volts and a load impedance of 50 ohms. The output of IC2 is AC-coupled by capacitors C12, C13, C14, and C16 to an adjustable T-attenuator network. The various values of the coupling capacitors combine to transmit the fast rise time edges (C12 and C13)

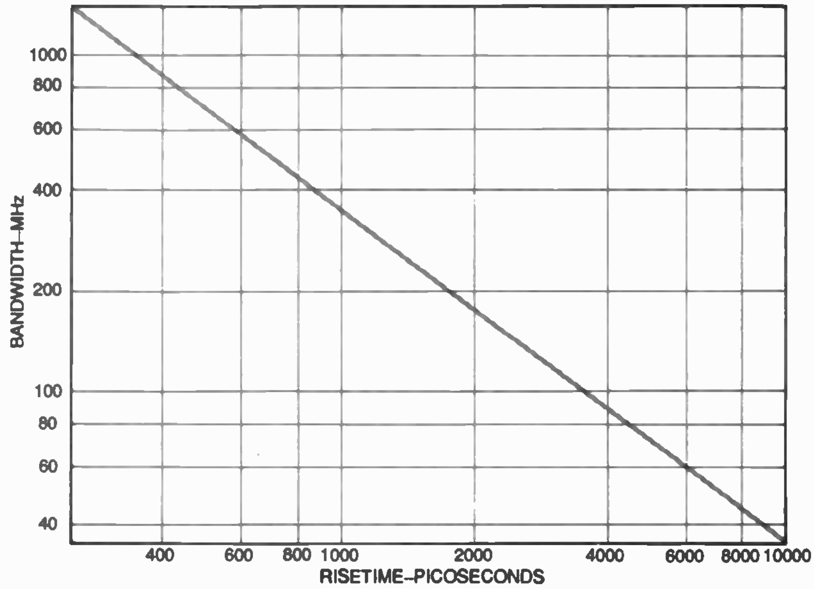


Fig. 3. The bandwidth of an oscilloscope can be found by observing how quickly the oscilloscope responds to a fast-rising input pulse. The quicker a scope responds to an input, the greater its bandwidth.

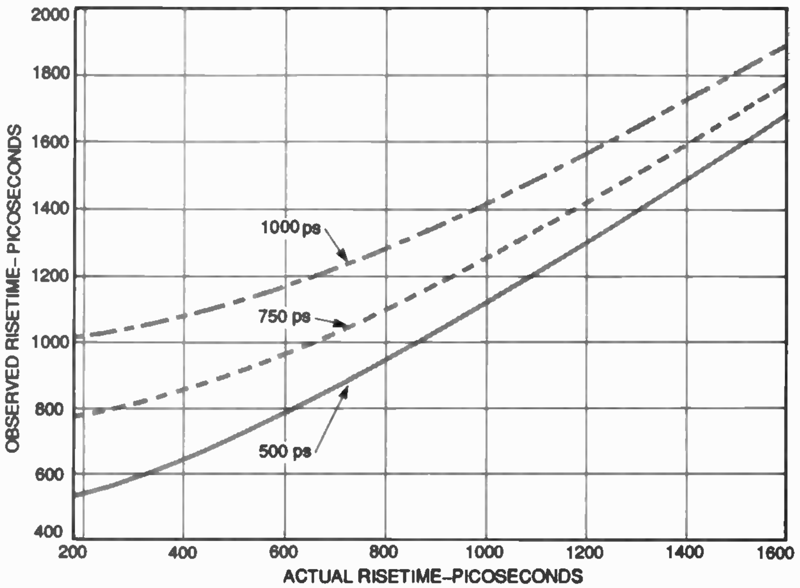


Fig. 4. A pulse with its own rise time will introduce additional error when measuring a scope's bandwidth. Keeping the pulse's rise time as short as possible will reduce such errors to an acceptable level.

while preventing droop at the 125-kHz base frequency (C14 and C16).

The output T-attenuator allows adjustment of open-circuit voltage level (R10) and output impedance (R11). Levels of 600-mV p-p open circuited and 300-mV p-p into 50 ohms were chosen to correspond to 6 divisions on an oscilloscope with a high-impedance input set to 100-mV-per-division, or 50-mV-per-division if the scope's input impedance is 50 ohms. That output is applied to a male BNC connector, which allows direct connection to the oscilloscope under test without using cables or adapters. The parasitic inductance of the output stage is kept small by the use of surface-mounted components. Even with that precaution, the output stage degrades the rise time to approximately 500 ps (0.5 ns). That rise time is adequate for testing oscilloscopes to 250 MHz with less than 10% error without using the correction formula or Fig. 4.

A switching power supply (IC3 and its associated components) was chosen to generate the required power for the circuit. The –5V supply needed to supply power to IC1 and IC2 is generated by IC3, a MAX777CSA switching regulator. Using two AA alkaline cells will supply power for almost 4 hours of continuous operation, and keep the project compact. Various types and sizes of batteries were tested with the power supply and it was found that 2 AA alkaline cells provide excellent performance without being very expensive.

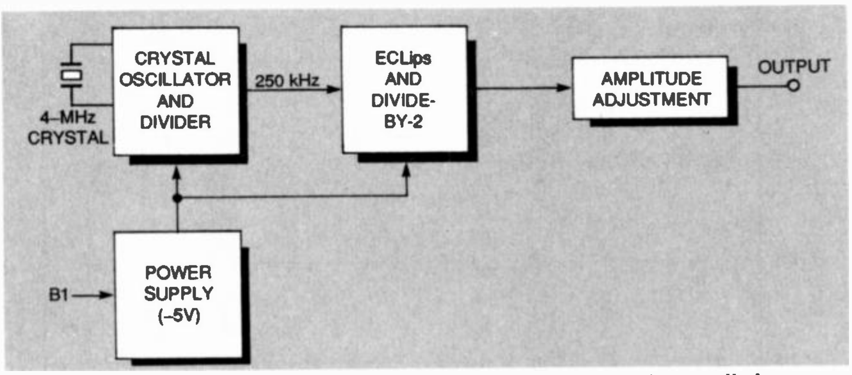


Fig. 5. Here's the block diagram of the Scope Calibrator. A crystal-controlled oscillator coupled with ECLips-based technology make for an accurate, reliable design.

Construction details. To maintain the high-speed performance of the instrument, the circuit board used consists mostly of a solid copper ground plane, with just enough area cleared away for the components. Other than a few pads and holes, the whole solder side of the circuit board is also a ground plane. Please note that if you plan to make your own boards from the artwork, the minimum trace width used is 8 mils (0.2 mm) which may cause etching difficulties. Note also that the back side ground plane is important for correct operation, so the feedthrough holes must be connected.

The parts placement diagram for the project is shown in Fig. 7. Since we

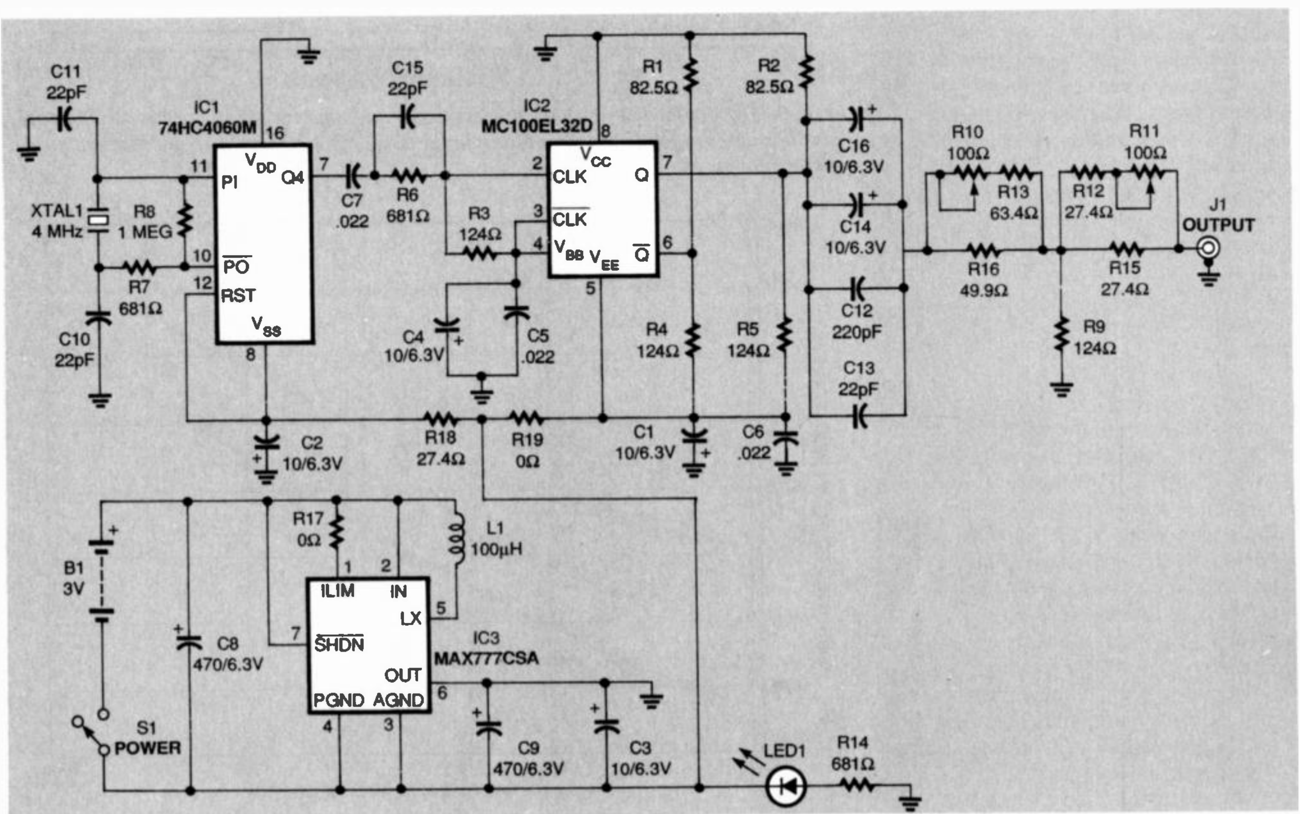


Fig. 6. The complete schematic for the Scope Calibrator is shown here. A Motorola MC100EL32D divide-by-2 ECLips flip-flop produces a signal unaffected by changes in temperature or supply voltage.

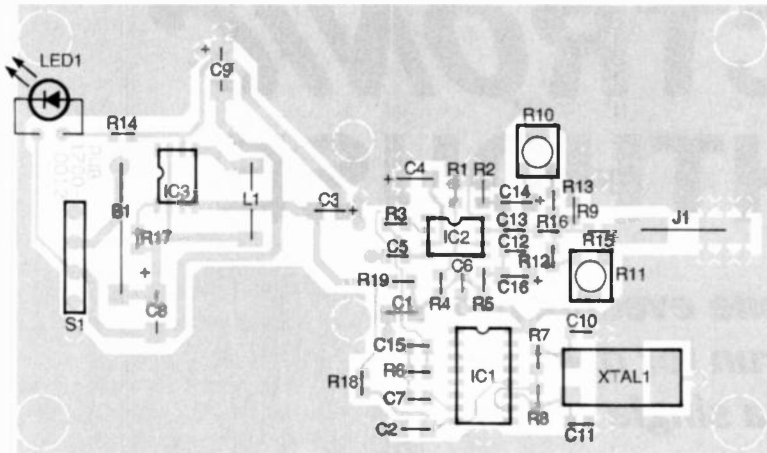
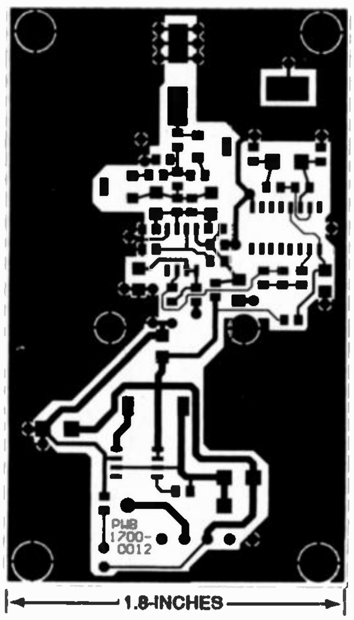
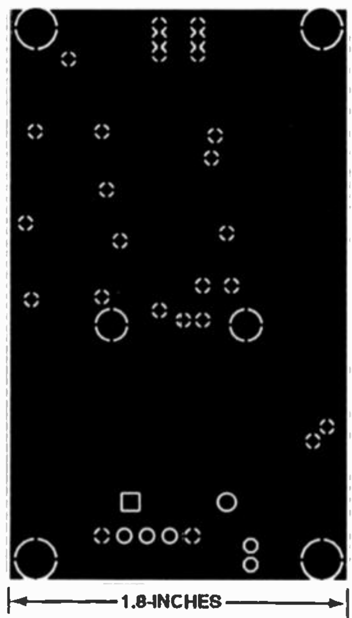


Fig. 7. Use this parts placement when building the Scope Calibrator. Surface-mount technology helps keep parasitic inductance to a minimum, as well as maintain a small physical size to the finished unit.



Here's the foil pattern for the component side of the Scope Calibrator printed circuit board. If you decide to etch your own board, take care that the narrow traces don't break apart during the etching process.



Here's the foil pattern for the solder side of the printed circuit board. Connecting the ground planes on both sides of the board to each other is important for proper operation.

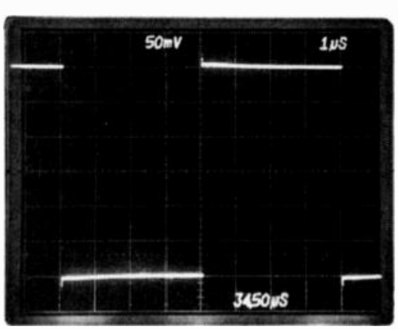


Fig. 8. Here we're testing the sweep speed and amplitude of an oscilloscope. You should count 8 divisions when the sweep is set to 1-µs/division.

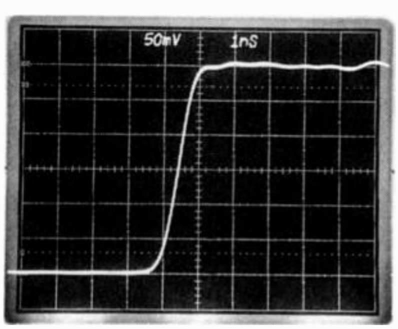


Fig. 9. Here we're testing the rise time of an oscilloscope. Measure the time it takes for the signal to rise from 10% to 90%, then use the chart in Fig. 3 to find the scope's bandwidth.

want a small sized instrument and the circuit has very high speed signals that require RF-design techniques, surface-mount components were chosen for the project. The small parts allow for optimized circuit specifications while reducing performance-degrading parasitic signals. They also allowed the complete project (less the batteries) to be enclosed in a 1.8- by 3-inch metal case.

Unfortunately, those small components make the assembly of the project rather difficult. If you have never handled SMT devices, you might want to look back at "Surface Mount Technology" in the November, 1987 issue of **Radio-Electronics**, or "A Hobbyist's Guide to Surface-Mount Technology" in the January, 1995 issue of **Popular Electronics** and first try some of the simple projects there. An assembled and tested Calibrator is also available from the source given in the Parts List.

The Scope Calibrator only needs calibration for amplitude. The basic accuracy of the crystal and the rise time are fixed by the design used and need not be calibrated. The easiest and most accurate way to calibrate the unit is to use a wideband (>200 kHz) AC rms voltmeter. With just the voltmeter load, adjust R10 for a reading of 300-mV rms (the rms value of an AC-coupled square wave is equal to one-half its peak-to-peak value). Now apply the squarewave output to the voltmeter through a 50-ohm feedthrough termination. Adjust R11 for 150-mV RMS. That sets the output impedance equal to your load, so the accuracy of your 50-ohm load determines the accuracy of your Fast Pulser calibrator.

Do not use test leads or cables as the signal will be degraded by overshoot and ringing. Use a direct connection to the meter, such as a BNC to banana-plug adapter. The assembled and tested unit is calibrated using a 1-MHz bandwidth rms meter and a ±1% 50-ohm load.

Applications. The Scope Calibrator is easy to use. Simply switch it on and connect the BNC output to the input channel of an oscilloscope under test. If the scope has a high input impedance (1 megohm is typical), set the vertical scale on the scope to 100-mV/division. If the scope has a 50-

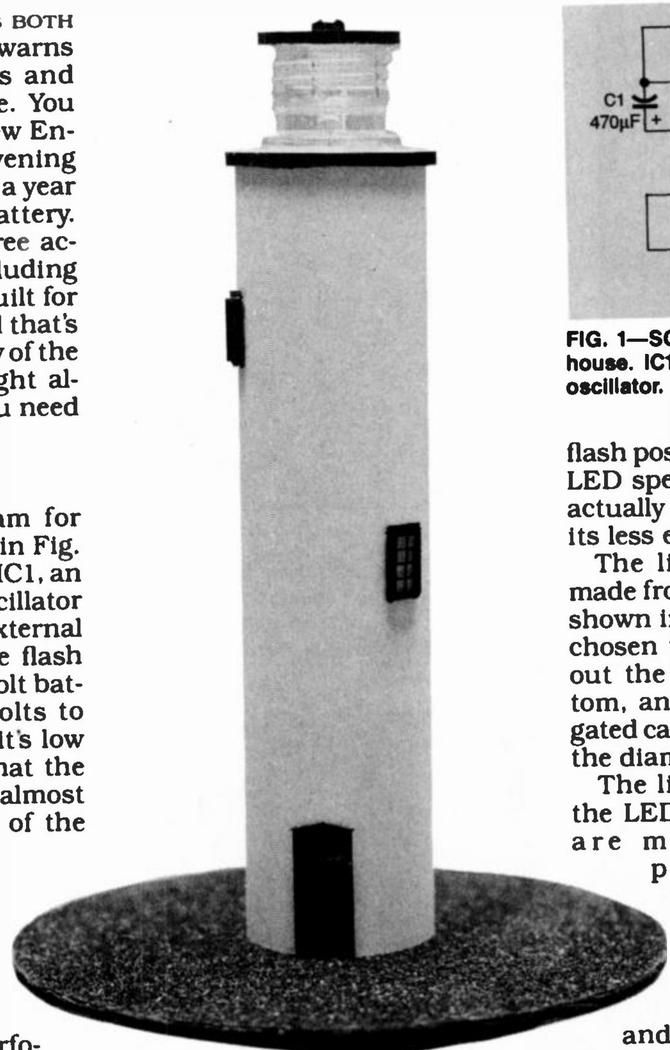
(Continued on Page 111)

ELECTRONIC LIGHTHOUSE

This one evening project will run for over a year on a single battery!

DEAN F. POETH, II K8TM

THE LIGHTHOUSE COMBINES BOTH beauty and utility as it warns ships of dangerous reefs and other hazards near shore. You can build a model of a New England lighthouse in one evening that will run for well over a year on a single flashlight battery. The circuit uses only three active components (not including the battery) and can be built for less than five dollars. And that's only if you have to buy any of the necessary parts. You might already have everything you need in your junkbox.



How it works

The schematic diagram for the lighthouse is shown in Fig. 1. The circuit is based on IC1, an LM3909 LED flasher/oscillator integrated circuit. An external capacitor determines the flash rate and boosts the 1.5-volt battery voltage to over 2 volts to light an LED. The circuit's low current drain ensures that the lighthouse will operate almost as long as the shelf life of the battery.

Construction

Construction is straightforward and the parts layout is non-critical. Because there are so few parts, perforated construction board is the preferred construction method. A super-bright LED is recommended for the most brilliant

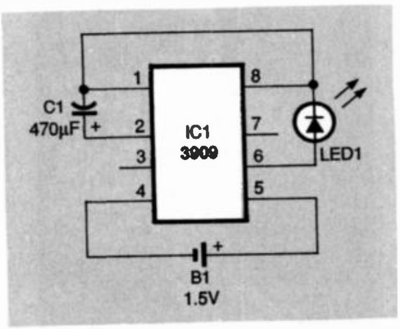


FIG. 1—SCHEMATIC FOR THE LIGHTHOUSE. IC1 is an LM3909 LED flasher/oscillator.

flash possible. The super-bright LED specified in the Parts List actually draws less current than its less efficient cousins.

The lighthouse is basically made from a cardboard tube, as shown in Fig. 2. Once you have chosen the tube you'll use, cut out the spacer disks, the bottom, and the base from corrugated cardboard. Cut them to fit the diameter of the tube.

The lighthouse floor (where the LED is mounted) and roof are made from 3/16-inch plywood. White card stock, cardboard, or balsa wood can be substituted, however. Cut out the parts with a band saw and drill two holes in the floor for the LED leads. Paint both discs black or color them with a large felt-tip marker.

Glue aluminum foil to the underside of the roof and white paper to the top of the floor. Trim away any excess foil and paper. The bump, or bubble, on top of the roof is a ceramic transistor with its leads cut off. Any similar "bump" could be used here, or you don't have to install one at all. The lighthouse details are merely suggestions, and you are certainly free to design your own lighthouse and add your own details if you so desire.

PARTS LIST

- IC1—LM3909 LED flasher (Radio Shack No. 276-1705)
- LED1—Super-bright 2000 mcd LED (Radio Shack No. 276-087)
- C1—470 µF, 35-volts, electrolytic
- B1—1.5-volt alkaline D cell
- Perforated construction board, cardboard tube, 2-liter plastic soda bottle, grass paper, wire, cardboard, plywood, burned out transistor (see text), and decorations such as doors, windows, and paint.

The dome lens is made from the threaded top part of a clear plastic 2-liter soda bottle. First cut the bottle near the top with a utility knife or scissors, and then finish the edges by sanding them smooth. A stationary belt sander works great for this. Then glue the roof to the top of the lens.

Pass the LED leads through the holes that you drilled in the lighthouse floor and glue the LED in place. Next glue the LED floor to the lighthouse lens. Once the glue has dried, you can wire the LED and battery to the circuit board.

The body of the lighthouse should be about 7 inches long. After gluing the cardboard bottom to the tube, either wrap the tube with plain white paper glued in place or paint the tube white. Trim off any excess paper hanging over the ends of the tube. Next glue some grass paper (used on model railroad layouts) to the top of the cardboard base and then glue the lighthouse to the base (see Fig. 3).

Insert the battery, circuit board, and spacer disks into the tube as shown in Fig. 2, and then glue the dome assembly to the top. You can add a few finishing touches to the lighthouse to give it that custom look by gluing an HO-scale door and some windows to it. You can also make your own doors and windows, if you like.

The lighthouse is now ready to be placed in a dimly light corner of an office or room. There it will sit, warning people of the "dangers" around it. Ω

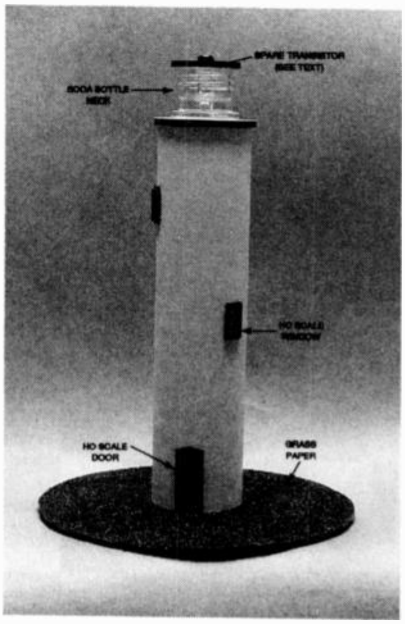


FIG. 3—THE BUMP ON TOP of the roof is an old ceramic transistor with its leads cut off. The dome lens is made from the threaded top part of a clear plastic 2-liter soda bottle. An HO-scale door and windows complete the look.

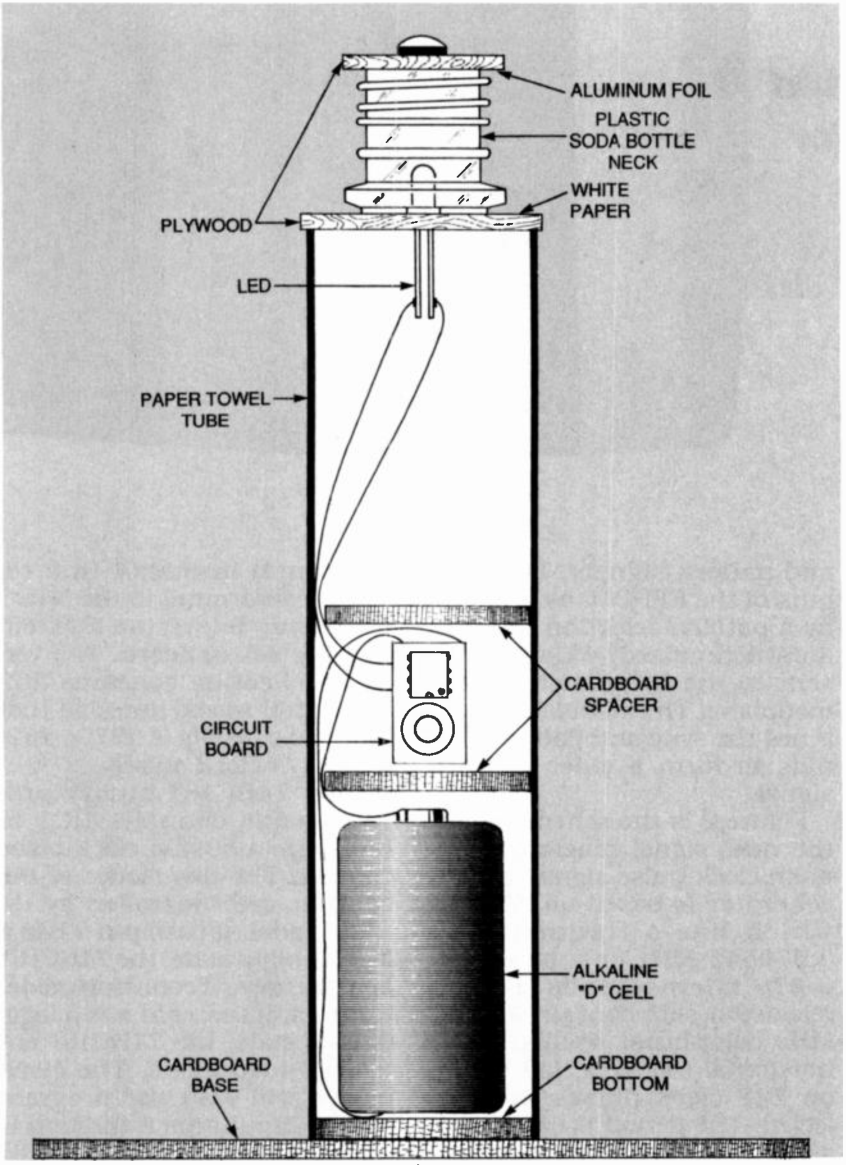
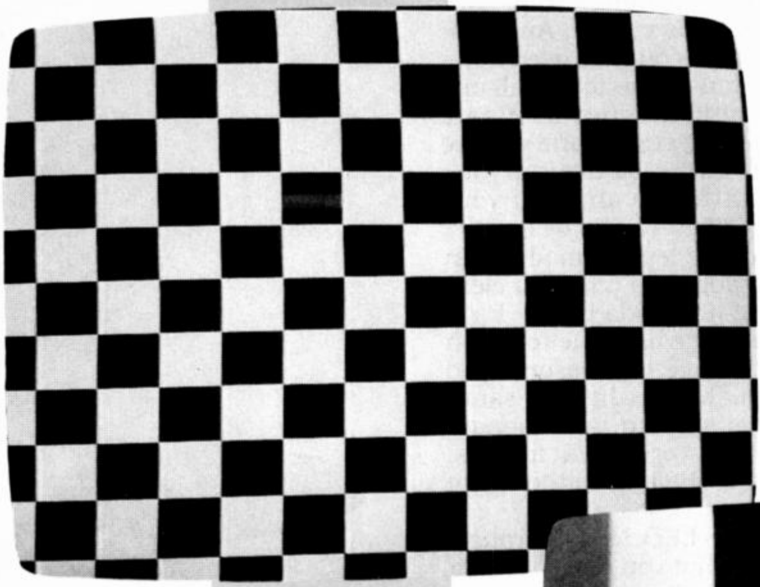
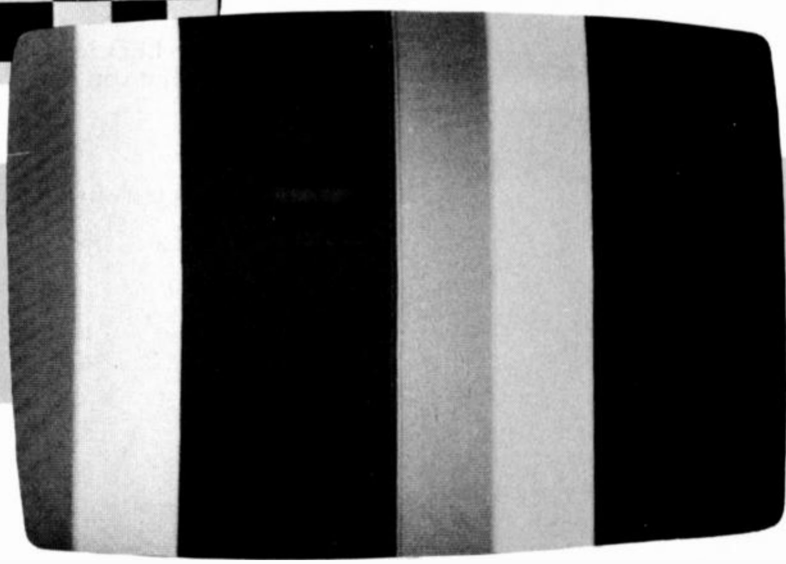


FIG. 2—THE LIGHTHOUSE IS MADE from a cardboard tube and other bits of wood and cardboard.



Build This Video Pattern Generator

YONGPING XIA



Build this EPROM-based video pattern generator and put it to work testing TV sets and experiment with the generation of video patterns.

THE MULTIFUNCTION VIDEO SIGNAL generator project described in this article produces three independent video test patterns: a black and white checker pattern, a color-bar pattern, and a programmable custom picture. When any one of those patterns is combined with a sync signal and sent to a television signal modulator IC, a video signal is formed.

How does it work?

Figure 1 is a block diagram for the video pattern generator. A clock pulse generator initiates the base time clock pulses. Those clock pulses drive a counter, which sends the address signals to an erasable programmable read-only memory (EPROM). The EPROM contains all of the previously stored sync and pattern signals. The outputs of the EPROM, as selected by a pattern-selection switch, are synchronized by a latch, and sent to the NTSC (television) modulator. The modulator combines the sync and pattern signals to form a video output signal.

Figure 2 is the schematic for the video signal generator. The main clock pulse signal for the generator is based on XTAL1, which has a frequency of 3.579545 MHz or a period of 0.279 microseconds. (Color television sets contain a 3.58 MHz color-burst oscillator.) A horizontal sweep period based on 227 clock pulses was selected. The period is calculated as 227 × 0.279 microseconds, which equals 63.33 microseconds, the length of time for a horizontal line scan in a receiver conforming to the NTSC (National Television System Committee) standard. The vertical deflection contains 262 horizontal sweep lines, so that one field consists of 227 × 262, or 59,474 clock pulses.

Four 74HC161 binary programmable counters (IC1 to IC4) form a 59,474 clock pulse counter. The two modes of the counter are controlled by its LOAD signal. If LOAD pin 9 has a logic 1 (high) state, the 74HC161 is in its normal counting mode. However, if LOAD pin has a logic 0 (low) state, the 74HC161 enters its load mode. The clock pulses will load the program data at input pins A through D (pins 3 to 6) of the four 74HC161 binary counters.

When all four binary counters

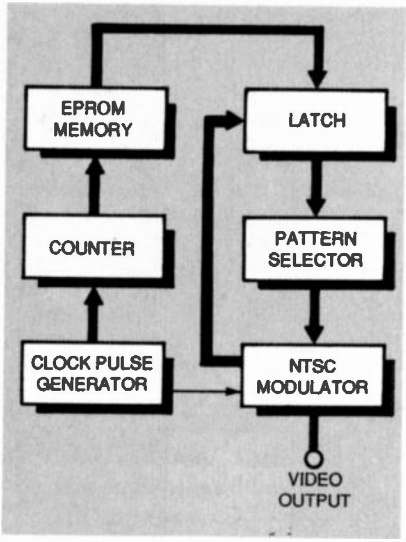


FIG. 1—FUNCTIONAL BLOCK DIAGRAM for the Video Pattern Generator.

count to logic 1 (FFFFH), IC4's ripple-carry output (RCO) pin 15 becomes a logic 1. This signal is sent to the four counters' load input pins after inversion by 74HC00 IC6-a. Then the counters load the data at their a to d inputs when the next clock pulse occurs. In this case, 0001 0111 1010 1110 equals 17AEH will be loaded into the counters. The binary counter, which counts from 17AEH to FFFFH, requires E851H or 59,473 clock pulses. This is the required counter sum after adding one more clock pulse for loading data.

The counters' outputs are sent to a 27C512-15 64K-×-8 CMOS EPROM (IC5) as address signals. For each address, IC5 provides an 8-bit output. These outputs are listed in Table 1.

Pins D0 to D2 of IC5 send the custom pattern signals red (R2), green (G2) and blue (B2). Pin D3 provides the black and white checker pattern. Pins D4 to D6 send the color bar red (R1), green (G1), blue (B1) signals. The sync signal that combines both the horizontal and vertical sync signals is obtained at pin D7.

The EPROM's outputs are latched by the 74HC273 (IC6) octal D flip-flops for synchronizing purposes. Three-pole, three-terminal switch S1 selects each of the three video patterns. As shown in Fig. 2 the S1 top position (1) selects the 14-×-18 B/W checker pattern. When this pattern is selected, the B/W signal is sent to the MC1377 television RGB-to-NTSC encoder (IC7) with equal red, green and blue values. As a result, the picture will be black if B/W is logic 0 and it will be white if B/W is logic 1.

TABLE 1—EPROM Outputs

D7	D6	D5	D4	D3	D2	D1	D0
Sync	R1	G1	B1	B/W	R2	G2	B2

The second pattern selected by the mid-position (2) of switch S1 is the color bar pattern. The order of the colors in the color bar pattern is *white*, *yellow*, *cyan*, *green*, *magenta*, *red*, *blue* and *black*, from left to right. The third video pattern selected by bottom position (3) of S1 is a custom picture which is composed of 237 lines, and each line contains 287 pixels. Thus, the total number of pixels in the custom pattern is 43,605. Each of those pixels can be programmed as one of the eight different colors in the color bar pattern.

The RGB to NTSC encoder MC1377 (IC7) performs all of the functions of a color TV encoder. These functions are: color subcarrier oscillator; RGB to R−Y and B−Y converters; voltage-controlled 90° phase shifter; and chroma modulators. The inputs required for the proper operation of the MC1377 are 1-volt peak-to-peak red, green and blue (R, G and B) signals, and a TTL-level sync signal. The MC1377 provides a 2.5-volt, peak-to-peak, composite-video output to jack J1.

Because IC-6 is a high-speed CMOS device, its output signal level will be very stable. This means that if the output is logic 0, the level will be close to zero volts. If output is logic 1, the voltage should be +5 volts. The selected pattern signals are divided by resistors R1 to R6 to meet the MC1377's input level requirements. Those resistors are specified as 1% to eliminate any error caused by different R G B levels that would cause color distortion. You can hand-select these from a group of 5% resistors by measuring and sorting them with a DMM.

PARTS LIST

All resistors are ¼- watt, 5%, unless other specified
R1, R2, R3—3900 ohms, 1% (See text)
R4, R5, R6—1000 ohms, 1% (See text)
R7—470,000 ohms
R8—75 ohms
R9—43,000 ohms
R10—2200 ohms
R11, R12—1000 ohms
R13—10,000 ohms
Capacitors
C1, C3—10-µF, 16-volts, aluminum electrolytic
C4—12-pF, ceramic disc
C5—20-pF, ceramic disc
C6, C7—220-pF, ceramic disc
C8, C9—0.01-µF, ceramic disc
C10, C11, C12, C13, C20—0.1-µF, ceramic disc
C14, C15, C17—1000-pF, ceramic disc
C16, C18—470-µF, 16-volts, aluminum electrolytic, axial leaded
C19—100-µF, 16-volts, aluminum electrolytic
C21—470-µF, 35-volts, aluminum electrolytic
Semiconductors
D1, D2, D3, D4—1N4001, silicon diode
IC1, IC2, IC3, IC4—74HC161N, 4-bit binary programmable counter (Motorola or equiv.)
IC5—27C512-15, 64K × 8 EPROM, AMD or equiv.
IC6—MC74HC273 octal D flip flops with clear (Motorola or equiv.)
IC7—MC1377P, RGB to PAL/NTSC encoder (Motorola or equiv.)
IC8—74HC00E, quad 2-input NAND gate (Motorola or equiv.)
IC9—MC7812T, +12-volt regulator IC (Motorola or equiv.)
IC10—MC7805T, +5-volt regulator IC (Motorola or equiv.)
Q1—2N3904, NPN transistor
Other components
J1—Coaxial jack, F series, panel mount.
T1—Transformer, 120 to 15 VAC, 300 mA
XTAL1—3.579545 Mhz crystal
Miscellaneous: Circuit board (see text); project case (see text); DIP sockets: four 16-pin, one 14-pin standard width, two 20-pin narrow width, and one 28-pin wide of EPROM; knob for rotary switch; length of RG-58 coaxial cable (see text); line cord with plug, insulated hookup wire, four standoffs, ¼-inch; screws, nuts and washers; solder

The output of IC7 (the MC1377) is buffered by Q1, a 2N3904 NPN transistor, to improve its drive capability. To keep the circuit simple, the main clock pulses are generated by the MC1377. Because pin 17 of the MC1377 can provide only 0.1 volts peak-to-peak subcarrier output, the signal is amplified by gate IC6-b of IC6, a quad

2- input NAND IC and shaped by gates IC6-c and IC6-d to drive the counter consisting of the four 74HC161 synchronous binary counters.

Figure 3 is a schematic for a dual +12-volt and +5-volt power supply that can be built on a separate perforated board or be integrated with the rest of the circuit on the main circuit board. It contains two integrated circuit voltage regulators, IC9, an MC7805 positive 5-volt regulator and an MC7812, a positive 12-volt regulator

EPROM code listing

The EPROM codes can be conveniently generated by a personal computer. The program in Listing 1 is the C program for forming the sync, B/W checker and color bar codes. However, the listing does not include the code for the custom pattern. This program will generate a VIDEO.DAT file with 59,474 pixels. Any EPROM programmer can be used to program the 64 K × 8 74HC512 EPROM, IC5.

Building the generator

Refer to the video pattern generator schematic, Fig. 2, the dual power supply schematic, Fig. 3, and the parts placement diagram, Fig. 4. The author built the video pattern generator and the dual power supply on a rectangle of perforated board that measures 3⅜ × 4½ inches. The perforations are 0.10-inch apart on centers, and the board has foil pads and power buses.

Before beginning any assembly work, drill the four mounting holes in the four corners of the circuit board, and drill a hole large enough to admit the bushing of panel-mounted switch S1. Make a paper template of the circuit board hole spacing and bushing hole location for later transfer to the base of the plastic project case as a hole-drilling pattern.

Begin circuit construction by inserting and soldering the eight DIP sockets approximately in the positions shown on Fig.

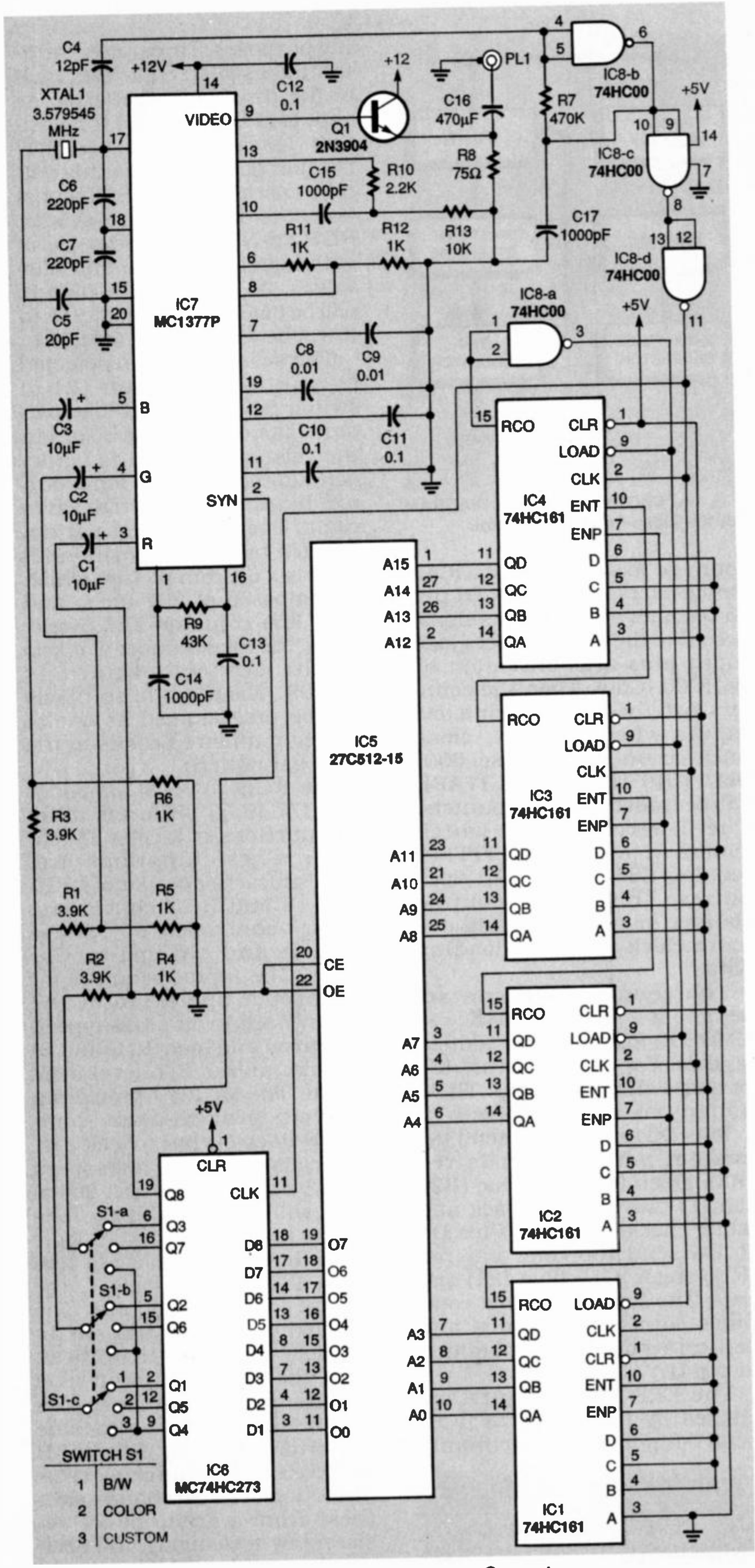


FIG. 2—SCHEMATIC DIAGRAM for the Video Pattern Generator.

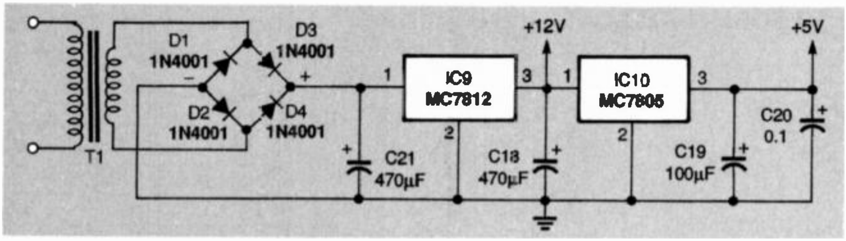


FIG. 3—SCHEMATIC DIAGRAM for the Dual Power Supply. This supply provides +12 and +5 volts. It can be built on a separate board.

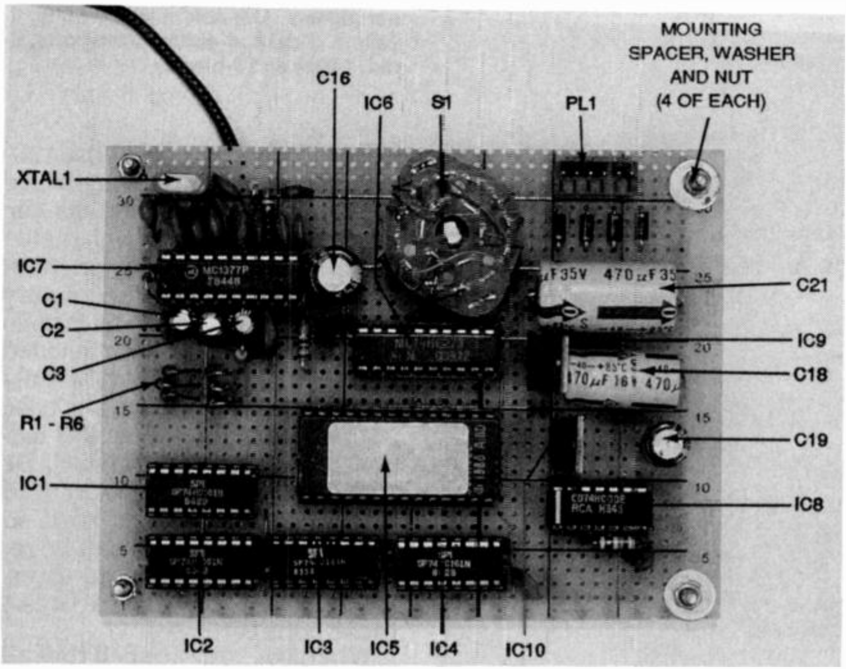


FIG. 4—SUGGESTED PARTS PLACEMENT DIAGRAM. The author integrated the video pattern generator and dual power supply (less transformer T1) on a single circuit board.

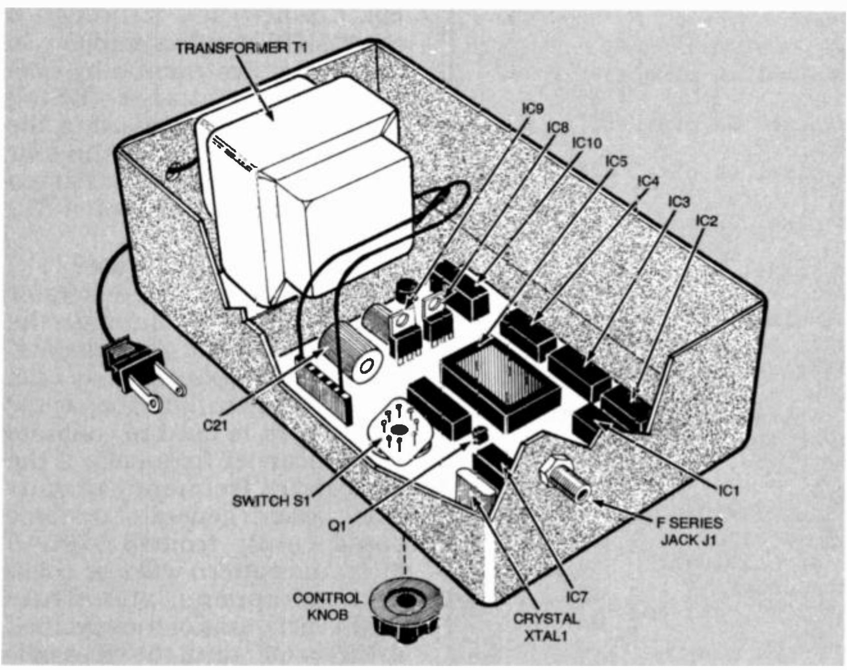


FIG. 5—ASSEMBLY DIAGRAM of the completed Video Pattern Generator. The power supply is located within the project case. The switch knob is attached to the PC board-mounted switch on the bottom of the case.

4. Insert and solder the axial-leaded 470 µF aluminum electrolytic capacitors C16 and C18 so they lie horizontally on the circuit board. Insert and solder the TO-220-packaged 7805 and 7812 voltage regulators at approximately the locations shown. Insert panel-mounted, rotary switch S1 on the circuit board in the pre-drilled hole, and fasten it with the ring nut and washer provided.

Insert and solder all resistors, radial-leaded ceramic disc and aluminum electrolytic capacitors, silicon diodes, and crystal case at the locations approximately as shown on Fig. 4.

Mechanical work

A standard commercial two-piece plastic project case was selected for this project. It measures 7¹⁄₇ × 4⅜ × 2¼ inches. This case is large and tall enough to accommodate the AC-line to 15-volt AC transformer T1. Locate transformer T1 at one end of the case as shown in the assembly drawing Fig. 5, and use the holes in its mounting bracket as a template for drilling the two mounting holes. Then drill those holes.

Position the paper template at the bottom of the case and tape it in position. Drill the four mounting holes and the hole for the switch shaft and bushing. Then drill a hole in the end wall of the case nearest the transformer location for the line cord, and drill another hole at the opposite end of the case for mounting the coaxial jack J1.

Final assembly

Refer to assembly diagram Fig. 5. Fasten ¼-inch standoffs to the underside of the circuit board at all four corners with screws or nuts. (The author selected standoffs with internal and external threads.) Solder a short length (approximately 6 inches) of RG174 or RG58 coaxial cable from capacitor C16 to the coaxial jack J1. Solder one end of the braided shield to the ground terminal of J1 and the other end to pin 3 of IC1.

LISTING 1—C PROGRAM TO FORM VIDEO.DAT

```
#include <stdio.h>
main()
{
int line, pixel, x, y, buffer;
int cross=0x08;
long data;
FILE *stream;
/* open EPROM code file "VIDEO.DAT" */
  if ((stream = fopen("VIDEO.DAT", "wb+")) == NULL)
  {
     fprintf(stderr, "Cannot open output file.\n");
     return 1;
  }
/* generate first four line codes */
  for (line=1; line<4; line++)
    {
      for (pixel=0; pixel<227; pixel++)
       {
           if (pixel<210)
               data=00;
               else data=0x80;
           fwrite(&data, 1, 1, stream);
       }
    }
/* generate 4-25th line codes */
  for (line=4; line<25; line++)
  {
      for (pixel=0; pixel<227; pixel++)
       {
           if (pixel<17)
               data=00;
               else data=0x80;
           fwrite(&data, 1, 1, stream);
       }
  }
/* generate 25-262th line codes */
  for (line=25; line<263; line++)
  {
  if (line-7==(line-7)/21*21)
    cross=cross^0x08;
      for (pixel=0; pixel<227; pixel++)
       {
           if (pixel <17)
               data=00;
           else if (17<=pixel && pixel<38)
            data=0x80;
           else if (38<=pixel && pixel<61)
              data=0xf0;
           else if (61<=pixel && pixel<84)
              data=0xe0;
           else if (84<=pixel && pixel<107)
data=0xb0;
           else if (107<=pixel && pixel<130)
              data=0xa0;
           else if (130<=pixel && pixel<153)
              data=0xd0;
           else if (153<=pixel && pixel<176)
              data=0xc0;
           else if (176<=pixel && pixel<199)
              data=0x90;
           else
              data=0x80;
           if (pixel==pixel/13*13)
              cross=cross^0x08;
           if (pixel>37 && pixel <223)
              data=data+cross;
           fwrite(&data, 1, 1, stream);
       }
  }
  fclose(stream);
  return 0;
}
```

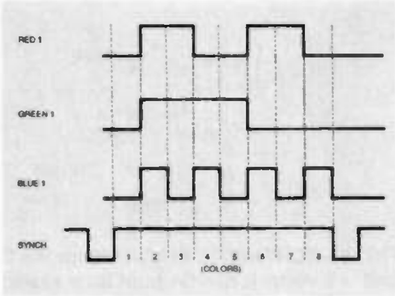


FIG. 6—TIMING DIAGRAMS for the color bar signals. The colors are: 1-white, 2-yellow, 3-cyan, 4-green, 5-magenta, 6-red, 7-blue and 8-black.

Insert the free end of the 120-volt line cord in the hole drilled for it in the case and solder the wires to the 120-volt input side of transformer T1. Then trim and solder the 15-volt secondary wires to the AC input terminals of the full-wave bridge formed by the four diodes D1 to D4. Fasten the transformer to the case with screws and nuts and fasten J1 to the case side wall. Be sure that the transformer and jack leads are long enough so that the circuit board can be removed from the case and inverted without having to break those connections.

When you are satisfied that all wiring is correct, install all the DIP-packaged integrated circuits in their designated sockets. *Caution:* ICs 1 through 6 are CMOS devices subject to damage or destruction by electrostatic discharge (ESD). Mount the circuit board in the case, and fasten it to the four standoffs with screws. Fasten the control knob to switch S1.

Calibrating the generator

This video pattern generator was designed to eliminate the need for periodic adjustments. The only component that calls for special attention is capacitor C17, which is used to calibrate the subcarrier frequency. If the subcarrier frequency of your video pattern generator deviates significantly from 3.579545 MHz, the pattern will lose color. If that happens, substitute slight variations of the specified value for C17 until the video patterns gain color. The order of the waveforms of the color bar pattern are shown in Fig. 6. Ω

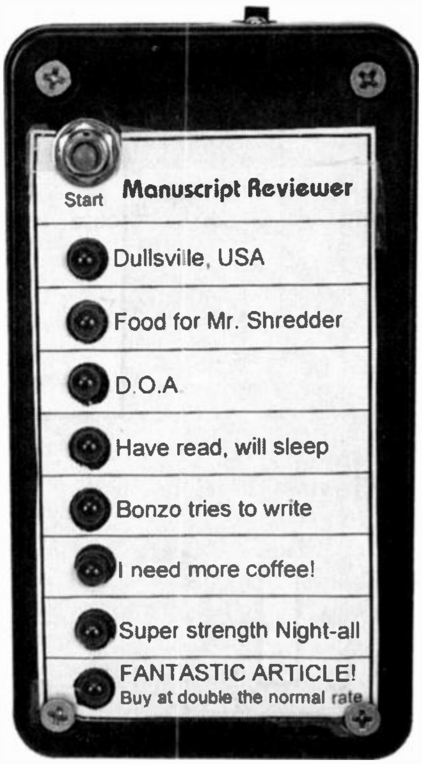
BUILD THIS

Executive Decision Support System

Here's a great gift for anyone who makes major decisions.

JAMES EDWARDS

How to make important decisions.



Let's face it—the world is getting more and more complicated every day. At the grocery store, it's aisles of breakfast cereals. For investors, there are more mutual funds than stocks to choose from. And don't even think about trying to select a computer without considering a mind-numbing range of configurations!

If you feel that this is all too much to deal with, we agree. And we want to help. *Ergo*, the Executive Decision Support System (or EDSS). Based on little known but indisputable scientific principles, the device can quickly and easily help you resolve all the troubling issues of your life. Can't decide what to eat for lunch? EDSS can help. Can't decide where to go to college? No sweat for EDSS. Can't decide whether to pop the question to your significant other? Easy. Just ask EDSS beforehand what the answer will be.

As useful as such a device can be in your own life, it also makes a great gift—one that's both inexpensive and easy to build. Not only that, but the device can be easily configured to cover a wide range of different types of decisions. So you might want to build several to have on hand, and customize them as the need arises.

For example, suppose your company is opening a branch office and your buddy John is being promoted to a management position in the new office. As you bid John farewell, you explain that in his new position he'll need to make a lot of important decisions. And, because you want the new office to do well, you certainly don't want to leave those decisions entirely in his hands! Therefore you give him an EDSS labeled as shown in Fig. 1. Now whenever John needs to make an important decision, he'll have all the help he needs.

The technology behind this wizardry is Motorola's popular 68HC705K1 microcontroller, a favorite of **Electronics Now** readers. We've purposely kept the cost low, used easy-to-find parts, and have made arrangements to supply circuit boards and preprogrammed microcontrollers. So you've got no excuse! (By the way—the scientific principle we referred to above is known as *random-number generation*.)

The project centers around a small microcontroller (a 68HC705K1), eight LEDs, a power switch, and a start switch. On the front panel of the unit, beside each LED, is a word or phrase describing a potential decision outcome. When you apply power to the circuit, the microcontroller initializes. That process involves reading the states of two jumpers, which determine operating mode. After determining mode, the microcontroller blinks out a test sequence on the eight LEDs, and sounds the buzzer to let you know the unit is operating properly. All lights are extinguished after the test sequence completes.

To begin the decision-making process, quickly press the start button. The lights then blink in a random pattern. Eventually the display settles down so that a single LED is lit; that LED represents the outcome of the decision-making process. Repeat the process as often as you like by pressing start.

To increase flexibility, EDSS has three modes of operation that are set using a pair of jumpers; those jumpers are implemented using a pair of 0.1-inch header blocks. Mode 0 provides truly random output; any of the eight LEDs may light up. Mode 1 *always* ends on LED8. Mode 2 *never* lights LED8.

The mode is determined on power-

Fig. 1. The Executive Decision Support System can be easily customized by changing the front-panel label. One possible example is shown here; others can be found as part of the EDSS.ZIP file on the Gernsback BBS.

up. If you set jumpers for Mode 1, but hold the start button when turning on the power, it actually comes up in Mode 0. Now give the EDSS to someone. That person quickly figures out that the answer is always the same. Of course, you insist that it's not, cycle the power with your finger on the Start button, and prove that it's not. Then you power down, return the unit to the "victim," and let him or her try again. It's positively devious!

Note that the trick only works when you start in Mode 1. If you start in Mode 2, the LED is physically disconnected from the circuit, so the EDSS cannot revert to either of the other modes.

The circuit. As shown in Fig. 2, the EDSS consists of a single microcontroller, a Motorola 68HC705K1. The microcontroller contains 32 bytes of RAM (for variable storage), 504 bytes of ROM (for code storage), and ten digital I/O ports, all in a 16-pin package. Although compact in size, it has plenty of resources for this application.

The 68HC705K1 drives nine outputs and reads three inputs. The outputs are the eight LEDs and a low-current buzzer, which emits a short beep whenever a new LED turns on. The three inputs are start switch S1 and two mode-select jumpers.

Careful readers may note that the circuit contains two more I/O devices (12) than the microcontroller has I/O lines (10). Close examination of the circuit yields the cause of the apparent discrepancy.

Pin 4 of the microcontroller is the interrupt request (IRQ) line. IRQ is a dedicated input line that, when temporarily shorted to ground via S1, tells the microcontroller to execute a special section of code known as an *interrupt service routine*, or ISR. In our application, the ISR starts the LED blinking sequence. By using that pin, one of the "regular" I/O lines is spared for other uses.

Microcontroller port PA3 (pin 8) does double duty. In Mode 2, LED8 never lights. We set Mode 2 by connecting JU2 to ground (position B). That in turn grounds PA3, which would otherwise be high. During power-up initialization, one of the first things the firmware in the microcontroller does is examine the state of PA3. It can only be high if the LED is connected via the

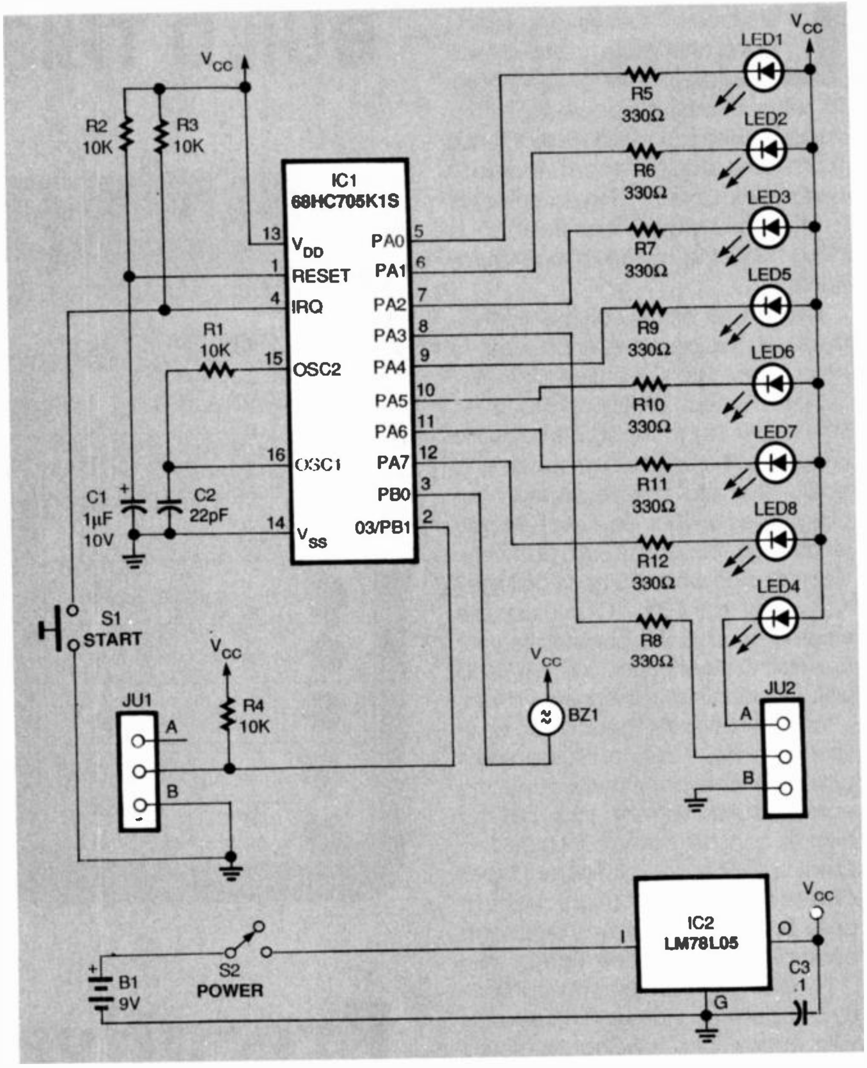


Fig. 2. The circuit centers around Motorola's popular 68HC705K1 microcontroller. Although fairly simple, it has power to spare for our application.

appropriate pins of JU2 (position A). If it is high, the EDSS enters Mode 0 or Mode 1, depending on the state of JU1 and S1, as described above. On the other hand, if the microcontroller sees a low, it puts the unit in Mode 2, and that's that. The appropriate jumper settings for each mode are summarized in Table 1.

The microcontroller has five other pins used for "housekeeping." Pins 13 and 14 supply the device with power and ground, respectively, and pin 1 is the reset line. Whenever reset goes low, the microcontroller restarts itself in an organized manner. For our purposes, the only reset required is on power-up.

TABLE 1—JUMPER SETTINGS

Mode	JU1	JU2
Mode 0: Random Output	B	A
Mode 1: Always the last LED	A	A
Mode 2: Never the last LED	A or B	B

The lines labeled OSC1 and OSC2, in conjunction with resistor R1 and capacitor C2, generate a clock signal that sequences events inside the microcontroller. The RC clock is not as accurate as a crystal clock, but it is significantly cheaper and more than accurate enough for our application.

Circuit power is supplied by a 9-volt battery. The battery drives a standard LM78L05 voltage regulator, which provides 5-volt circuit power. Capacitor C3 filters the regulator's output.

Software. The software that controls the EDSS must be "burned" into the microcontroller. If you have the appropriate hardware, you can burn the IC yourself. The object code is stored in a file called EDSS.ZIP, which is available on the Gernsback BBS (516-293-2283). The Zip file contains an S-record file, a readme, and some sample labels and templates you can use (with Word for Windows 2 or later versions) to dress up the front panel. You can also simply purchase a pre-programmed IC, as explained in the Parts List. Even if you don't want to burn your own microcontroller, you might want to download the Zip file for the label templates.

Construction. The main design goals of this project were that it be inexpensive as well as quick and easy to build. Thus we used very common components, most of which are available at RadioShack.

Most components mount on a single PC board, as shown in Fig. 3 (the parts-placement diagram) and Fig. 4 (the assembly diagram). The PC board is designed to slide into containment rails molded into the sides of the recommended project enclosure. This slide-in design greatly reduces assembly time because no additional mounting hardware is required.

With that mounting scheme, the board stands perpendicular to the enclosure's display face. Consequently, the LEDs must be bent at a right angle relative to the surface of the PC board. Lead length both before and after the bend is critical; if the leads are too long the enclosure cover will not fit, but if they're too short the board will not mount securely. You'll want approximately ⅛-inch be-

(Continued on Page 109)

PARTS LIST FOR THE EXECUTIVE DECISION SUPPORT SYSTEM

R1–R4—10,000-ohm, ¼-watt, 5% resistor
R5–R12—330-ohm, ¼-watt, 5% resistor
C1—1.0-µF, 10-volt, tantalum capacitor
C2—22-pF, polyester capacitor
C3—0.1-µF, ceramic-disc capacitor
IC1—68HC705K1S microcontroller, integrated circuit
IC2—LM78L05, +5-volt, 100-mA regulator, integrated circuit
LED1–LED8—Light-emitting diodes, red
BZ1—9-volt piezoelectric buzzer (Radio Shack 273-074 or equivalent)
B1—9-volt transistor battery
S1—Normally-open, momentary, pushbutton switch
S2—SPST toggle or slide switch, panel mount
JU1, JU2—0.1-inch male PCB mount 3-pin connectors
Enclosure (RadioShack 270-221 or equivalent), PC board, 0.1-inch female header blocks, 16-pin DIP socket, wire, solder, etc.

Note: The following are available for purchase from: Aurora Software, PO Box 080133, Rochester, MI 48309-0133: pre-programmed 68HC05K1CP microcontroller ($12.78); 360k (5.25-inch) or 1.44M (3.5-inch) PC disk containing S-record file of the software for IC1 ($6). Please add $2 shipping and handling for all orders and (sorry) no Michigan orders can be accepted. An etched, drilled, and tinned PC board for the project is available for $4.50 from Chelco Electronics, 61 Water Street, Mayville, NY 14757. NY residents must add 7% sales tax.

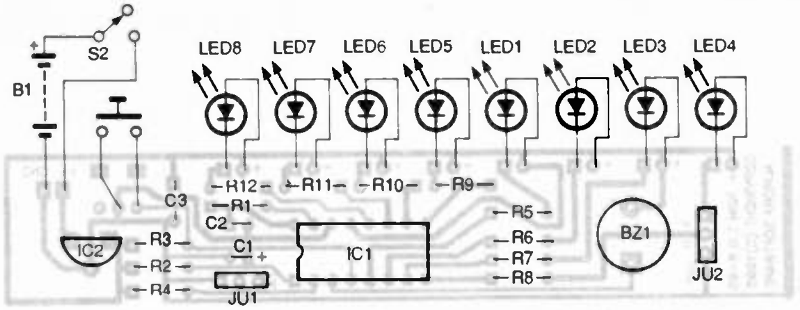
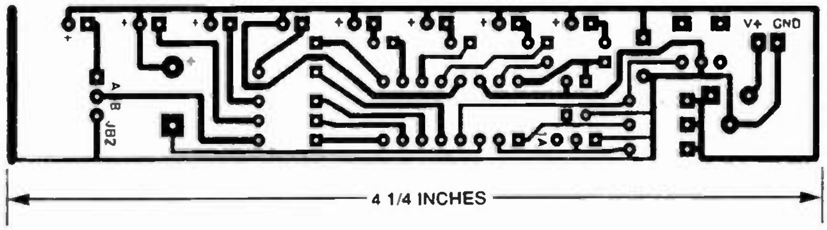


Fig. 3. Here's the component placement diagram. The LED lead length is critical, so test one LED before soldering the rest to the board.



Here's the PC board for the Executive Decision Support System. It is shown full sized.

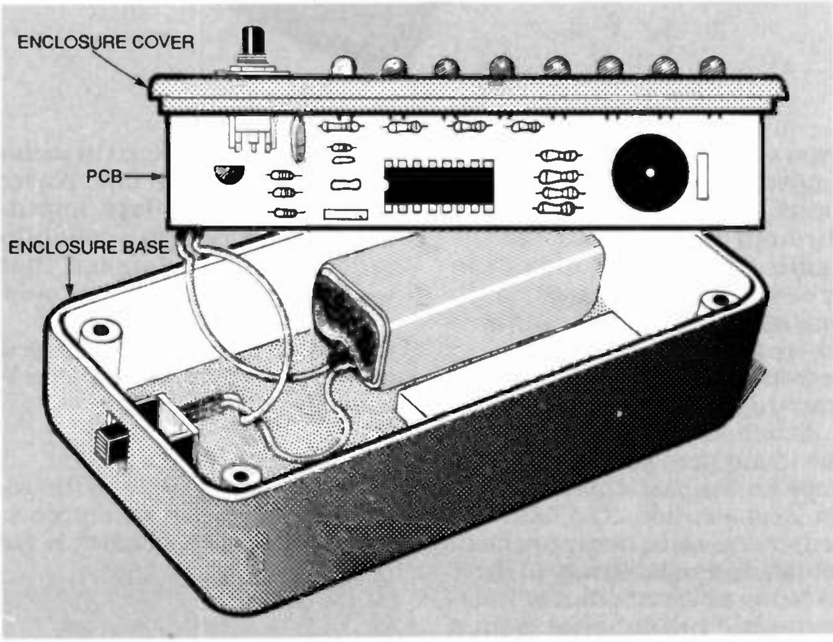


Fig. 4. The recommended case for the project has molded rails that allow the PC board to slide in to its permanent mounting spot. Use the left-most set of moldings to allow room for the 9V battery.

This simple projects lets multiple users share a tape player or radio through headphones.

BUILD THE Listening CENTER

MICHAEL A. COVINGTON

WHAT DO YOU DO WHEN HALF A DOZen people need to listen to the same tape player or radio, through headphones, at the same time? That situation arises often in classrooms, libraries, language labs, and anywhere speakers cannot be used because they might be too distracting to others.

Although you can connect all the headphones in parallel and hope for the best, that's far from an ideal solution. The listening center described here provides a robust and reliable way to drive as many as seven pairs of Walkman-style headphones from a single signal source. Unlike a simple parallel connection, the listening center takes care of all the following requirements:

- The radio or tape player can be mono or stereo, and either way, the listeners will hear sound in both ears.
- The radio or tape player need not contain a resistor to protect the headphones. That means you can feed the listening center from a speaker-level signal if you wish.
- Plugging a mono earphone into a stereo jack will not short out a channel.
- Even with seven 32-ohm headphones connected in mono mode, the radio or tape player sees a seven-ohm load impedance, which is high enough to protect it from damage that would be caused if it were overdriven.
- The listening center is rugged and "student-proof" for classroom use.

The circuit

How's it all done? With resistors. As shown in Figure 1, each side of each headset is fed

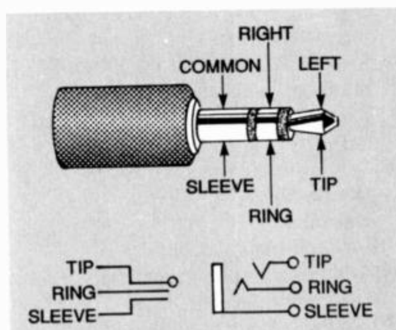


FIG. 2—A PHONE PLUG and the schematic symbols for plug and jack. A mono plug has a longer sleeve and no ring.

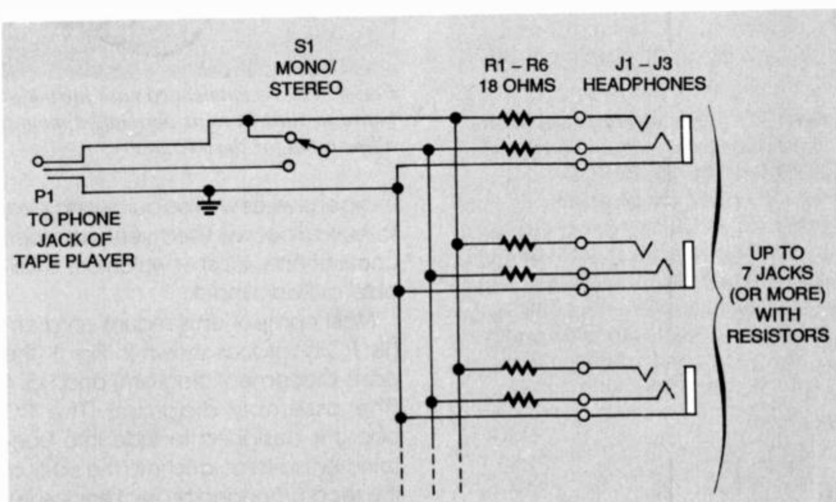
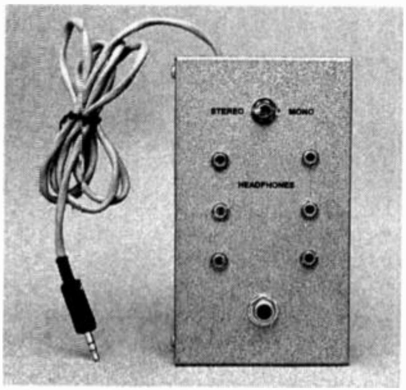


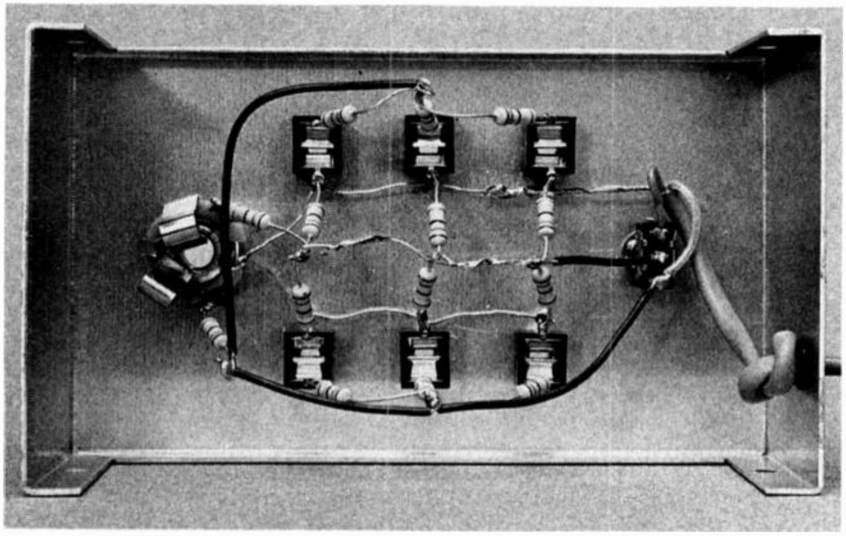
FIG. 1—THE LISTENING CENTER. Three jacks are shown, but you can use up to seven or more.



THE ENCLOSURE for the listening center can be either plastic or metal. Install both large and small headphone jacks for maximum flexibility.

PARTS LIST

P1—Stereo (3-conductor) phone plug to fit radio or tape player (3.5-mm or ¼-inch)
S1—Subminiature SPDT switch
R1-R6—18- or 22-ohm, ⅛-watt resistor (two for each headset)
J1-J3—Stereo (3-conductor) phone jack to fit headset (3.5-mm or ¼-inch)
Miscellaneous: Metal or plastic enclosure, approximately 3×5×2 inches; flexible 3-conductor cable or 2-conductor shielded cable, about 3 feet long; hardware, grommets, labels, etc. as needed.



YOU DON'T NEED A CIRCUIT BOARD to build the listening center. The resistors are supported by their leads.

through its own 18-ohm resistor.

Because the impedance of Walkman-style headphones is normally 32 ohms, this doesn't reduce the sound level very much, but it does protect the headphones if the listening center is connected to a speaker-level signal. It also protects the headphones from each other—a single low-impedance headphone won't "hog" all of the signal, and even a short circuit to ground won't do any harm.

Short circuits are usually a risk because of the way stereo phone plugs are made. As Figure 2 shows, each stereo plug has three conductors: tip (left channel), ring (right channel), and sleeve (common ground). A mono plug has no ring; instead, the sleeve extends up where the ring would be. Therefore, if you were to plug a mono plug into a stereo socket, one channel would be shorted out, possibly damaging the amplifier.

The listening center eliminates that problem by using only stereo plugs. Its stereo/mono switch lets you feed both channels of the stereo headphones from the tip of the plug when using a mono signal source.

Construction

The listening center can be built in a small metal or plastic box. The phone jacks can be small (3.5-mm) or large (1/4-inch); we chose to use six small ones and one large one for maximum flexibility.

No circuit board is needed; the terminals of the phone jacks can serve as tie points, with each resistor supported by its own leads. The cable to the radio or tape player need not be shielded, but shielding may help prevent pickup of radio frequency (RF) interference. Shielded or not, the cable that you choose should be strong and flexible, and long enough to allow comfortable positioning.

If you want to use more than seven headsets at a time, make the resistors slightly larger (such as 22 instead of 18 ohms). Depending on the signal source and the loudness needed, you may be able to use as many as a dozen headsets.

Checkout and use

To try out the listening center, plug it into the headphone jack of a stereo system or "boom box" and plug in two or three Walkman-style headsets. If the headsets are reasonably well matched, you should hear the program with equal volume in all of them.

With the STEREO/MONO switch set to MONO, you should hear the sound for the left channel in both ears of each headset, and you can use a monophonic signal source such as a mono tape recorder.

Because the listening center includes no amplification, you'll have to turn up the volume of the signal source louder than normal, but almost any radio or tape player should be able to drive multiple headsets with no difficulty. Tiny pocket-size units are the only exception; a tape player powered by two AA cells can probably only drive two or three headsets at a time with adequate volume.

Imported Walkman-style headsets suitable for classroom use are available for as little at $1 each (check the "Everything's A Dollar" store in your local mall). As long as their impedance is 32 ohms, all the headsets should give equal loudness when used simultaneously. Headphones of other impedances can be used but will not necessarily give equal loudness. Ω

MARK O. BENDER

TONAL VOLTMETER

This circuit gives an audible indication of voltage levels.

MOST VOLTMETERS HAVE A DIGITAL or analog moving-needle display to indicate the voltage being measured. However, the tonal voltmeter, or TVM presented here emits a tone that changes in pitch according to changes in the voltage being measured. While this is no substitute for the accuracy of a digital display, it can give a quick, relative indication of a voltage value without the user having to stop and look at a display.

The TVM is a great time-saver when performing quick voltage-level checks as normally done with a logic probe. If one regularly repairs or tests many of the same circuits, a tonal pattern of the various test points will soon be recognized. Then, any voltage reading that generates an unfamiliar tone will immediately be suspected as an indication of a possible problem that can then be investigated in greater detail with more sophisticated test equipment. The TVM is also a great way to find voltage peaks or nulls when making circuit adjustments. The simple circuit's main limitation is that the input voltage to be measured cannot be greater than the TVM circuit's supply voltage.

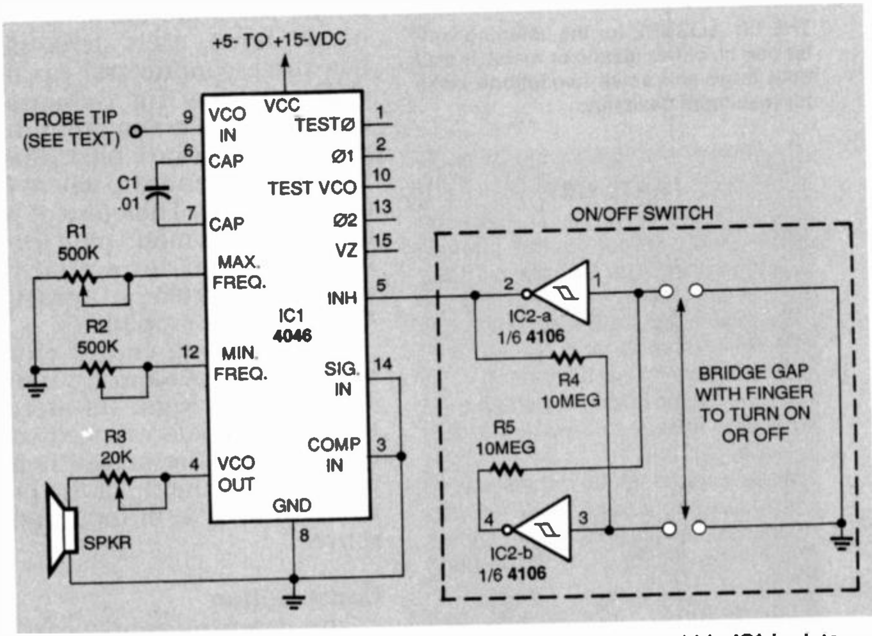


FIG. 1—TVM SCHEMATIC. The frequency of the VCO contained within IC1 is determined by the voltage at pin 9, C1, R1, and R2.

Circuitry

A schematic of the TVM circuit is shown in Fig. 1. The circuit is based on a CD4046B phase-locked loop (PLL) IC with a built-in voltage-controlled oscillator (VCO). The frequency of the VCO is determined by the voltage at pin 9, capacitor C1 between pins 6 and 7, potentiometer R1 at pin 11, which sets the maximum frequency, and potentiometer R2 at pin 12, which sets the TVM's minimum frequency.

The VCO output, which appears at pin 4, is normally fed back into the comparator input at pin 3. However, in this circuit, the VCO output drives a speaker directly. The VCO operates while the inhibit line (INH) at pin 5 is held logic low, and it turns off when INH is logic high.

A touch switch consisting of two Schmitt-trigger inverters (IC2-a and -b) turns the circuit on and off to conserve power when the TVM is not being used. The touch switch can be replaced with a standard SPST switch, if so desired. This is recommended if you don't have a Schmitt-trigger inverter and don't want to purchase one.

The TVM emits a low tone when reading a logic low. As voltage input increases, the tone pitch increases until the input voltage reaches a logic high. As the voltage input decreases, the pitch decreases.

Construction

The circuit is simple enough for point-to-point wiring on perforated construction board; no foil pattern is available. As mentioned before, a standard switch can replace the touch switch. If you use the touch switch, bring the two touch points shown in Fig. 1 (IC2 pins 1 and 6) to the outside of the enclosure you use and connect them to any pair of conductive pads. Leave a gap between the pads that you can bridge with your finger.

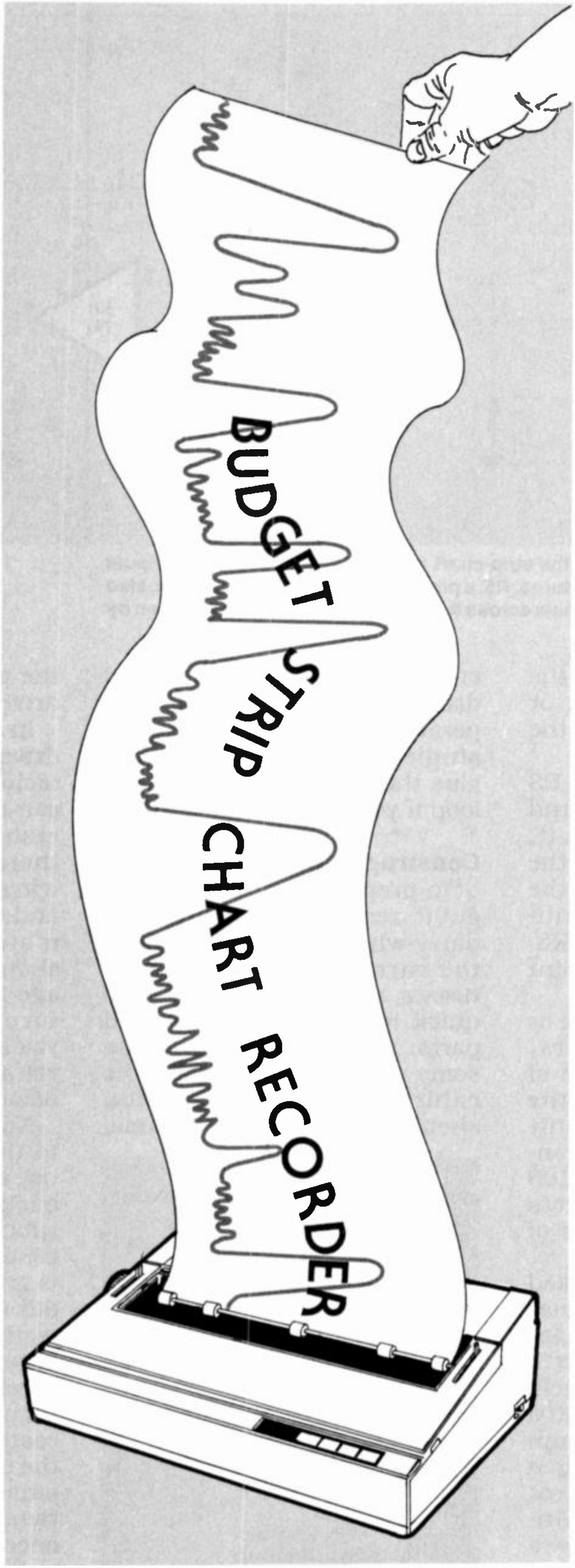
A probe for the VCO input can be made from a ball-point pen

Continued on page 108

PARTS LIST

- R1, R2—500,000 ohms, potentiometer
- R3—20,000 ohms, potentiometer
- R4, R5—10 megohms
- C1—0.01 µF, ceramic disc
- IC1—CD4046B CMOS phase-locked loop, Harris or equiv.
- IC2—CD4106B CMOS hex Schmitt trigger, Harris or equiv.
- 8-ohm speaker, probe body and tip (see text), shielded cable, 5-volt power supply, enclosure, solder

JACK WRIGHT



Convert that old computer printer into a strip-chart recorder

CONVERTING AN OBSOLETE computer printer into a strip-chart recorder is both easy and inexpensive. With about $40 in parts, construction of a simple circuit, and some minor mechanical fabrication, you can have a functioning chart recorder. We built the prototype as a weather station to record air temperature, but it could be used for any number of things ranging from seismography to radio astronomy.

The chart recorder works by comparing the voltage on a potentiometer to the voltage on a temperature-sensing thermistor. The potentiometer is mechanically connected to the printer carriage. A marking pen is also connected to the printer carriage. Any difference in the voltages on the potentiometer and the temperature sensor causes an op-amp to attempt to bring the voltages back in balance. In so doing, the print-head carriage moves left or right, thereby causing a mark on the paper. We drive the platen (i.e., pull the paper through the device) using a standard household timer.

How it works

Figure 1 shows the complete circuit. We use a standard 741 op-amp as a comparator. The comparator monitors the voltages at the junctions, marked TP1 and TP2 in Fig. 1, of two voltage-divider networks. The op-amp compares the voltages from the two networks at its inputs (pins 2 and 3). When the voltages are identical, the op-amp's output (pin 6) is zero, so neither driver transistor (Q1 and Q2) turns on, and therefore the motor does not turn.

But if thermistor R2's resistance changes because of a change in air temperature, a new voltage occurs at the op-amp's inverting input (pin 2). For example, assume the value of R2 decreases. The pin-2 voltage then increases, so the op-amp's output swings negative, thereby biasing Q2 on. That in turn starts the motor, which moves the carriage left or right.

Potentiometer R5 is also coupled to the carriage, so, as the carriage moves, R5's wiper moves, thereby varying the voltage on the non-inverting input of IC1. When the op-amp's input voltages become equal, the output goes to zero, both transistors turn off, and so does the motor. Now the circuit remains quiescent until the temperature changes again.

The potentiometer is a precision, 10-turn type with a value of 20K. A 50K device would provide a wider range, but with reduced resolution. You should be able to buy a surplus 10-turn unit from an electronics supplier for $1–5.

For temperature sensing, we used a common thermistor available from Radio Shack. (Internally, each device actually consists of two separate thermistors.) A thermistor is a device whose resistance changes with temperature. The thermistor is not linear; its resistance increases disproportionately fast at cooler temperatures. That nonlinearity restricts the range of the recorder. Also, the resistance range of your probe, be it a thermistor or some-

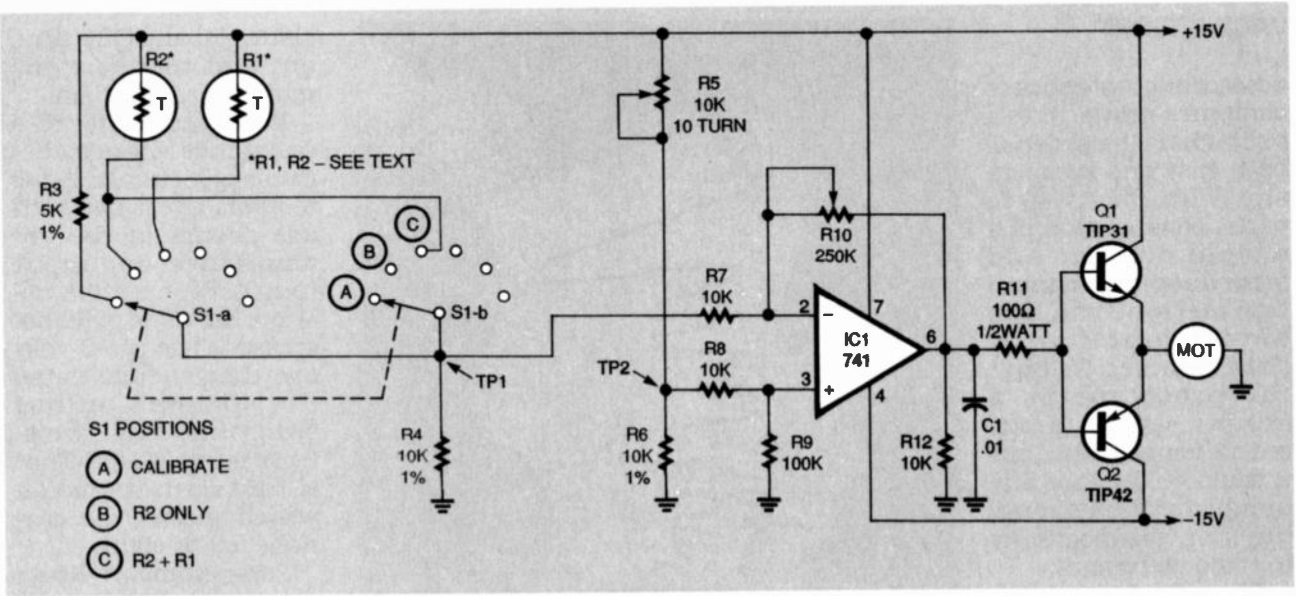


FIG. 1—COMPLETE SCHEMATIC of the strip-chart recorder. When the op-amp inputs differ, the motor turns. As the motor turns, R5, a precision ten-turn potentiometer, also turns. When R5's value equals the value across the temperature sensor (as chosen by S1), the motor stops.

thing else, must not exceed the range of the potentiometer, or the pen will try to run off the side of the chart.

We use precision resistor R3 in conjunction with S1-a and S1-b to calibrate the circuit. When R3 is in the circuit, the carriage will move to where the value of R5, the 10-turn potentiometer, equals the value of R3. That provides a reference point for the chart printouts.

By switching in either one or two temperature sensors, switch S1 allows the choice of two ranges. Position 1 of the switch is for calibration; only R3 is connected. Position 2 connects R2, for a range of 20–108 °F; and Position 3 connects both R1 and R2, for a range of −6–76 °F.

For the prototype, we picked up a derelict daisy-wheel printer at a local second-hand store for $5. Note that a dot-matrix printer would work just as well. If you live near a university, check whether it has an equipment-disposal unit, typically a warehouse with old, broken, and outdated equipment. Another potential source is a printer repair shop.

For marking the chart paper, we simply installed a pencil, using a rubber band to maintain tension against the platen, as shown in Fig. 2. We used several different colors of soft lead drawing pencils to track temperatures for several days on a single chart. You could even glue the chart into a multi-day loop if you wish.

Construction

To prepare the printer, first gut it, removing PC boards, the daisy-wheel mechanism from the carriage, the wiring harnesses, the fan, etc. Don't be too quick to dispose of the gutted parts; you may be able to use some of them, particularly the cables and connectors. You should end up with the frame, the platen, and a carriage and drive mechanism.

In most printers the carriage-drive motor has several wires attached. By trial and error you can determine which wires operate the motor. In our case, there were two red and black wires. We merely tried one red and one black wire and got the motor to turn. The motor should operate on a low DC voltage—the prototype begins to turn at about 2–3 volts—but you may want to determine low-voltage DC operation for certain before you buy.

Now affix the potentiometer to the carriage. Some printers use a cable to move the carriage back and forth; others use a rubber belt. Our unit used a cable drive, but because the cable is greasy and hard to get at, we did not attach to the cable directly. Instead, as shown in Fig. 3, we fixed the potentiometer securely to the carriage and then strung a length of strong, coated twine from one side of the printer frame to the other. A small coil spring keeps the twine taut. The twine wraps once around a spindle attached to the potentiometer shaft. The diameter of the spindle should be such that the potentiometer turns ten rotations (or a little less than ten) over the length of the carriage movement.

PARTS LIST

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

R1, R2—Thermistors, Radio Shack 271-110 or equiv.
R3—5000-ohms, 1%
R4, R6—10,000 ohms, 1%
R5—20,000 ohms, potentiometer, 10-turn
R7, R8, R12—10,000 ohms
R9—100,000 ohms
R10—250,000 ohms, potentiometer
R11—100 ohms, ½ watt, 5%

Other components

C1—0.01 µF
IC1—741 op-amp
Q1—TIP31 NPN Transistor
Q2—TIP42 PNP Transistor
S1—Rotary switch, 2 pole, 6 position

ORDERING INFORMATION

Precision 10-turn potentiometers are available from Ra-elco, Inc., 2780 South Main St., Salt Lake City, Utah 84115, 801-487-7749.

To calculate the diameter of the spindle, simply measure the total distance the carriage moves from left to right, and divide that value by ($\pi \times 10$). Anything that size or slightly larger will do. The spindle material is not critical; we used two hard rubber spacers bracketed by a couple of large washers, and brushed with paint to increase friction. You could also use a wooden spool, a small diameter pipe, or a stack of washers. Incidentally, the spindle must be wide enough to allow the string to worm its way across without jamming into the bracketing washers.

To drive the platen, we used a plug-in appliance timer, available at most hardware and variety stores. We glued the timer dial directly to the platen knob, giving a chart speed of about ⅙-inch per hour, which is satisfactory for temperature recording.

That type of timer is not intended to drive anything, so you should keep a close eye on it until you are certain it can do the job without overheating. We tried three different brands, old and new, and they all worked. Be sure to minimize the drag on your platen by removing all drive gears, stepper motors, etc. Also, because of mechanical slack in the system, it may take up to an hour for the timer to begin turning the platen. If you desire a faster chart speed, other drive arrangements can be constructed, possibly using the built-in mechanics.

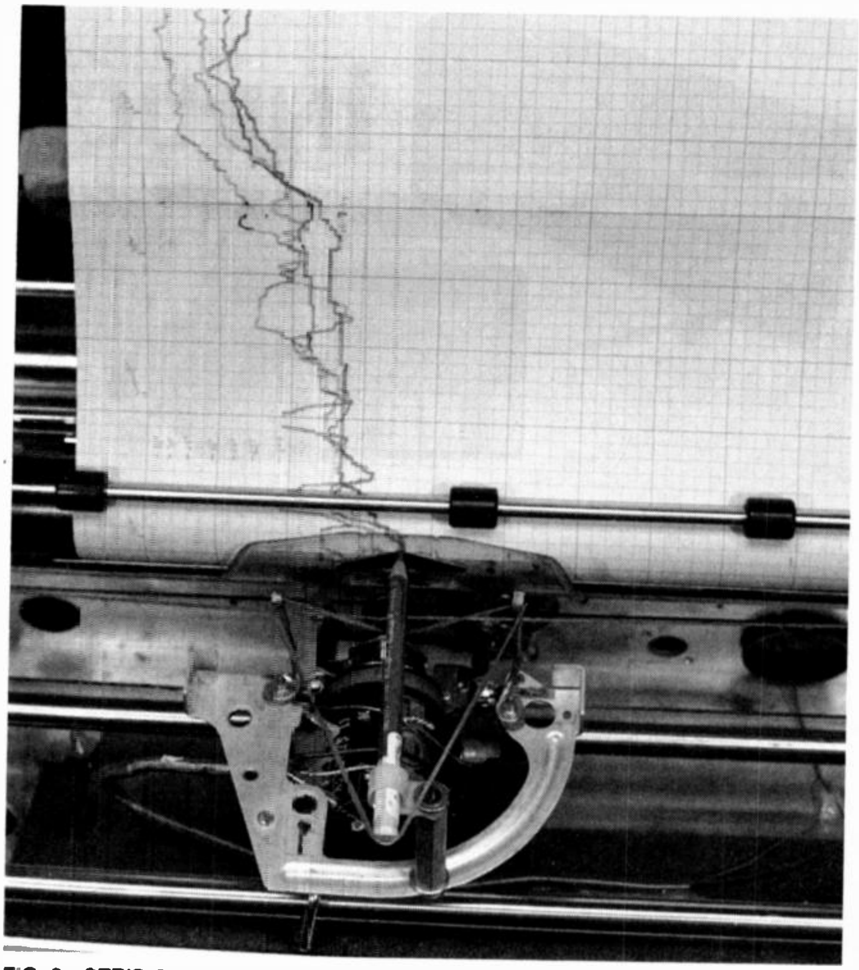


FIG. 3—STRIP-CHART RECORDER IN ACTION. Note how the rubber band holds the pencil against the chart. Chart speed here was about 17 mm/hr.

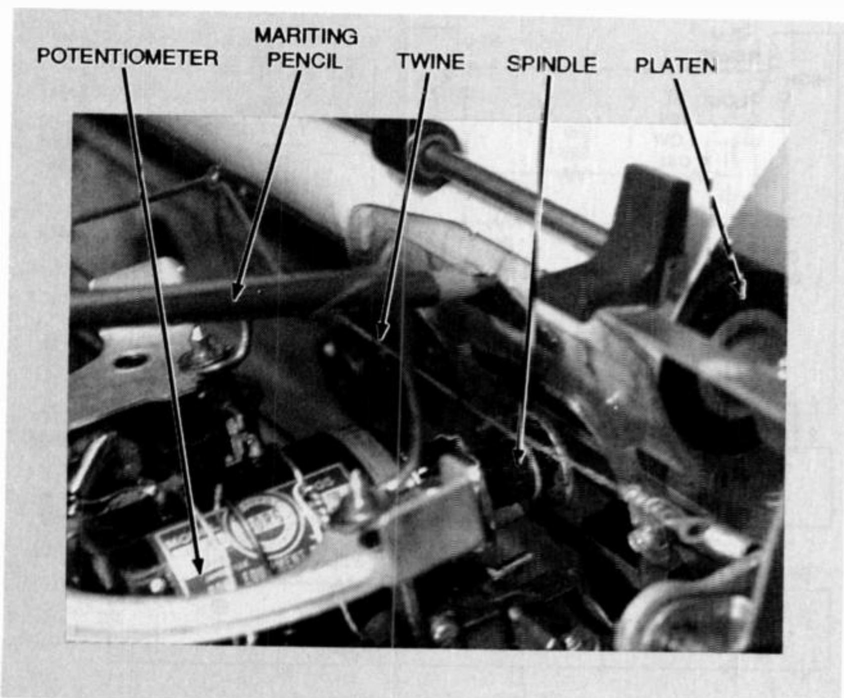


FIG. 2—MECHANICAL ARRANGEMENT of the strip-chart recorder. Note twine wrapped once around the spindle attached to the shaft of the potentiometer.

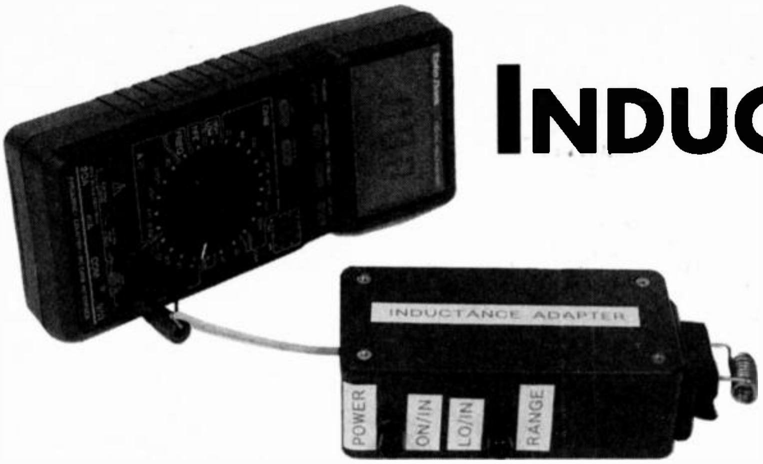
Your printer may have operable DC power supplies. Ours didn't, so we bought two wall-mount DC adapters. Anything in the range of 12–15 volts DC at 500 mA should work, but check the current draw of your carriage drive motor to be safe.

Calibration and testing

Switch R3 into the circuit, let the carriage settle down, and then mark that point as a reference. You may want to slip the twine to move the carriage assembly to a convenient location.

The simplest way to calibrate

(Continued on page 94)



INDUCTANCE METER ADAPTER

Measure inductance with this add-on circuit and an ordinary DMM.

BY MARC SPIWAK

An inductance meter could be a valuable test instrument for a hobbyist to own. However, few people own them because of the high price tags found on such instruments. That's about to change.

The *Inductance Meter Adapter* described in this article is a circuit that, when connected to digital multimeter (DMM), lets you measure low-value inductances. The project can be built for a couple of dollars, or less, depending on what parts are in your junk box. Or you can buy a kit of parts including a PC board from the source mentioned in the Parts List.

The range of the Adapter is actually quite impressive. It allows your DMM to measure inductance from 3 microhenries to 7 millihenries in two ranges. Basically, when the Adapter has an inductance connected at its input terminals, it develops a DC voltage at its output terminals that your DMM can measure and display as a calibrated inductance measurement. An analog multimeter cannot do the job because its input resistance is below the minimum 1-megohm required for the Adapter's proper operation.

The Adapter certainly can't replace a fine piece of test gear, but it's a handy little instrument for sorting unlabeled parts, screening out bad or out-of-spec parts, and matching inductors to one another. Another great feature of the Adapter is that you can have it working in less than an hour, with or without the kit.

Circuit Description. The schematic diagram for the Adapter is shown in Fig. 1. The circuit is powered from a 9-volt battery, B1, and a LM7805 regulator, IC2, provides a regulated 5-volt source for the rest of the circuit. Switch S2 turns power on and off.

The heart of the circuit is a single 74HC132 quad Schmitt NAND-gate IC1. The first gate in the package, IC1-a, is configured as an oscillator whose frequency is determined by the RC components (including trimmers R6 and R7) in its feedback loop; IC1-b is a buffer/inverter. One input of both IC1-c and IC1-d is tied to +5 volts, with both sections configured as inverters. The square-wave output from IC1-b is fed to the pin-9 input of IC1-c, and pin 9 also connects to J1, one of the test-inductor input terminals.

When an inductor is connected across J1 and J2, the voltage input to IC1, pin 9 stays higher for a longer period, depending on the value of the inductor. With the output of IC1-c feeding IC1-d, the resulting average DC voltage across the output terminals (J3 and J4) is directly proportional to the unknown inductance. Potentiometers R6 and R7 calibrate the circuit for the high and low ranges, respectively, and potentiometer R1 sets the zero point on the DMM. When the circuit is calibrated with a known

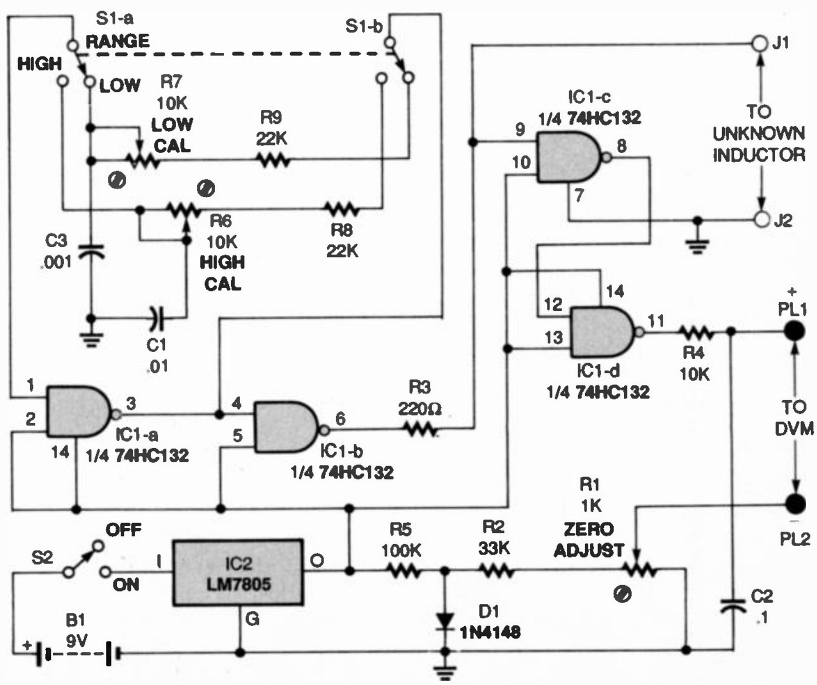


Fig. 1. With this simple Adapter circuit and an ordinary DMM you can measure inductances from 3 μH to 5 mH.

inductance and properly zeroed out, the output voltage can represent inductance. Switch S1 selects the Adapter's range; the circuit will measure from 3 µH to 500 µH in the low range and from 100 µH to 5 mH in the high range.

Construction. The Adapter circuit is simple enough to build using point-to-point wiring. However, if you prefer to use a PC board, you can etch your own from the foil pattern shown in Fig. 2, or order the kit from the source mentioned in the Parts List.

If you're using a PC board, refer to the parts-placement diagram shown in Fig. 3 when building the circuit. Begin by mounting a socket for IC1; be sure to match the orientation shown. Install the resistors and capacitors.

Solder the switches to the board. Then go on to mount the diode and potentiometers, making sure they are oriented properly. Install wire-jumper JU1 and a battery-snap connector for B1. Then solder insulated wire leads for the connections to J1, J2, PL1, and PL2. Keep the leads to J1 and J2 as short as possible, as they could affect the readings given by the unit. The leads for PL1 and PL2, on the other hand, should be somewhat long; that will make it easier to connect the Adapter to a DMM. Solder banana-plugs PL1 and PL2 to the leads. To complete on-board assembly, mount IC2 and insert IC1 into its socket, being sure to check the polarity of both.

The next step is to prepare the en-

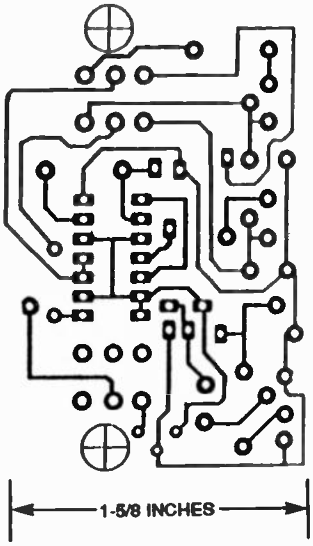


Fig 2. If you'd like to etch your own PC board for the Adapter, use this foil pattern.

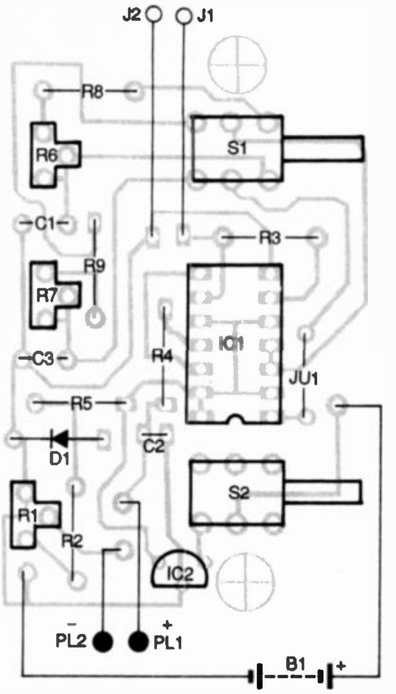


Fig 3. Use this parts-placement diagram as a guide when assembling the Inductance Meter Adapter.

closure for the Adapter. Any enclosure of a suitable size can be used. Mount jacks for J1 and J2 to the case first. To make it easier to temporarily connect unknown inductors to the circuit, use spring-loaded terminals for J1 and J2 (they come with the kit). Drill holes in the case to accommodate the switches and the PL1 and PL2 wires. Mount the PC board.

Calibration and Use. After checking your work, connect a 9-volt battery to the battery clip and set S2 to on. To calibrate the circuit, you'll need a couple of inductors with known values, preferably values equal to or near 400 µH and 5 mH. If possible, measure the value of the inductors you use with an accurate meter to determine their exact values. Connect output leads PL1 and PL2 to a voltmeter set to the 200-millivolt scale and place a short piece of wire directly across terminals J1 and J2. Set range switch S1 to low and adjust R1 for a reading of zero on the meter.

Now set the DMM to the 2-volt range. Remove the wire from J1 and J2 and connect the 400-µH inductor (or whatever value you have that's closest). Adjust R7 so that the voltage displayed on the DMM is the absolute value of the inductance. For example, a 400-µH inductor will give a reading of 0.400 volt. Now connect the 5-mH inductor and set the range switch to high. Adjust R6 so that the voltage displayed on the meter is the same as the inductance value. A 5-mH inductor should read 0.500 volt on the DMM.

To use the Adapter, connect it to your DMM and set it to the 2-volt range. In the low range you can measure from 3 to 500 µH, and the display will read between 0.003 and 0.500. Remember to disregard the decimal point. In the high range, measure from 100 µH to 5 mH and the display will read from 0.001 to 0.500. ■

PARTS LIST FOR THE INDUCTANCE METER ADAPTER

SEMICONDUCTORS

IC1—74HC132 quad Schmitt trigger NAND gate, integrated circuit
IC2—LM7805 positive 5-volt regulator, integrated circuit
D1—1N4148 diode

RESISTORS

(All fixed resistors are ¼-watt, 5%.)
R1—1000-ohm trimmer potentiometer
R2—33,000-ohm
R3—220-ohm
R4—10,000-ohm
R5—100,000-ohm
R6, R7—10,000-ohm trimmer potentiometer
R8, R9—22,000-ohm

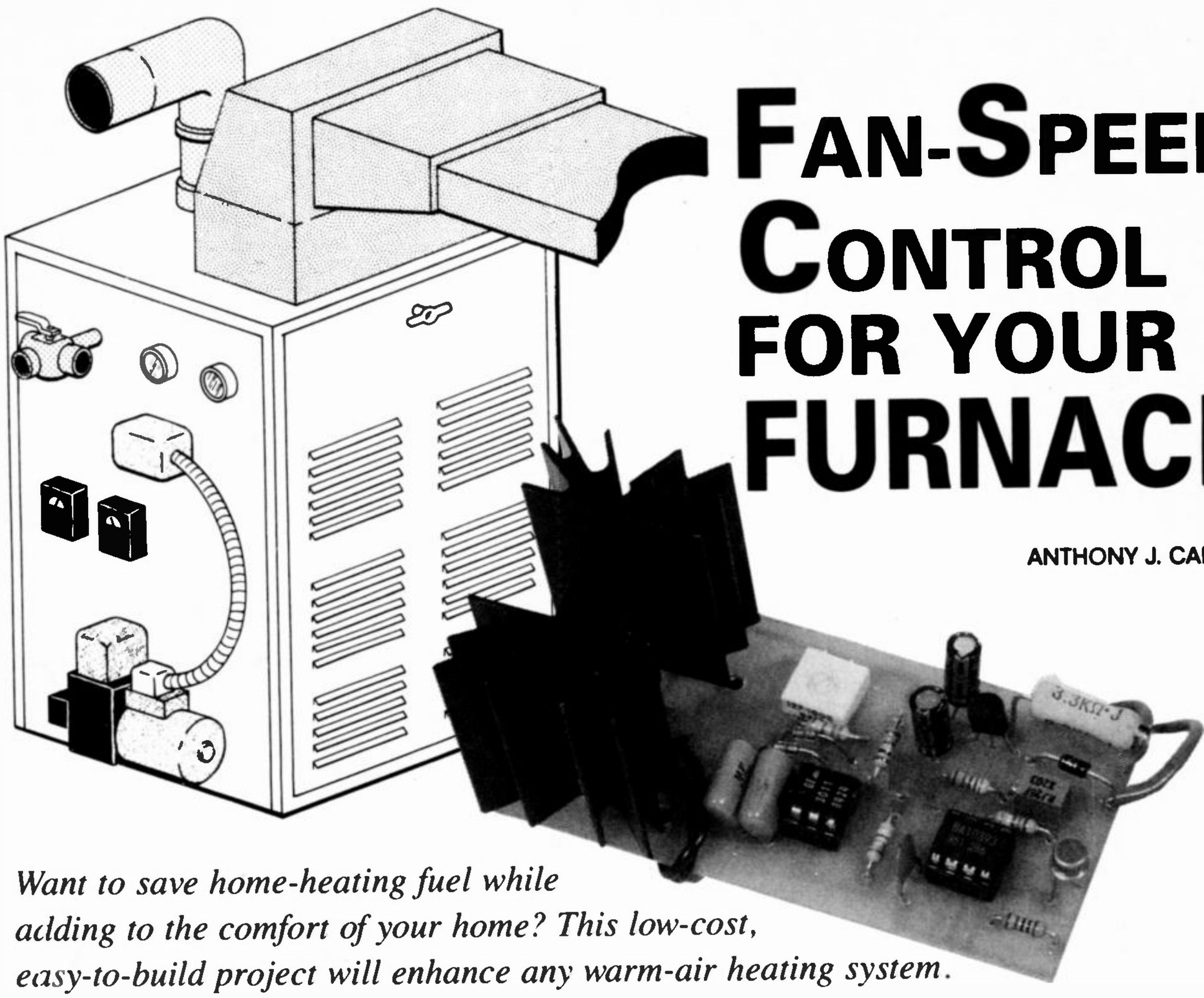
CAPACITORS

C1—0.01-µF, monolithic
C2—0.1-µF, monolithic
C3—0.001-µF, monolithic

ADDITIONAL PARTS AND MATERIALS

S1—DPDT switch, PC-mount
S2—SPDT switch, PC-mount
J1, J2—Spring-loaded terminal
PL1, PL2—Banana plug
B1—9-volt alkaline battery
Printed-circuit materials, project enclosure, battery connector, 400-µH and 5-mH (or similar-value) calibration inductors, wire, solder, hardware, etc.

Note: The following is available from Marlin P. Jones & Associates, Inc. (P.O. Box 12685, Lake Park, FL 33403-0685; Tel. 800-432-9937): Inductance Meter Adapter kit (including everything except a battery, case, and banana plugs)—$14.95 plus $4.50 shipping and handling. Florida residents please add appropriate sales tax.



FAN-SPEED CONTROL FOR YOUR FURNACE

ANTHONY J. CARISTI

Want to save home-heating fuel while adding to the comfort of your home? This low-cost, easy-to-build project will enhance any warm-air heating system.

Unless the warm-air furnace which heats your home is one of the very latest, most highly sophisticated units available today, it suffers from one drawback: its constant blower speed. Most 80% AFUE (annual fuel utilization efficiency) warm-air furnaces manufactured today use a fixed-speed blower, which is set to work best during the coldest, most severe weather conditions. Most of the time such conditions do not exist, so the blower speed is too great for maximum comfort. It cools the furnace's main warm-air distribution duct (the plenum) too fast, shuts down, and deprives you of a very important feature of a properly designed warm air heating system—Continuous Air Circulation, or CAC.

An ideal situation is where blower motor speed is set by the temperature of the furnace plenum. At relatively low temperatures, the blower runs slowly; it increases in speed as the plenum gets warmer. Not only does that provide increased comfort, but the noise level of the blower system is greatly reduced most of the time, and less electrical power is used to drive the motor.

Chances are your warm-air heating system does not have a two-speed blower control. However, you can easily modify your system by installing our low-cost Blower Speed Control. It will enhance your comfort during the heating season, and might allow you to set your thermostat a couple of degrees lower, letting you save precious and expensive fuel.

Design Overview. The Automatic Blower Speed Control sets the blower motor RPM to either of two speeds, low or high, as required by the heating load on the heating system. Low speed will operate most of the time when the furnace plenum is at a relatively cool 110° Fahrenheit or less. That will keep air circulating throughout the home and help eliminate that cold feeling that sometimes occurs when the blower shuts down.

When heating demand increases from either colder outside temperatures or by setting the thermostat higher, the increase in plenum temperature is sensed by the Speed Control, which automatically switches the blower motor to high speed. Air flow is boosted to the maximum possible volume, transferring as much heat as it can from the furnace heat exchanger to the living area of the home.

Once the thermostat is satisfied and the plenum cools down below about 110°F, the blower automatically returns to low speed. You'll benefit from continuous air circulation and enhanced comfort, all while saving fuel.

About the Circuit. The heart of the blower speed control is the phase-controlled Triac circuit illustrated in Fig. 1. During each AC half-cycle, capacitor C_A is charged through adjustable resistor R_A. The voltage on C_A is applied to a diac, which acts like a bidirectional Zener diode. The diac will trigger and conduct current when its switching voltage is reached. That current is in turn applied to the gate terminal of the Triac, which will switch on and let current flow through the load. The Triac will continue to conduct until the end of the AC half-cycle, when it switches off and waits for the next trigger input.

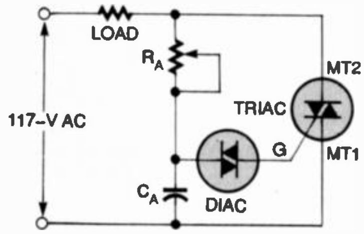


Fig. 1. A typical phase-control Triac circuit. Adjusting the resistance of R_A changes the time it takes to charge up C_A, and fire the diac.

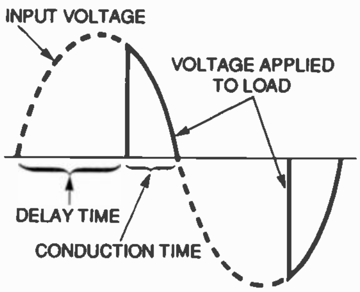


Fig. 2. If the Triac's trigger pulse is delayed, this waveform is the result. Delaying the trigger applies less energy to the load.

The amount of resistance R_A is set to controls how fast C_A charges up to the trigger voltage of the diac. The greater the resistance, the longer it will take. That delay controls how much current the load sees. A longer delay in triggering the Triac allows less time in the half-cycle for the Triac to conduct, so less electrical energy is applied to the load. Figure 2 is an example of that type of waveform. When the load being driven is a permanent split-capacitor (PSC) induction motor, the reduced amount of available electrical energy slows the motor down. By adjusting the value of R_A, we can control the motor's speed.

Let's look at Fig. 3, the schematic diagram of the blower-control circuit. The basic variable-motor-speed circuit described above is composed of Triac TR1 along with phase-control network D4, R8, R9, and C5. Those components form the low-speed circuit, with R8 adjusted for the desired low-speed operation of the blower motor. That network is always in place, so the motor cannot rotate at a speed that is less than the desired minimum.

A second RC network composed of R7, C4, and diac D3, forms a duplicate phase-control network that is connected, through optoisolator IC3, in parallel with the first network. In effect, either phase-control network can be used to control motor speed. In the second phase-control network, the value of R7 is low enough to provide a minimal delay, essentially delivering full line power to the motor. That results in high-speed blower operation. Note that when the high speed phase-control network controls the Triac, the low-speed circuit has no effect on motor performance since the Triac will have been triggered earlier in the half-cycle.

Optoisolator IC3 is used to switch in the high-speed phase-control network. That permits the low-voltage part of the circuit to be electrically isolated from the motor wiring.

When plenum temperature is below 110°F, IC3 is off, allowing the low-speed phase-control network to run the motor. Above 110°F, IC3 is activated. That turns the second phase-control network on, which runs the motor at high speed.

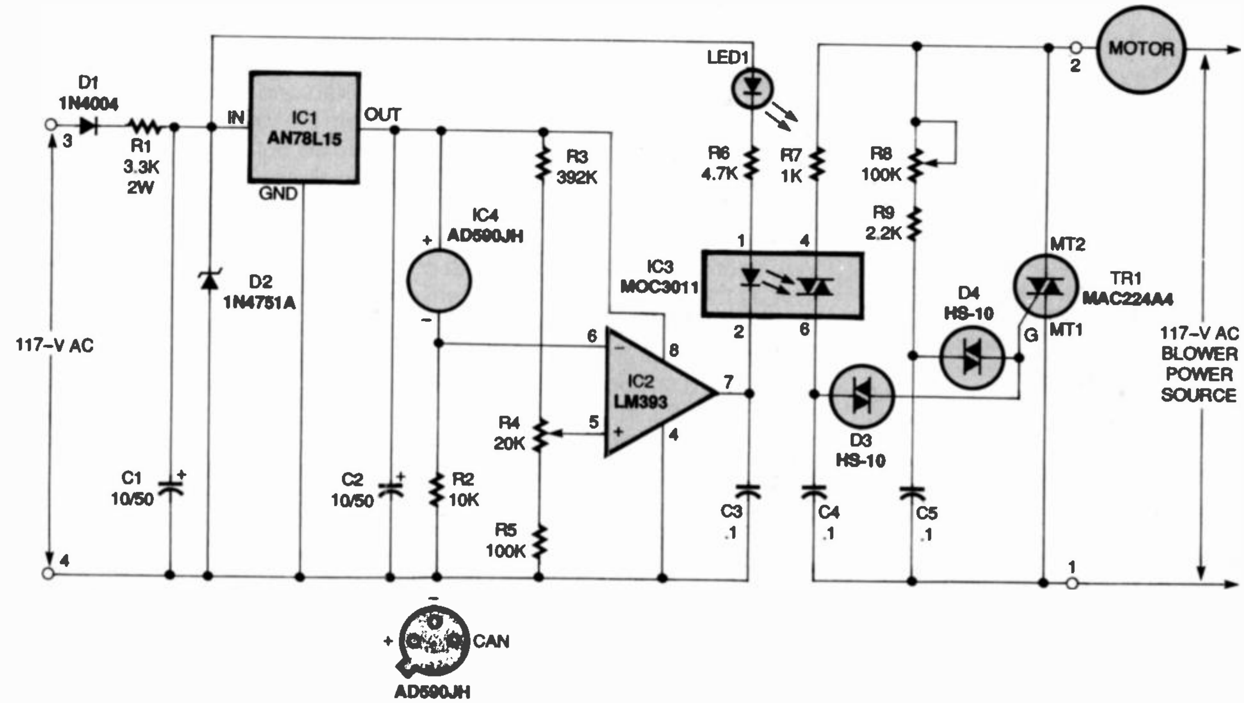


Fig. 3. Here is the schematic of the Automatic Blower Speed Control. An optoisolator protects IC2 from the destructive voltages of the blower motor. It's a good idea to use two different-colored wires for the temperature sensor's "+" and "−" terminals. The sensor terminal marked "CAN" is not used.

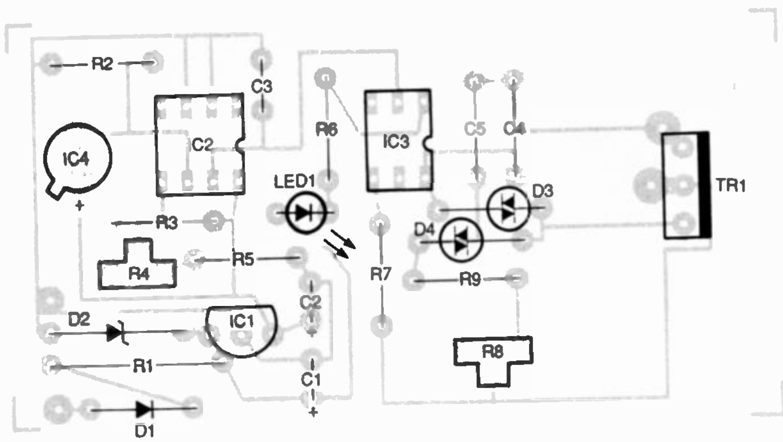
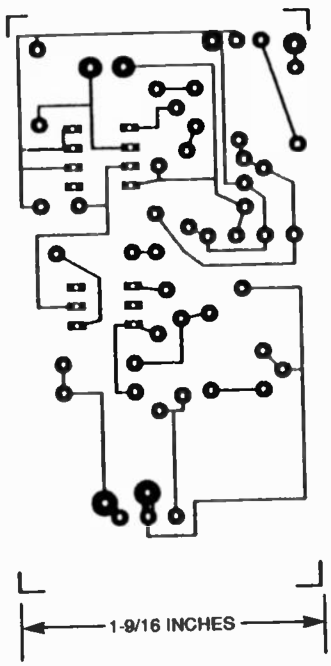


Fig. 4. Component layout of the Blower Speed Control is simple and straightforward. Take care that all polarized parts, such as ICs, capacitors, and diodes are inserted with the proper orientation or they could be damaged.



Here's the foil pattern for the Automatic Blower Speed Control. The design of the Controller is simple enough to use a single-sided printed circuit board. If you don't want to drill and etch your own board, the Controller can be hand wired on a piece of perfboard.

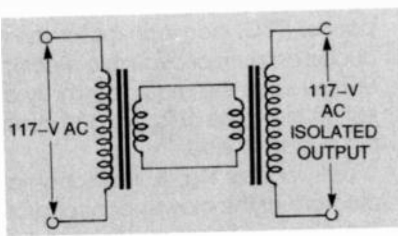


Fig. 5. If you have to troubleshoot the high-voltage section of the Blower Speed Control, it's a good idea to use an isolation transformer for additional safety. You can wire two transformers back-to-back for reasonable isolation.

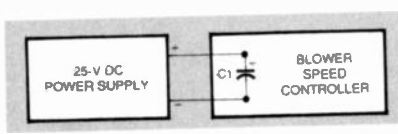


Fig. 6. When you're ready to do preliminary testing of the low-voltage side of the Blower Speed Control, temporarily hook up a 25-volt DC power supply in this way to power the circuit.

A half-wave Zener-regulated DC power supply formed by R1, D1, D2, and C1 feeds 30-volts DC to the input of IC1, a fixed 15-volt linear regulator. The regulator supplies temperature sensor IC4 and a voltage divider network composed of R3, R4, and R5.

The output of IC4 is designed to provide a current of 1 microampere-per-degree Kelvin in response to the ambient temperature surrounding it. Its output current is passed through R2 to produce a known temperature/voltage relationship. At a temperature of 25°C (77°F), the equivalent Kelvin temperature is 25 + 273.2, or 298.2° K. A sensor current of 298.2 microamperes produces a voltage of about 2.98-volts across R2. In order to measure the temperature of the warm air, IC4 is placed inside, or in close contact with, the plenum.

Only one section of voltage comparator IC2 is used. A voltage comparator, as its name implies, compares the level of two input voltages. It acts like an op-amp that has no external feedback, resulting in very high gain. The output voltage of the comparator is either 15-volts or 0, depending on which of the two voltages present at the input terminals is higher than the other.

The negative input terminal of the comparator is the voltage across R2, accurately representing the plenum temperature. The positive input of the comparator is connected to a voltage level set by potentiometer R4. That level is set to about 3.16 volts during calibration of the circuit. That is the voltage that appears across R2 when the furnace plenum is at about 110°F.

When the plenum temperature is below 110°F, the comparator's output terminal is high. That leaves the LED in IC3 dark. As a result, the high-speed phase-control network is disconnected, and the motor runs at low speed when the plenum switch calls for blower operation.

When plenum temperature exceeds 110°F, the output of IC2 goes low, and its open-collector NPN output transistor sinks current through the internal LED of IC3. That activates the high-speed phase-control network, causing the blower motor to run at maximum speed.

An LED indicator is connected in series with the input circuit of IC3 to provide visual indication of high speed motor operation. That feature is useful when testing the Blower Speed Control.

Construction. The blower speed-control circuit is contained on a single-sided printed-circuit board. A drilled and etched board is available from the source given in the Parts List if you do not wish to etch your own. Alternatively, the circuit may be hand wired on a perfboard using good construction techniques.

Figure 4 illustrates the parts placement of the board. Note that the Triac will require a heatsink since it will dissipate several watts, depending upon the size of the blower motor. The Parts List suggests one possible selection, but you may use any heatsink that provides sufficient cooling. Bear in mind that the metal tab of the Triac is electrically hot, so both it and the heatsink must not be shorted to any part of the circuit or furnace.

Before starting assembly, clean the copper side of the PC board with steel wool to remove any dirt or oxidation. Wash it with detergent and water, and dry thoroughly. Refer to Fig. 4 for proper location of all the parts. All polarized components, such as semiconductor devices and electrolytic ca-

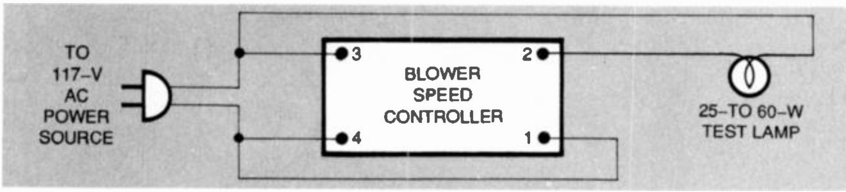


Fig. 7. Wire the Blower Speed Control in this way to test the high-voltage side. Use a 25- to 60-watt light bulb to simulate the blower motor. The Triac and its heatsink will be electrically live—don't touch them unless the Controller is unplugged from the wall socket.

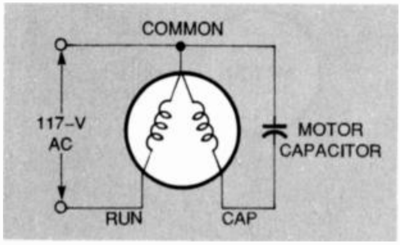


Fig. 8. This is how a typical permanent split capacitor (PSC) motor is wired. Sometimes both capacitor terminals are isolated.

pacitors, must be properly oriented. Just one part placed backwards in the board will prevent the circuit from working, and will probably cause damage to one or more components.

The integrated circuits should be soldered directly onto the printed circuit board for reliability, since the circuit might be exposed to vibrations from the furnace while the blower is operating. Before soldering, be absolutely sure that each IC is properly oriented as illustrated in Fig. 4. Be careful; it is difficult to remove an IC from the board once it has been soldered in place. The two diacs are bi-directional; they are placed into the circuit board without regard to polarity.

It is important to use metal-film resistors where specified in the Parts List to ensure proper calibration and stability of the temperature-switching point. Ordinary carbon resistors are not temperature stable, and should not be used where metal-film types have been specified.

Be very careful when handling the Triac. If the leads need to be bent slightly, be sure that the bends take place away from the plastic body of the Triac. That will avoid any possible damage to the Triac from mechanical stress. It is best if two long-nose pliers are used to perform the bending operation. Be absolutely certain that the orientation of the Triac is correct when inserting it into the printed circuit board. The Triac should be mounted to the heat sink using suitable hardware and heat-sink compound. If necessary, use 16-gauge wire to connect the power leads of the Triac to the PC board. Refer to Fig. 4 to properly locate those connections. The heatsink should be securely mounted to prevent breaking the Triac's leads.

The temperature sensor will be mounted either in close contact, or inside the plenum of the furnace to sense plenum temperature. Refer to the schematic diagram (Fig. 3) before wiring the temperature sensor to the circuit board. Only two of its three terminals are used: positive and negative. The third terminal is connected to the sensor's metal case and is not used. It is mandatory to insulate the wiring and body of the sensor to prevent any possible short circuit to the sheet metal of the furnace. A short circuit here might destroy the sensor and other components.

Connections between the PC board and the sensor is made with 20-gauge stranded wire with insulation rated at 105°C (221°F). Any length will be satisfactory. Use different color wires if possible. That will make identifying the sensor leads easier. Measure and cut the required length of wire, noting the final location of the PC board and sensor.

When the printed-circuit board is completed and the Triac is securely mounted to its heatsink, examine the assembly very carefully for opens, short circuits, and bad solder connections, which might appear as dull blobs of solder. Any solder joint that is suspect should be redone by removing the old solder with desoldering braid, cleaning the joint, and carefully applying new solder. It is far easier to correct problems now rather than later if you find that the circuit does not work.

If the circuit board is to be mounted outside the furnace cabinet, it must be placed in a small covered plastic enclosure to protect it from dirt and inadvertent short circuits; if mounted inside, the enclosure could be omitted. If an enclosure is used, remember that the heatsink will need some air flow to maintain Triac cooling. Drill holes in the sides of the enclosure for

PARTS LIST FOR THE AUTOMATIC BLOWER SPEED CONTROL

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—3,300-ohm, 2 watt, metal-oxide
R2—10,000-ohm, ¼ watt, 1%, metal-film
R3—392,000-ohm, ¼ watt, 1%, metal-film
R4—20,000-ohm, cermet potentiometer (Digi-Key 36C24 or similar)
R5—100,000-ohm, ¼ watt, 1%, metal-film
R6—4,700-ohm
R7—1,000-ohm
R8—100,000-ohm, ½ watt, cermet potentiometer (Digi-Key 3386P104 or similar)
R9—2,200-ohm

CAPACITORS

C1, C2—10-µF, 50-WVDC, electrolytic
C3—0.1-µF, ceramic disc
C4, C5—0.1-µF, 250-WVDC, Mylar

SEMICONDUCTORS

IC1—78L15 regulator, integrated circuit
IC2—LM393 dual comparator, integrated circuit
IC3—MOC3011 optoisolator, integrated circuit
IC4—AD590JH temperature sensor (Analog Devices)
TR1—MAC224A4 Triac (Motorola)
D1—1N4004 silicon diode
D2—1N4751A Zener diode
D3, D4—HS-10 diac (Teccor)
LED1—Light-emitting diode, red

ADDITIONAL PARTS AND MATERIALS

Heatsink (Mouser 532-529802B25 or similar), printed-circuit board, hardware, enclosure (optional, see text), hookup wire

Note: The following items are available from: A. Caristi, 69 White Pond Road, Waldwick, NJ 07463: Etched and drilled printed circuit board, $12.95; TR1, $4.75; IC1, $2.75; IC2, $3.25; IC3, $3.25; D3, $2.00; D4, $2.00; IC4, $9.75. Please add $5.00 postage/handling. NJ residents must add appropriate sales tax.

air flow and the power input and output leads. It is best to use 16-gauge, 105°C insulated stranded wire for those connections. Use several different colors to help avoid miswiring.

Do not install the circuit board into its case or the sensor into the furnace at this time. The assembly must first be checked out to be sure it is operating properly.

Preliminary Testing. The preliminary test is divided into two parts. First, the primary side of the circuit is checked using a low-voltage DC power supply as the source of power. The second part consists of checking the AC power side of the circuit using an ordinary lamp bulb to simulate the blower motor of the furnace.

CAUTION: Since the circuit will be powered directly by the AC line during the AC power portion of the test procedure, it is mandatory that no contact be made to any part of the Triac circuit. If you have to troubleshoot that part of the circuit, an isolation transformer must be used to prevent electrical shock. Figure 5 shows how two identical step-down transformers might be connected back-to-back for line isolation.

Refer to Fig. 6 when setting up a DC power supply for the first half of the preliminary test. The supply voltage should be no more than about 25 volts. If the voltage breakdown rating of D2 (about 27 to 33 volts) is exceeded, D2 will burn out.

Connect the negative lead of the DC power supply to the negative side of C1, and connect the positive lead to the positive side of C1. Measure the voltage at the positive side of C2. A normal reading is between 14.75 and 15.25 volts. If you do not obtain that voltage, disconnect power and troubleshoot the circuit before proceeding. Check the orientation of D2, IC1, C1, and C2. Measure the resistance across C2 to be sure there is no short circuit on the 15-volt line. A normal reading is about 13,000 ohms. If that is not seen, examine the board thoroughly for shorts, opens, and bad solder joints. When the fault has been located and repaired, continue with the checkout procedure.

Connect a DVM or VOM across R2 to monitor the sensor current. Apply 25-volts DC power to the circuit and note the voltage reading of the meter,

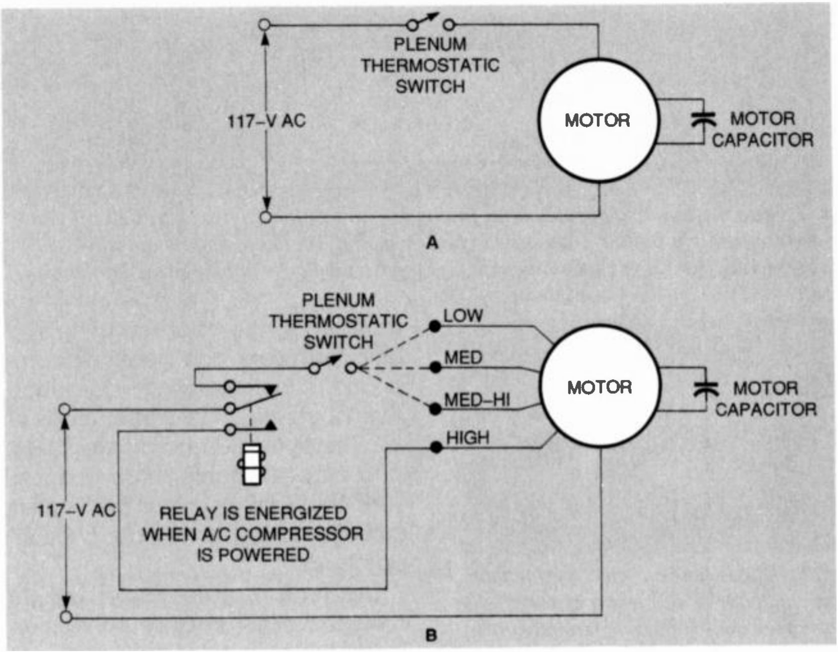


Fig. 9. Here are some typical blower motor wiring diagrams, showing a single-speed (A) and a four-speed (B) arrangement. The lower speeds in arrangement (B) are usually hard-wired to one choice, depending on the size of the house and the capacity of the furnace. The high speed is automatically selected by the air conditioner.

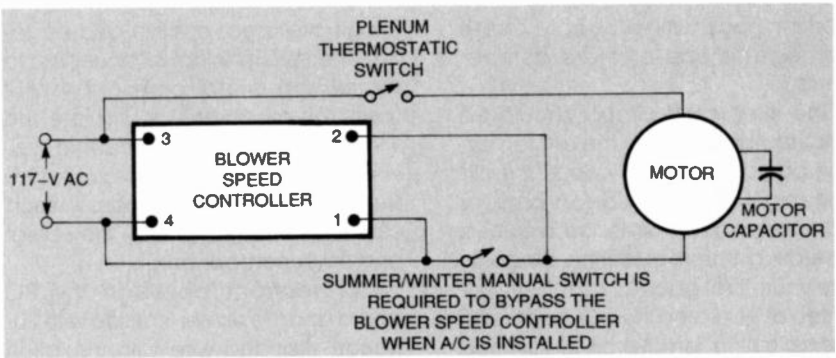


Fig. 10. The Blower Speed Control is connected to a single-speed motor system like this. If you also have air conditioning, you'll have to add the summer/winter bypass switch shown.

which should be about 3-volts DC, depending upon ambient temperature. If the reading is not correct, check the sensor's polarity.

With 25-volts DC applied, measure the voltage at pin 5 of IC2. Adjust R4 for a reading of 3.16 volts.

Assuming that the temperature sensor is at normal room temperature (much less than 110°F), LED1 should be off. Take a hand-held hair dryer and gently heat the sensor while monitoring the voltage across R2. Do not touch the sensor with the dryer. As the sensor heats up, the reading on the meter should begin to rise. When the voltage exceeds 3.16 volts, LED1 should come on. Remove the heat. When the voltage across R2 falls below 3.16 volts as the sensor cools back down to room temperature, LED1 should turn off.

If LED1 does not light up, check its orientation. Check IC2 and IC3 to be sure they are inserted into the board as shown in Fig. 4. Try a new LED.

Disconnect the power supply. Refer to Fig. 7 and very carefully wire the circuit board, lamp, and AC power cord as shown. Double check the wiring before applying power, and be very careful not to touch any of the wiring or circuit board components.

Insert the line cord into an AC receptacle. Adjust R8, using an insulated screwdriver, over its range and note that it is possible to obtain anywhere from full to partial brightness of the lamp bulb. Set R8 so that the bulb is noticeably dim.

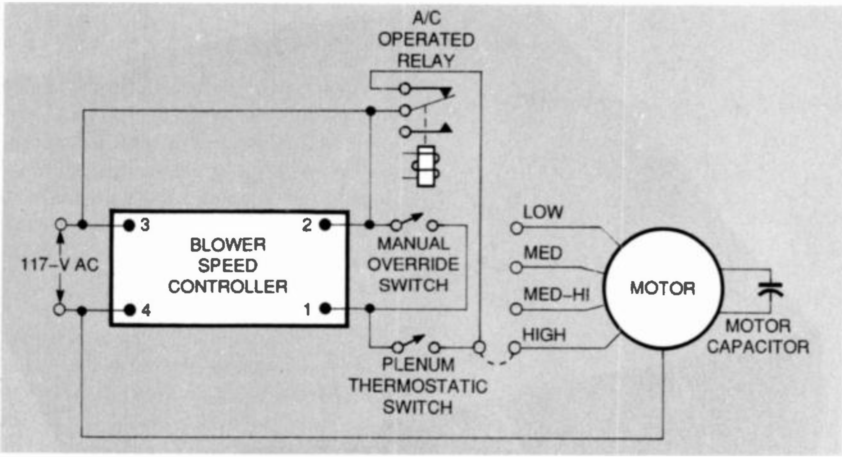


Fig. 11. The Blower Speed Control is connected to a multi-speed motor system like this. The air conditioning relay automatically bypasses the Controller during the summer. The lower speeds are no longer needed as the Controller will automatically set the blower motor's speed.

Gently heat up the temperature sensor as before, being very careful that the hair dryer does not touch the sensor. When LED1 comes on, the lamp should change to full brightness. If the lamp does not respond as described, check the orientation of the Triac. Check the circuit board for opens and shorts. If possible, try replacing IC2, IC3, D3, D4, or TR1 with new parts.

When the board is operational as described, it is ready to be installed into the furnace.

Installation. There may be literally hundreds of models of warm-air furnace in use today, so it is not possible to address each and every one. However, most furnaces will have either a single-speed or multi-speed permanent split-capacitor (PSC) blower motor (Fig. 8). Units designed to handle both air conditioning and heating will usually have a two-, three-, or four-speed motor that is automatically set to high speed for cooling and low speed for heating with a switching relay. Two such wiring diagrams are illustrated in Figs. 9-a and 9-b.

When installing the Blower Speed Control, the motor wiring should be such that it operates at maximum speed when its two input leads are powered by 117-volts AC. The phase-controlled Triac in the circuit will take over setting optimum motor speed.

Figures 10 and 11 illustrate typical wiring diagrams for single speed and multi-speed blower motors. Note that for systems that include central air conditioning, a manual summer/winter switch or an A/C-operated relay must be included as shown to provide maximum motor speed during A/C compressor operation.

Before starting any wiring, disconnect power from the furnace by throwing the circuit breaker and emergency switch off. Then locate the 117-volt input wires to the motor and disconnect them from the furnace wiring. Rewire the circuit as shown in Fig. 10 or 11, depending on which type of system you have. Connect a pair of wires from the 117-volt AC power source at the furnace emergency switch to the 117-volt AC input terminals of the Controller.

As described earlier, the temperature sensor must be placed inside, or in close contact with, the plenum of the furnace where it can respond to temperature rise. Remember, the sensor cannot short out to any metal part of the furnace. Insulate and secure the sensor at the desired location.

Final Test. If you can, obtain a narrow stem thermometer that can be placed inside the plenum to measure the plenum air temperature. Otherwise, your hand placed on the sheet metal provides a fair measure of temperature.

Set the room thermostat down as far as it will go. Turn the furnace power on. Initially, the blower should be off. Locate the blower's plenum thermostatic switch, which turns the blower on and off. Set that switch to its minimum temperature setting. The blower motor should turn on. If the plenum is too cold, operate the burner for a minute or two to warm it so that the blower will operate at the minimum temperature setting.

Using an insulated screwdriver, adjust R8 for the desired minimum blower speed. Do not set the speed too slow; check to be sure the motor is self-starting when power is applied. Once low speed has been set, you'll find the noise level in the living area is virtually non-existent.

Now turn the thermostat up so the burner operates. Monitor the temperature of the plenum. When the plenum becomes slightly warm (about 110°F) and LED1 glows, the blower should switch to high speed.

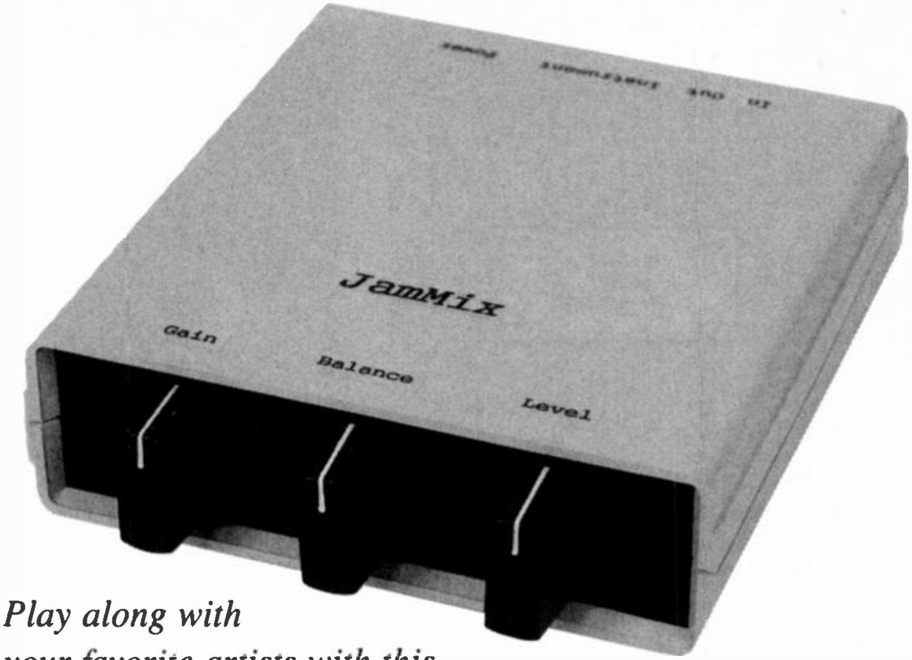
Turn the thermostat down to shut the burner off, and wait for the plenum to cool. The blower should switch back to low speed.

The final adjustment is the switching temperature of the plenum thermostat. For optimum heating efficiency, the blower motor should run when the plenum reaches about 95- to 100°F. The motor will operate at low speed, wringing every possible BTU out of the furnace plenum.

When the system has been set up as described, you will find that the furnace fan operates almost all of the time (continuous air circulation), is quiet, and provides a significant increase in your comfort level.

After operating the system through several variations in weather conditions, you may wish to fine tune the blower switching temperature (R4) and low speed adjustment (R8) to suit your individual preference. Ω

WILLIAM C. HENDRY IV



Build The JamMix

Play along with your favorite artists with this easy-to-build, fun-to-use, stereo mixer.

The JamMix project described in this article is a three-channel stereo mixer that blends any amplified musical instrument with line-level stereo audio, so that a musician can accompany prerecorded music. Other benefits are that JamMix is battery powered and is universally compatible with consumer audio components. The range of suitable equipment varies from "walkman"-type stereos to state-of-the-art separate components. When headphones are used with JamMix to mute the music from the outside world, you can achieve dramatic volume levels without disturbing your neighbors (or perhaps the neighborhood). The JamMix also makes a great personal-practice amplifier, especially for guitars.

The unit's gain and level amplification stages were designed especially for guitars and offer a wide range of volume and distortion control. For example, the gain and level can be adjusted to present a clean signal until the guitar playing intensifies, whereby the distortion increases with the attack on the strings. That is a useful effect for adding power to solos. It can also be set for virtually any blend of *nasty* high-energy sound or *squeaky* clean sound.

Circuit description. Refer to the schematic diagram in Fig. 1. Nine of the ten amplifier sections in five MC1458C dual op-amp integrated circuits are used. The INSTRUMENT jack, J1, provides a signal to IC1-a, which is a non-inverting buffer-amplifier with a gain of 2. The gain is determined by R3 and R4. The amplified instrument signal is fed to audio-gain stage IC1-b which is controlled by potentiometer R6. The circuit location of control R6 provides a desirable interplay with the volume control on the guitar. Whenever the output of IC1-b exceeds about 2-volts p-p (peak-to-peak), light-emitting diodes LED1 and LED2 begin to illuminate and clip the audio signal, providing a high-quality distortion effect. LEVEL control, R10, sets the level of the output of the high-gain distortion stage IC4-a, which in turn drives the ganged potentiometers, R14-a and R14-b.

Unity-gain amplifiers IC5-a and IC5-b feed summing amplifiers IC2-b and IC3-b, which in turn drive the external load connected to stereo OUT jack J3. The load may be either stereo headphones or additional external stages used for audio amplification. Integrated-circuit sections IC2-a and IC3-a are non-inverting amplifiers, each with a gain of 2. Their inputs are the line-level stereo input signals, each having a gain of 2. Their outputs mix with the instrument signal in amplifiers IC2-b and IC3-b; both of these amplifiers also have a gain of 2.

Power is provided by two 9-volt batteries, B1 and B2, via switch S1, which is a double-pole, double-throw switch. Batteries B1 and B2 are series connected with the interconnecting lead grounded, thus providing two 9-volt supplies, one negative and the other positive.

Software circuit model. The JamMix circuit was entered into a Spice electronics-circuit analysis program to verify the design. The program was used primarily to check that no undesirable operation could result from the various component tolerance interactions and temperature changes. The circuit was modeled from R1 to R14, and R14 was taken as the load. Since the line-input amplifiers are identical to the instrument amplifier, it was unnecessary to model the entire circuit. Furthermore, the response at the output would vary with the type of load (amplifier input, headphones, etc.).

A worst-case Monte Carlo analysis was performed, which randomly adjusts the component tolerances that might be found in an actual production run of a circuit. This shows that using normal component values within their tolerances in what could be an unfavorable selection, no circuit would be rejected, indicating excellent circuit stability. The frequency response was also plotted (see Fig. 2)

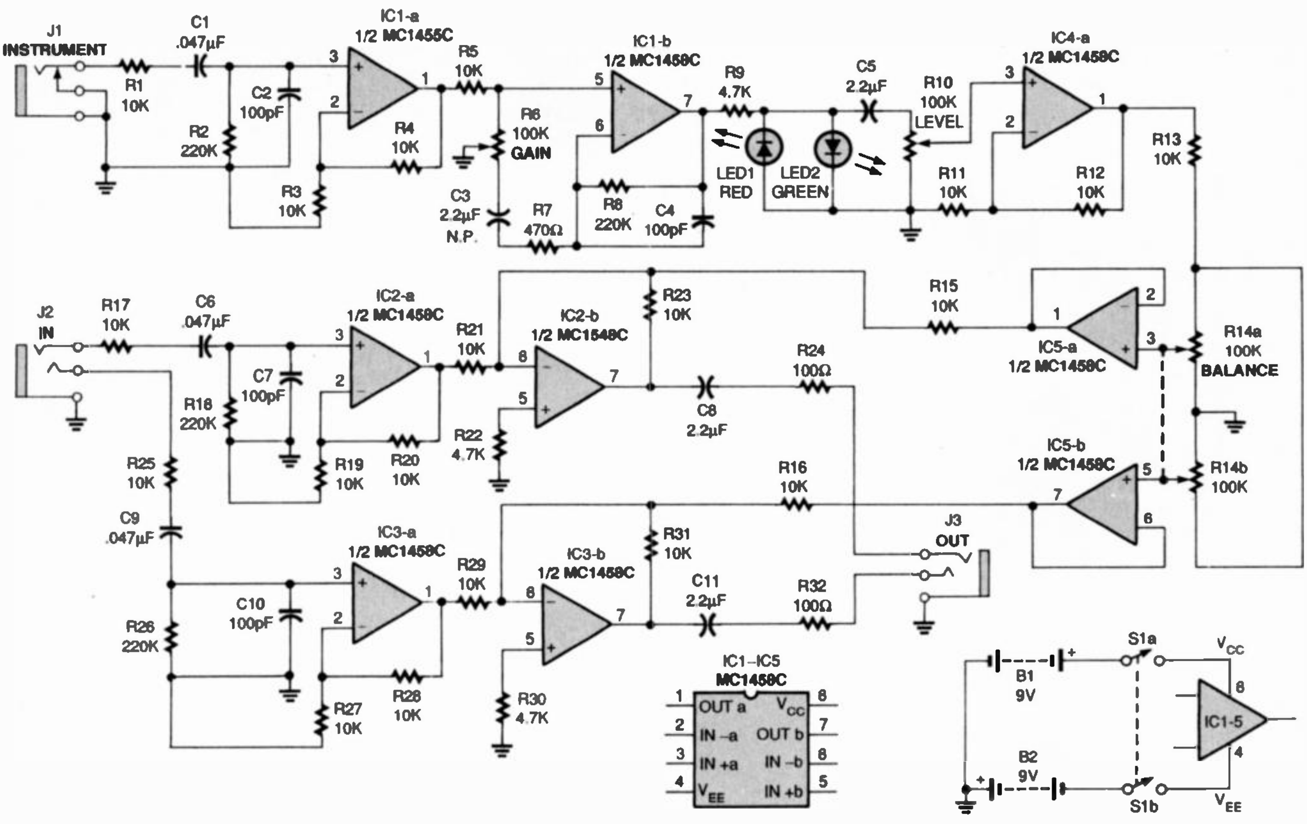


Fig. 1. Here's the schematic diagram for JamMix. Note that nine out of ten sections from five MC1458C dual op-amps are used.

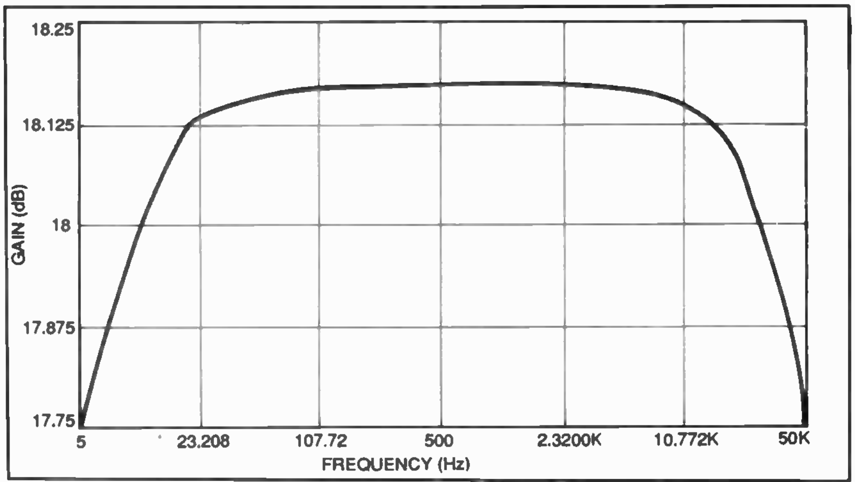


Fig. 2. Frequency response curve for JamMix is ultra flat considering that the curve shown covers only 1 dB of gain.

and proved to be far better at +0.0dB/–0.4 dB from 5 Hz to 50 kHz than required for consumer high-fidelity systems. A typical high-fidelity specification would be a flat (within 3 dB) audio response from 20 Hz to 20 kHz.

Construction. All components are readily available from local and mail-order sources. The components were selected to make the assembly of JamMix from scratch as easy as possible for the novice. JamMix is well suited for construction with perf-board or wire-wrapping techniques.

A PC board is recommended because it makes construction much easier and goof proof. A PC board can be made from the same-size foil pattern provided in the article. That pattern was developed with the AutoCad program. Iron-on and other etching-resist methods are available for PC board fabrication, and the holes can be drilled with a hand drill or Dremel tool. Novice builders are advised to install 8-pin DIP sockets instead of soldering the integrated circuits directly to the PC board. Be sure you have properly located pin 1 of each of the ICs before installing them.

The following is a suggested assembly sequence. Install all the PC-board components first (see Fig. 3). Be sure to observe battery polarity when installing the battery snaps. Don't forget to install four wire jumpers when using the PC board. Mechanically install all of the enclosure-mounted devices such as jacks, controls, and the switch on the plastic case front and rear panels. Use color-coded hookup wire between the jacks and controls to the PCB. Only one set of holes is provided for LED1 and LED2. Connect the two light-emitting diodes back-to-back (anode to cathode) and insert into the board. Polarity is not important here.

Mount the PC board inside the plastic case. Secure the PC board to the deck of the plastic case with double-sided tape or drops of RTV cement. Use the same technique to secure the

PARTS LIST FOR THE JAMMIX

SEMICONDUCTORS

IC1–IC5—MC1458C dual op-amp, integrated circuit
LED1—Light-emitting diode, red
LED2—Light-emitting diode, green

RESISTORS

(All fixed resistors are ¼-watt, 5% units.)
R1, R3–R5 R11–R13, R15–R17, R19–R21, R23, R25, R27–R29, R31—10,000-ohm
R2, R8, R18, R26—220,000-ohm
R6, R10—100,000-ohm, panel-mount potentiometer
R7—470-ohm
R9, R22, R30—4700-ohm
R14—100,000-ohm, dual, ganged, panel-mount potentiometer
R24, R32—100-ohm

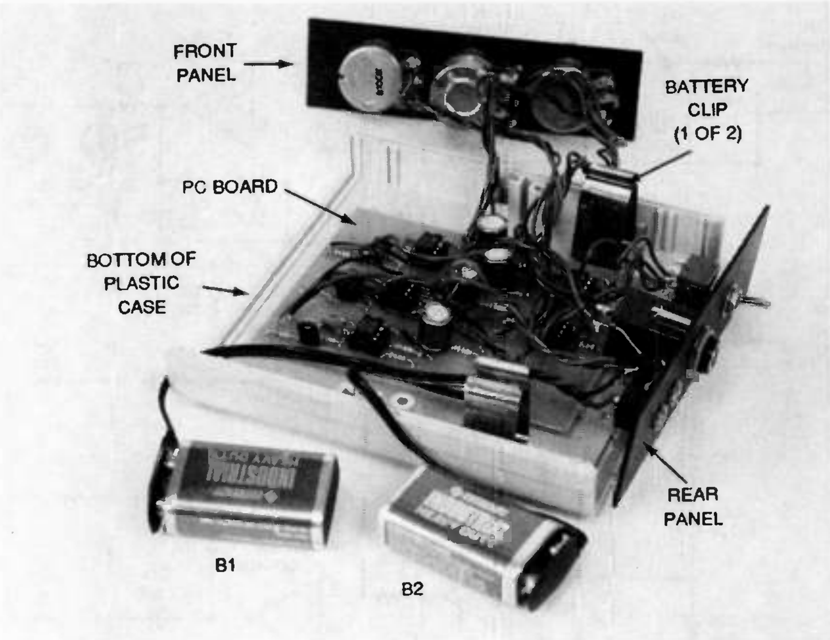
CAPACITORS

C1, C6, C9—0.047-µF, polyester-film
C2, C4, C7, C10—100-pF, ceramic-disc
C3, C5, C8, C11—2.2-µF, 50-WVDC audio-frequency non-polarized electrolytic

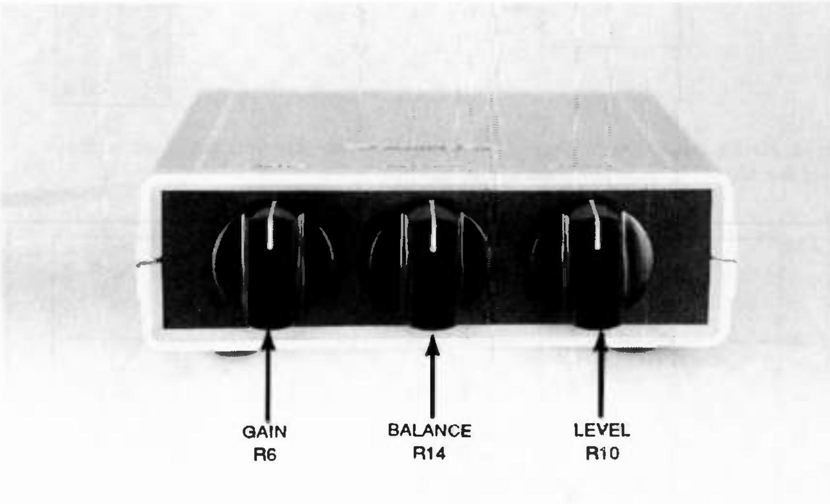
ADDITIONAL PARTS AND MATERIALS

B1, B2—9-volt, alkaline battery
J1—Phone jack, ¼-in., panel-mount, single closed-circuit
J2, J3—Phone jack, ⅛-in., panel-mount, stereo open-circuit
S1—Toggle switch, dpdt, panel-mount
Battery snap (2); battery (clip-type) holder (2); plastic case, 5 × 1½ × 5¼ inches; PC board; hardware, hookup wire, solder, etc.

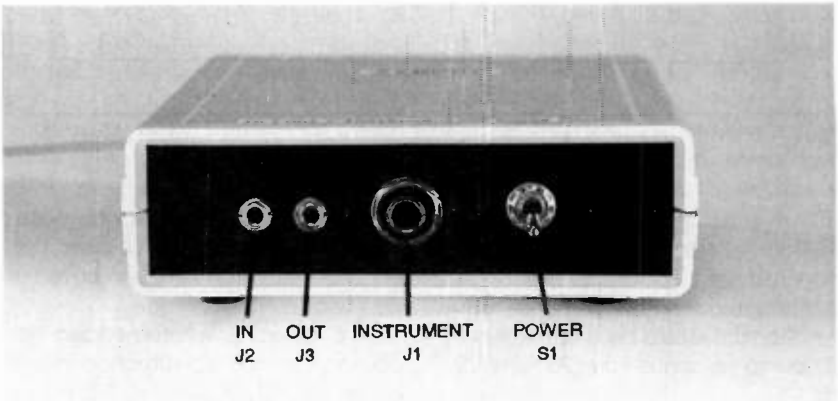
Note: The following are available from Hendry Technology, 1107 Toler Pl., Suite 2, Norfolk, VA 23503. A one-sided, etched PC board is available for $20.00. A complete JamMix kit is available for $65.00. A 3.5-in. floppy disk with the following files is available for $20.00: The original AutoCad drawings in .dxf format; all PCB Gerber, drill, and template files; the original article in .txt format; and step-by-step assembly instructions. The files will be in the .ZIP format. Check or money order in U.S. dollars only. U.S. and Canada orders only. Virginia residents must add appropriate sales tax.



Here's a view of the completed JamMix prior to closing the plastic case.



Connection to the program signal and mixing instrument signal are made from the back panel. Remember to set POWER switch to off when JamMix is not in use.



The three user controls on the front panel of JamMix are all that the musician needs to know about. The GAIN control regulates the instrument's signal level. Too much gain introduces desired clipping distortion. The LEVEL control provides the desired instrument mixing level with the input program signal. The BALANCE control moves the instrument's stage setting from extreme right to extreme left.

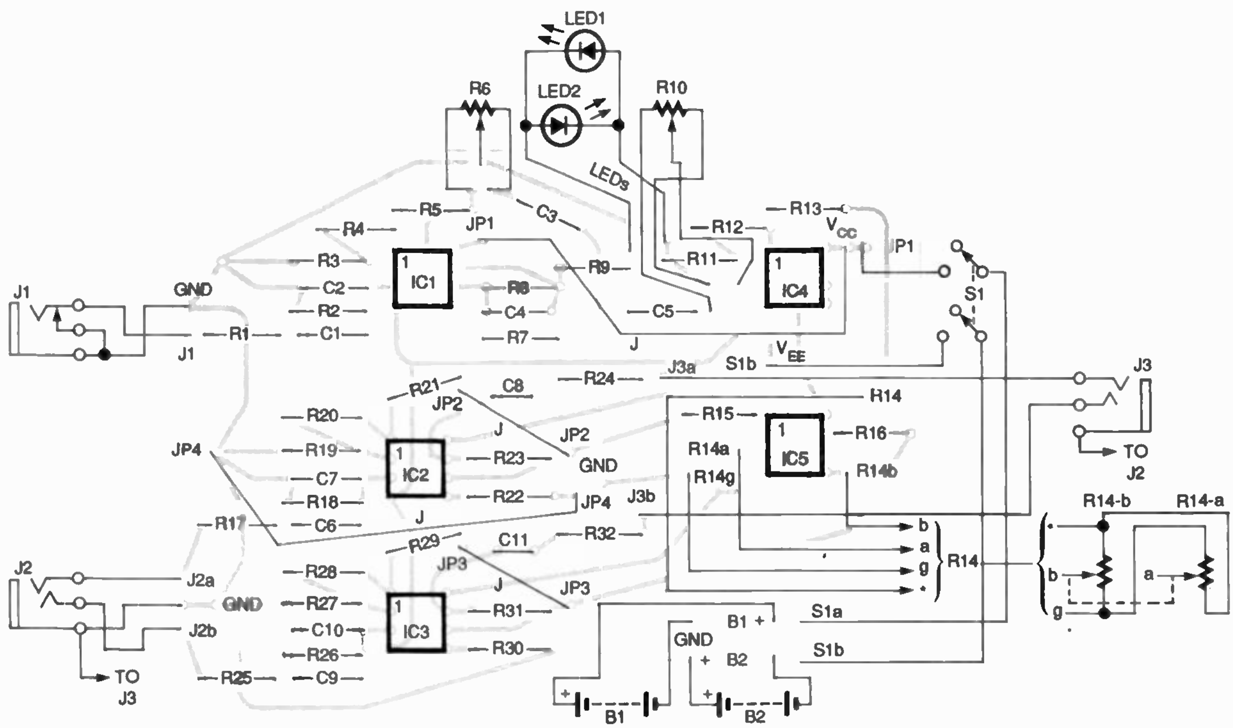
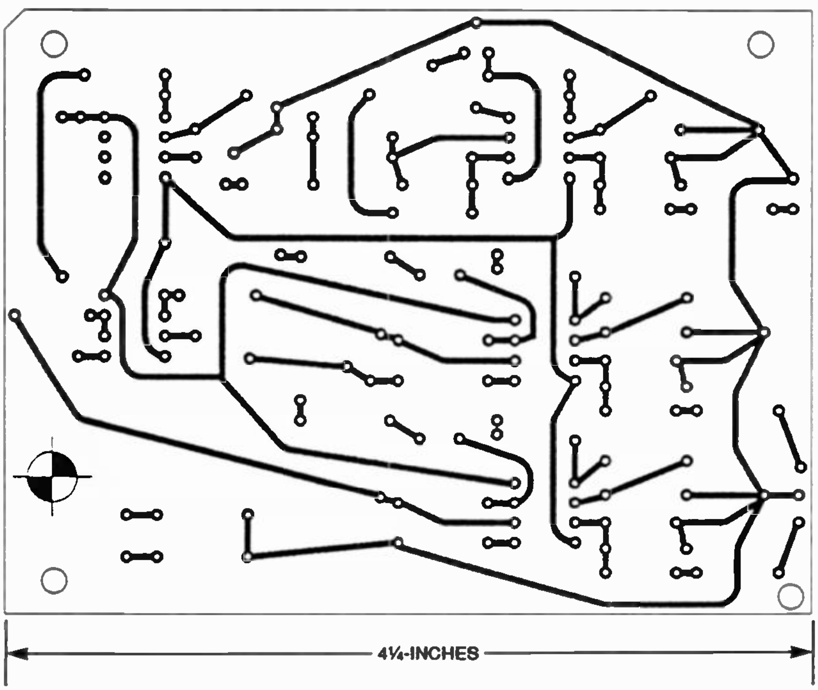


Fig. 3 Use the parts-placement diagram when mounting the components on the suggested PC board. The use of sockets for ICs is recommended.



PC board foil pattern is shown here same-size for use by experimenters who prefer to etch their own board.

battery clips. Add labels to the outside of the case to identify the jacks, switch, and controls. Close the case and you are done. The unit is now ready for jamming.

Notes on distortion. Devices that generate distortion for musical instruments have been around since amplified instruments were available. Often the distortion was an inherent and undesirable condition caused by the design or poor component quality. As a teenager, I would hunt through the local libraries for electronic projects attuned to the guitar. I recall installing a germanium diode in series with the center lead of a guitar cord. It didn't work as promised, as a local AM radio station was received much louder than any guitar sound my new "fuzz box" produced.

The first store-bought "stomp box" I used was a small black and silver wedge that had the guitar cord permanently connected. Since then, I have used the Big Muff (because Hendrix used one) and a Morley Distortion One, MOD-LED1B. I still have the Morley, and it was in service for many years, mostly since the distortion control would allow me to blend the distorted signal with the clean signal, and partly because it never quit working. I often prefer just a small amount of distortion that kind of rides on the clean signal. The JamMix distortion effect maintains this desirable characteristic (quite on purpose, I might add), and also provides a full range of distortion levels.

Stereo-balance control. In addition to the gain and level controls, a balance control was designed into the JamMix to enable the user to set a chosen position within the band. This is accomplished by mixing all, some, or none of the instrument's signal in the right and left channels of JamMix. The

(Continued on page 108)

MILLI-OHM ADAPTER

Extend the range of your DMM down to the milliohm level with this inexpensive, easy-to-build adapter.

SKIP CAMPISI

Have you ever tried to measure accurately a low-value resistance, only to find that your test leads had a higher resistance than the device you were measuring? Even with a meter capable of *nulling out* the lead resistance, the null is never stable due to the hooks or clips used for the connections.

The Milliohm Adapter was specially designed to get around that problem and to do it with an accuracy of ±1% for readings over a range of 10 milliohms (0.01 ohms) to 5.0 ohms. Used with a 4½-digit DVM, the adapter can resolve resistances as low as 10 microohms, and be able to measure the resistance of a short length of hookup wire! Checking switch-contact resistance is a breeze with the adapter plugged into your DVM.

When measuring a resistance below 1.0 ohm, the leads of a resistor contribute significant error to the reading. Thus, a novel circuit approach was taken in designing the adapter. To generate an output-signal voltage high enough to be measured easily, a current of about 1.0 ampere is desirable. That current could easily fry some circuit components and damage the unit under test. However, by applying a low duty-cycle, 1.0-ampere pulse, no damage will occur. By using Kelvin voltage sensing probes right at the connections to the resistance, all of the other voltage drops due to the 1.0-ampere pulsed current in the other leads are essentially eliminated.

About the Circuit. The schematic diagram (Fig. 1) for the adapter can be partitioned into four sections: power supply, oscillator, current source, and peak detector. The R_X (resistance to be measured) is connected between BP1 and BP2, and with the 1.0-ampere pulse applied to R_X, the resulting output transfer function appearing at J1 is 1.0 ohms-per-volt output to the DVM.

The power supply consists of IC2, a 78L12 voltage-regulator chip that provides regulated +12 volts to the circuit, and a 2N2222 transistor, Q2, which provides −0.7 volts to IC3 and a virtual power ground to the rest of the circuit. Transistor Q2 is used as a diode-connected transistor; that type produces only half of the ripple voltage that would appear if a standard rectifier were used. Battery B1 is user selectable and, although 18 volts is specified in the schematic diagram, it also can be any voltage source from 15-volts DC to 25-volts DC. For example, two series-connected 9-volt batteries will power the adapter quite nicely. Further, note that the prototype shown in the photos does away with B1 entirely; it uses a 117-volt AC power-pack adapter rated at 17.4-volts DC at 50 mA plugged into a jack on the instrument. Power switch S2 was not used on the prototype.

A TLC555 CMOS timer, IC1, is configured as an astable multivibrator operating at a frequency of about 100 Hz. The components used provide a duty-cycle of 99%; thus, a negative-going pulse of about 100 µs results at the output, which in turn gates (switches) the current source on for 100 µs at a duty-cycle of 1%. The resulting average current is 10 mA—safe for almost all circuits and circuit elements.

Light-emitting diodes LED1 and LED2 are standard red LEDs that have a forward voltage of about 1.75 volts each, and they are used as the voltage-reference diodes. As Q1 (a TIP125) has a forward voltage of about 1.5 volts, about 2.0 volts appears across R2 and R3, whose net resistance is 2.0 ohms; thus, a current pulse of 1.0 ampere is generated at Q1's collector. The current pulse is supplied via a capacitive-discharge type setup, from C1 (100 µF), which is recharged via R1 (33 ohms) during the 99% off state.

Adequate compensation for any temperature drift by Q1's two base-emitter junctions are provided by LED1 and LED2, and calibration is provided via CAL potentiometer R4, which adjusts the LEDs' forward voltage by varying the bias current. The prototype adapter uses a one-turn potentiometer for R4; you might wish to use a multi-turn trimmer instead. Also, you can trim fixed resistors R2 and R3 to adjust into R4's calibration range.

The TLC272 CMOS dual op-amp, IC3, is configured as a positive voltage-peak detector, which converts

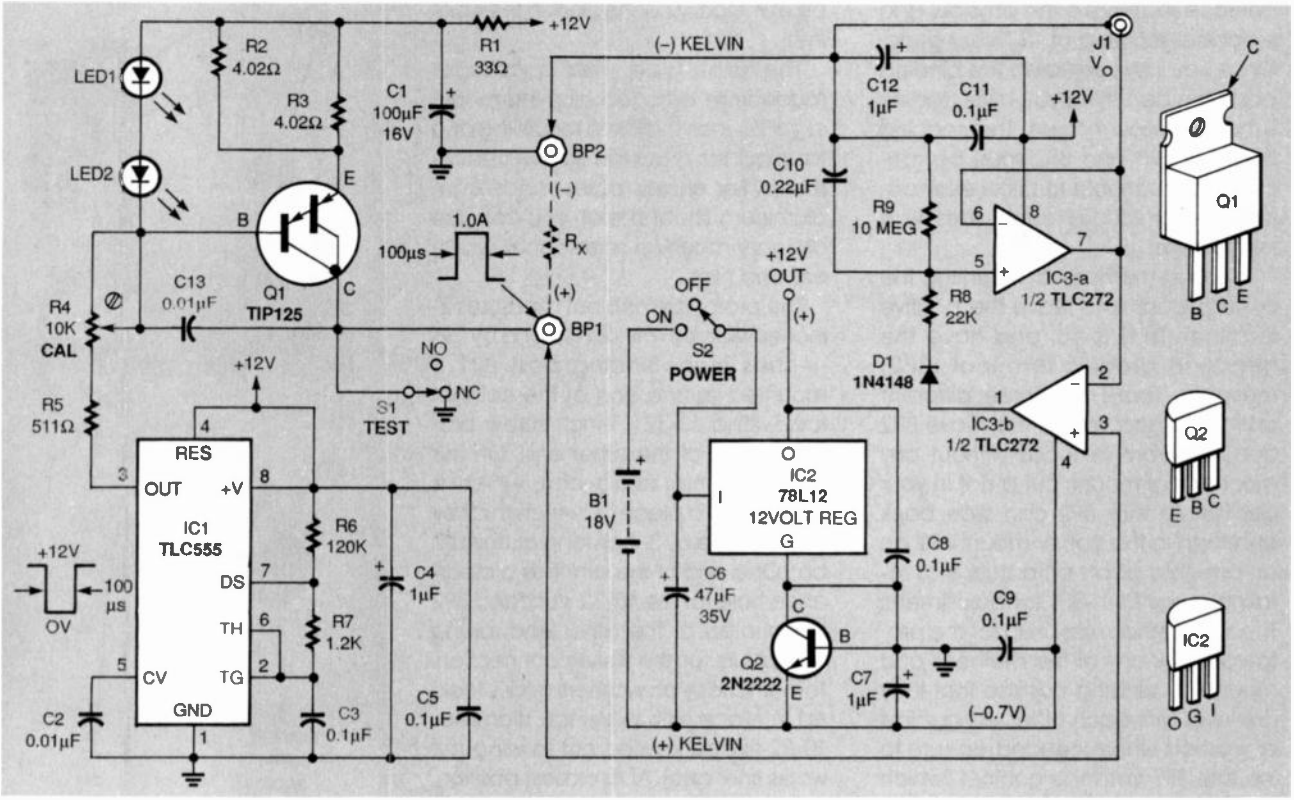
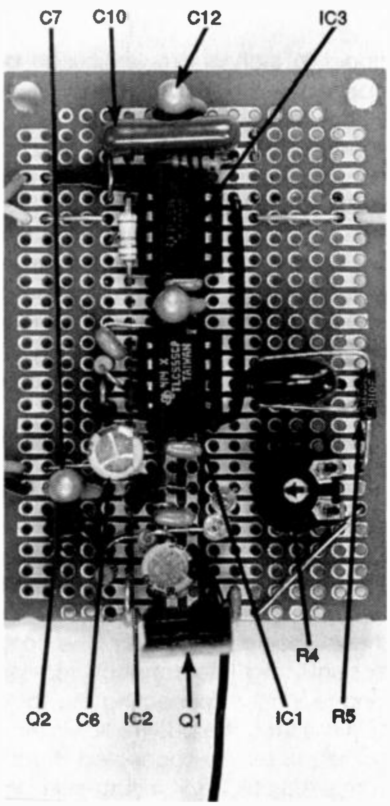
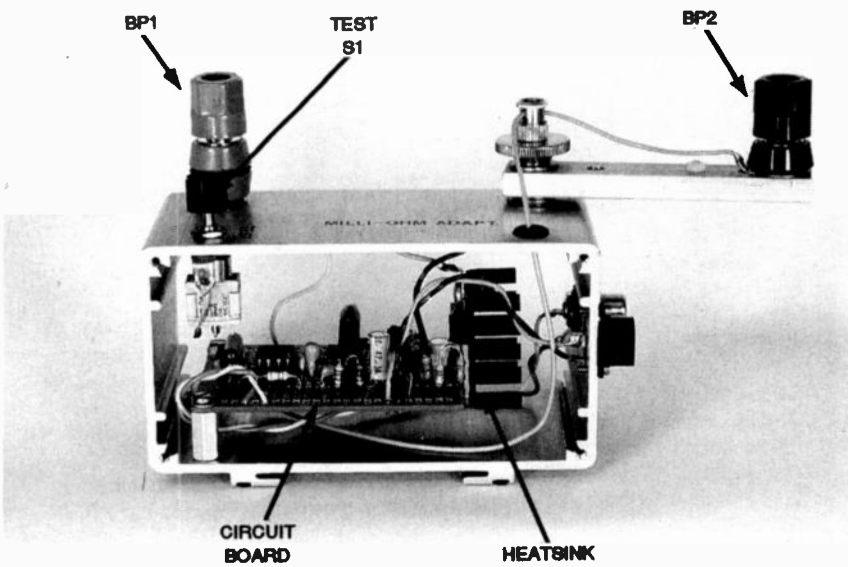


Fig. 1. Here's the schematic diagram for the Milliohm Adapter. The circuit can be separated into four sections: power supply, oscillator, current source, and peak detector.



A piece of a PC board that matches a solderless board supports most of the circuit's parts. Layout is not critical; however neatness is important.



A view of the Milliohm Adapter before the side covers are installed. Note that the heat sink has been attached to the Darlington transistor Q1 and stands free of any metallic contact.

the 1% duty-cycle voltage pulse generated across "R_X" to a steady DC voltage having the exact magnitude of the pulse's peak voltage value. Thus, the output at J1 is a DC voltage with the transfer function of 1.0-ohm-per-volt across R_X.

Construction. The only critical sections of the adapter are the binding-post connections to the resistance to be measured. Use a pair of jumbo (5-way) binding posts rated for 15 amps or more; the posts specified in the Parts List have large-area gold-plated contacts that make the physical and electrical securing of "R_X" very good. Once you have selected the binding posts, the next thing you must decide is how to mount them. The spacing between BP1 and BP2 must be mechanically variable to allow easy adjustment for various resistor sizes, wire lengths, etc.

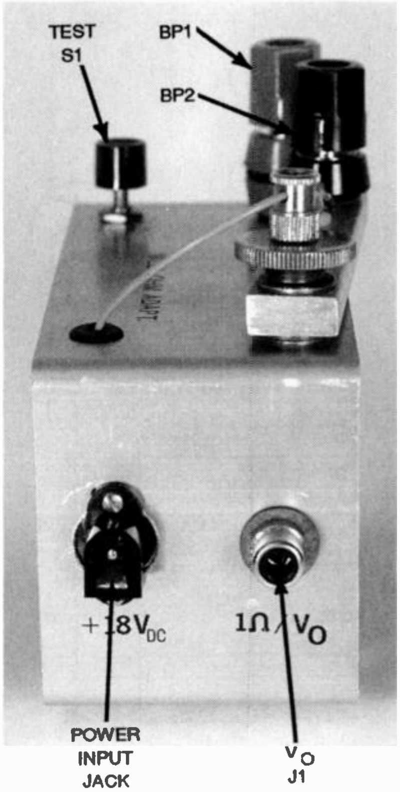
The best method for mounting the binding pasts is to leave the positive terminal (BP1) fixed, and have the negative ground terminal (BP2) movable. There are three different options to accomplish this: leave BP2 dangling from its leads without any mechanical mount; cut a slot in your cabinet so that BP2 can slide back and forth in the slot; or mount BP2 on an arm that pivots on a stud, thus rotating away from BP1 for adjustment. The last method was used for the prototype. Pick any of the methods and mount the binding posts so that they are level with each other, using shims or washers where needed. Be sure to insulate BP1 from the cabinet (which has to be aluminum), while BP2 should be electrically connected to the cabinet.

The prototype uses a cabinet made from extruded aluminum having a 3⁄32-inch thick wall for drilling and tapping for machine-screw attachments. For chassis boxes made from aluminum sheet metal, you can use ordinary machine screws, lock washers, and nuts.

The prototype cabinet measures 2-inches wide by 4⅜-inches long by 2⅜-inches high. Binding post BP1 is mounted at one end of the cabinet top, with a 10-32 × 1-inch screw protruding out of the other end. On this stud rides the swing arm, which is made from a piece of ¼-inch thick by ⅝-inch wide by 3-inch long aluminum bar. One end of the arm has a clearance hole for the 10-32 stud, and BP2 is mounted at the other end, along with a lug for the Kelvin connection. The arm rides on washers and is locked in place with a ¾-inch diameter, 10-32-thread knurled nut (a wing nut works fine, also). At its closest position, the binding post terminal spacing is about ¾ inch apart, which can be opened to a maximum of about 5½ inches. Output jack J1 and an optional power-input jack are mounted on one end of the cabinet with normally-closed push-button switch S1 (TEST) mounted on the top, near BP1. Jack J1 has to be isolated from ground. Use fiber shoulder washers or an insulated phono jack made for the purpose. If you use POWER switch S2, mount it near S1 for the most convenience.

Assemble the circuit board, following the parts location shown in the photos, on a 1⅞-inch by 2⅞-inch circuit board (see Parts List) starting with Q1 on one end of the board. Attach a small heat sink to Q1. Install two 8-pin DIP sockets and potentiometer R4 as shown; then add the rest of the components and interconnects leaving long leads for connecting the jacks and switches. The positive Kelvin lead is a separate wire connected directly from pin 3 of IC3 to binding-post BP1, and the collector tab of Q1 is also connected directly to BP1 via a separate wire.

(Continued on page 109)



The power input jack (optional, see text) and insulated RCA phono jack (J1) that supplies the output signal to the DVM mounts on one side of the case

PARTS LIST FOR THE MILLIOHM ADAPTER

SEMICONDUCTORS

IC1—TLC555 or TLC555CN CMOS timer integrated circuit.
IC2—78L12 12-volt, 100-mA, positive-regulator integrated circuit
IC3—TLC272/TS272CN CMOS dual op-amp, integrated circuit
Q1—TIP125 PNP Darlington transistor
Q2—2N2222 PNP general-purpose transistor
D1—1N4148 switching diode
LED1, LED2—Light-emitting diode, red, T1 case

RESISTORS

(All fixed resistors are ¼-watt, 5% units, unless otherwise noted.)
R1—33-ohm
R2, R3, R_C—4.02-ohm, 1%, metal film
R4—10,000-ohm, one-turn potentiometer, PC mount, cermet (see text)
R5—511-ohm, ¼-watt, 1%, metal-film
R6—120,000-ohm
R7—1200-ohm
R8—22,000-ohm
R9—10,000,000-ohm

CAPACITORS

C1—100-µF, 16-WVDC, electrolytic
C2, C13—0.01-µF, monolythic ceramic
C3—0.1-µF, polyester (Mylar)
C4, C7, C12—1-µF, 35-WVDC, solid tantalum
C5, C8, C9, C11—0.1-µF, monolythic ceramic
C6—47-µF, 35-WVDC, electrolytic
C10—0.22-µF, polyester (Mylar)

ADDITIONAL PARTS AND MATERIALS

B1—See text
BP1, BP2—Binding post, insulated, 30 ampere (H.H. Smith #257)
J1—RCA phono jack, isolated (Mouser#16PJ050, or equiv.)
S1—Mini-push-button, spdt, momentary, 3 A
S2—Mini-toggle switch, spdt, 1-amp (optional)
Protyping board (RadioShack 276-150, or equiv.), 8-pin IC socket (2), TO-220 heat sink, post spacers (2, threaded holes at ends with matching screws), threaded ends with screws to match, aluminum cabinet (see text), aluminum bar (see text), wire, phono plug, DVM plug, etc.

Note: The semiconductors and precision resistors are available from Mouser Electronics and other sources. All other parts are available at most local electronics stores and electronics mail-order houses.

NEIL HECKT

Build this self-calibrating L/C METER

This microcontroller-based digital inductance and capacitance meter is self-calibrating.

COMMUNICATIONS ENGINEERS, EXperimenters and technicians working with RF filters, oscillators and amplifiers need an instrument to accurately measure small values of inductors and capacitors. The instrument presented here will fill the bill perfectly.

The L/C (inductance/capacitance) meter features a measurement range of 0.001 to 100 microhenrys (μH) and 0.010 picofarads (pF) to 1 microfarad (μF).

The meter automatically selects the proper range, and provides a worst-case accuracy of 3% of reading, and a resolution of four digits. The measurements are displayed on a 16-character intelligent LCD. The meter's sampling rate is about four samples per second.

Circuit description

The heart of the L/C meter is the oscillator circuit on the left side of the schematic in Fig. 1. The oscillator's function can best be visualized by assuming that the output of the LM311 voltage comparator is a square wave at the resonant frequency of the tank circuit formed by L1 and C1. The square wave is applied to the tank circuit through R3 and AC-coupling capacitor C3. The tank circuit filters out the fundamental sine wave, which is then applied to the input of the voltage comparator and causes a square wave to be generated at its output, thus sustaining oscillation.

When power is first applied, the voltage at pin 2 of the LM311 quickly builds up to one half of the supply voltage through the voltage divider formed by R1 and R2. This causes the output, pin 7, to be at a high level equal to the supply voltage. This high level output charges C4 via R4 until the voltage at pin 3 is equal to the voltage at pin 2. The output then switches to a low level, introducing a transient in the tank circuit that causes it to ring at its resonant frequency. This ringing is turned into a square wave at the resonant frequency of the tank at the output pin, thus sustaining oscillation as described above. The square wave will have a 50% duty cycle causing C5 to remain charged to a voltage equal to that of pin 2.

The nominal values of L1 (68 μH) and C1 (680 pF) were chosen because an increase in L of 1 nH (.001 μH) produces a frequency change of slightly less than 5 Hz. The 0.2-second measuring period can resolve 5 Hz and therefore 0.001 μH.

Besides being simple, this oscillator circuit is very reliable. It always starts, and it can tolerate a large variation in the inductances and capacitances used in the tank circuit. The range of

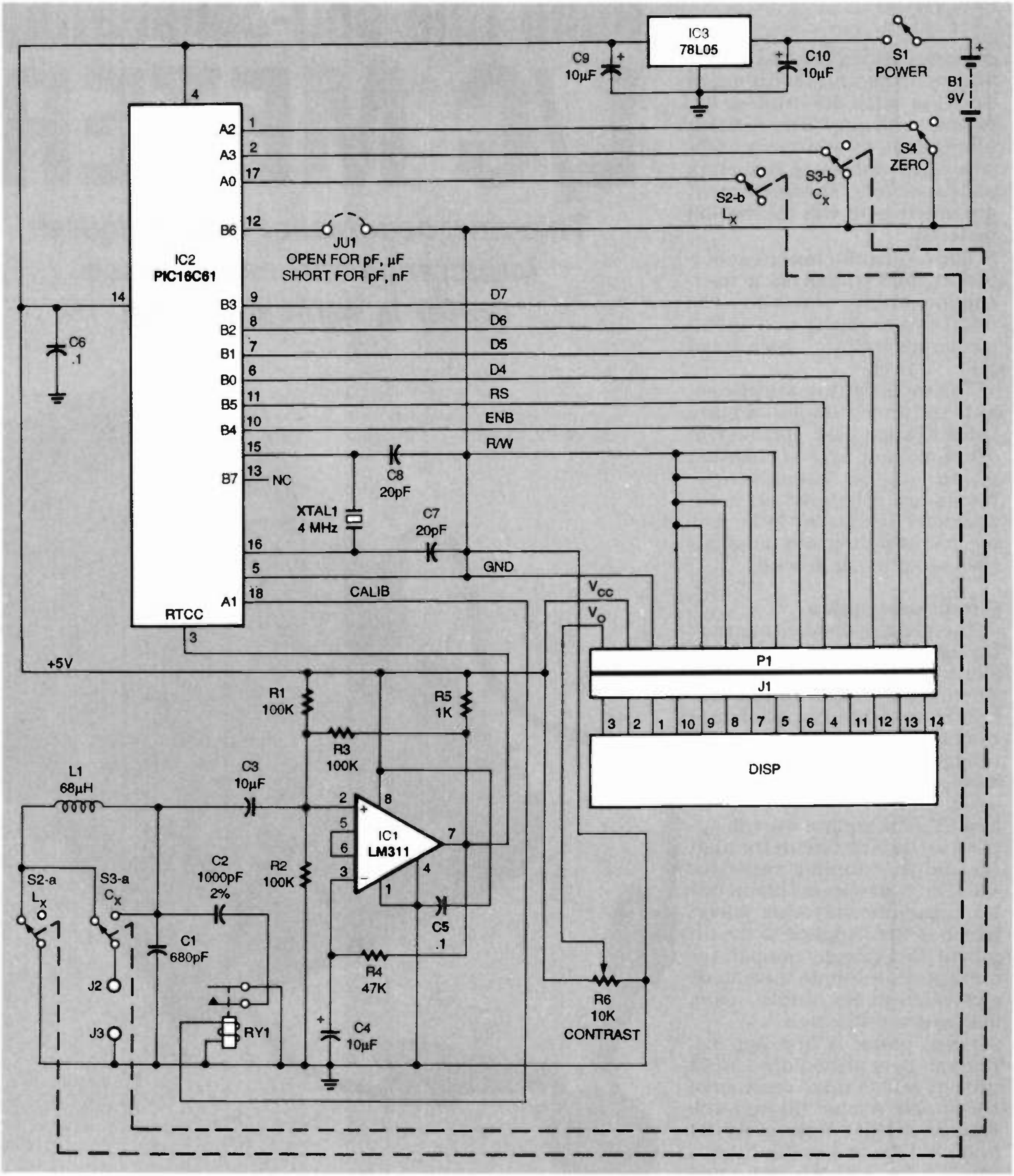


FIG. 1—THE L/C METER SCHEMATIC. The oscillator built aroud IC1 is the heart of the circuit. IC2, a PIC16C61 microcontroller, is its brains.

inductance and capacitance is limited by the amplitude of the sine wave voltage across the tank circuit. The minimum peak-to-peak voltage is equal to the offset voltage specification of the LM311—about 2 to 10 millivolts. The maximum peak-to-peak voltage is limited to about half the supply voltage, 2.5 volts. These voltage limits can be translated to inductance and capacitance limits in the simplified equivalent circuit of a parallel resonant tank shown in Fig. 2.

The resistor R is normally part of the inductor and is caused by the resistance of the wire from which it is wound. The maximum impedance of the parallel resonant tank is:

$$Z_{max} = Q\sqrt{L/C}$$

where Q $2\pi fL/R$.

It can be seen that the imped-

It can be seen that the impedance increases with increasing L or Q and decreases with increasing C. Higher impedances develop higher voltages across the tank in the oscillator circuit described above, while lower impedance's develop lower voltages. The maximum value of L is determined by the upper limit of 2.5 volts peak-to-peak while the maximum value of C is determined by the lower limit of 2 to 10 millivolts. For the oscillator described above, these limits are approximately 200 millihenrys and 2.0 microfarads, but they are also a function of the Q of the inductors or capacitors. The L/C meter's top range is specified at 100 millihenrys and 1 microfarad, but values up to the maximum limits mentioned above can usually be measured depending upon their Q. Capacitors must be non-polarized.

The microcontroller

If the oscillator is the heart of the L/C meter, then IC2, a PIC16C61 microcontroller, is its brain. The PIC16C61 is an advanced version of the familiar PIC16C54 18-pin microcontroller from Microchip Technology. The 16C61 has a 14 bit instruction that allows CALLs and GOTOs to anywhere in its 1024-instruction program memory without the page management overhead of the 16C54. It has 36 bytes of RAM and an eight level deep stack rather than the two level stack of the 16C54. The outputs can sink or source up to 20 milliamperes, allowing it to drive LEDs or, in the case here, a reed relay. It also has interrupts which are not used in L/C meter. Another useful feature is built-in pull-up resistor on the inputs which helps reduce the parts count.

The output of the oscillator is applied to the RTCC REAL-TIME CLOCK COUNTER pin. This increments an 8-bit counter inside the microcontroller. The microcontroller accumulates the count for a period of 0.2 seconds. Discrete signals from the L_X, C_X, and ZERO switches are input to the microcontroller so it knows what the operator wishes it to do. Seven outputs are used to drive the intelligent LCD display which is operated in its 4-bit (nibble) mode. Four of the outputs are data bits (D4–D7), one is REGISTER SELECT (RS), one is READ/WRITE (R/W) and the last is ENABLE (ENB). One input pin is a jumper which provides two ways to display capacitance values as shown in Table 1.

The jumper-shorted option is for those more inclined toward metric units who want capacitances specified in nanofarads, when appropriate. The jumper-open is for old timers like me, who prefer only picofarads and microfarads. That option has one less digit of resolution in the .0100 to 0.999 range.

TABLE 1—DISPLAY OPTIONS

Inductance	Capacitance (jumper shorted)	Capacitance (jumper open)
0.000 - 0.999 µH	0.00 - 0.99 pF	0.00 -0.99 pF
1.000 - 9.999 µH	1.00 - 9.99 pF	1.00 - 9.99 pF
10.00 - 99.99 µH	10.00 -99.99 pF	10.00 - 99.99 pF
100.0 - 999.9 µH	100.0 - 999.9 pF	100.0 - 999.9 pF
1.000 - 1.999 mH	1.000 - 9.999 nF	1000 - 9999 pF
10.00 - 99.99 mH	10.00 - 99.99 nF	.0100 - .0999 µF
100.0 - 999.9 mH *	100.0 - 999.9 nF	.1000 - .9999 µF
1.000 - 9.999 H **	1.000 - 9.999 µF *	1.000 - 9.999 µF *

* Programmed into the computer but some values may be out of range.
** Programmed into the computer but out of range.

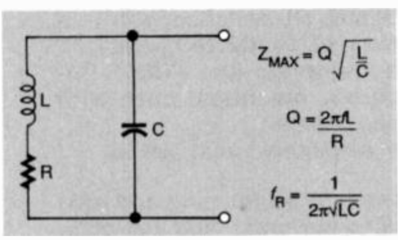
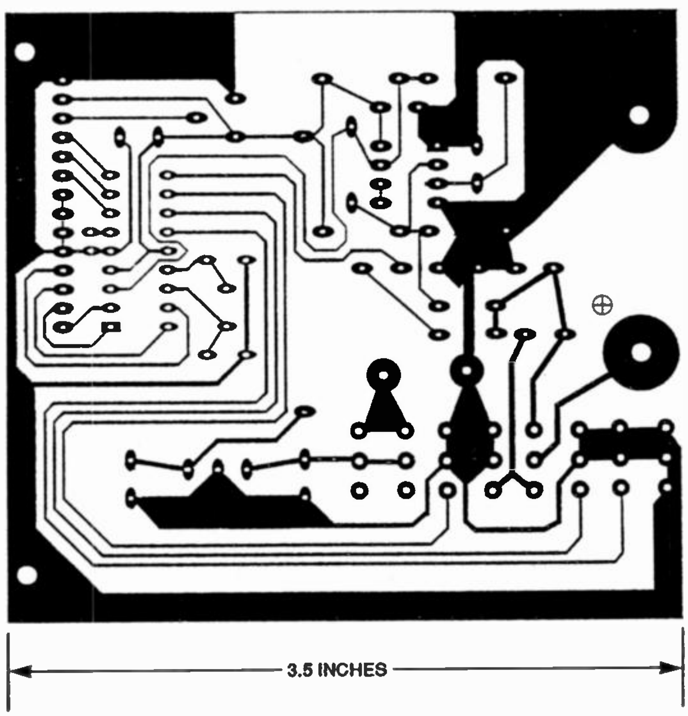


FIG. 2—THE OSCILLATOR'S OPERATION can be best understood by examining this simplified equivalent circuit of a parallel-resonant tank.



FULL-SIZE L/C METER foil pattern.

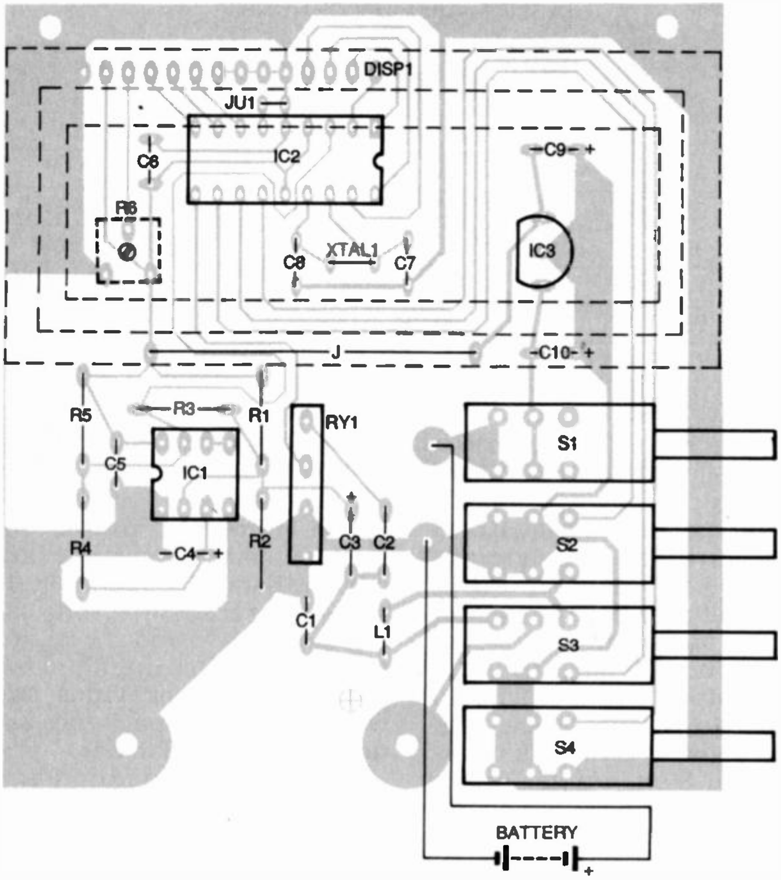


FIG. 3—PARTS PLACEMENT DIAGRAM. Be sure to mount R6 on the rear of the board so you can adjust the display's contrast after the display is installed.

Self-calibrating

One of the truly unique attributes of the L/C meter is that it is self-calibrating. It's really a "put it together and it works" project. That is, if all the parts are in the right place and you do a good job of soldering, then it will work.

During the calibrate cycle the microcontroller first measures f_1, the frequency when only L1 and C1 are in the tank circuit. The frequency will be:

$$f_1 = \frac{1}{2\pi\sqrt{L1C1}}$$

This is one equation with two unknowns and therefore cannot be solved for L1 and C1. To obtain another equation, a known capacitor is switched into the tank circuit. The microcontroller raises the CALIB line to a logic high level. This energizes relay RY1, which switches capacitor C2 (a 1000-pF, 1% polystyrene capacitor) into the tank circuit. That causes the frequency to become:

$$f_1 = \frac{1}{2\pi\sqrt{L1(C1+C2)}}$$

The two equations can be solved simultaneously to give:

$$C1 = \frac{f_2^2}{f_1^2 + f_2^2} C2$$

and finally:

$$L1 = \frac{1}{4\pi^2 \quad f_1^2 \quad C1}$$

Because of this self-calibration capability, the exact values of L1 and C1 are not critical and components with tolerance ratings of 10% are used. The accuracy of the device is dependent upon C2 which is a capacitor with a tolerance rating of 1%..

PARTS LIST

All fixed resistors are ¼ watt, 5%
R1, R2, R3—100,000 ohms
R4—47,000 ohms
R5—1000 ohms
R6—10,000 ohms, potentiometer

Capacitors
C1—680 pF ceramic disc
C2—1000 pF, 2% (Mouser 140-PF2A102F or equiv.)
C5,C6—0.1 µF, ceramic disc
C3—10 µF, 10 volts, Tantalum
C4,C9,C10—10 µF, 10 volts, electrolytic
C7,C8—20 pF, ceramic disc

Semiconductors
IC1—LM311N voltage comparator
IC2—PIC16C61 microcontroller (Microchip Technology)
IC3—78L05 voltage regulator

Other Components
XTAL1—4.0 MHz crystal (Digi-Key X006 or equiv.)
L1—68 mH (Mouser 434-1120-680L or equiv.)
RY1—SPST N.O. reed relay (Hamlin HE3621A0500 or equiv.)
DISP—LM-16151 (Digi-Key OP116 or equiv.)
J1—14 pin square post socket (Digi-Key 929974-01-36 or equiv.)
P1—14 pin square post plug (Digi-Key S1022-36 or equiv.)
S1, S2, S3—DPDT alternate action switch (Digi-Key EG1001 or equiv.)
S4—DPDT momentary switch (Digi-Key EG1002 or equiv.)

Miscellaneous: case (PacTec HP9VB), 5-way binding posts, hardware.

Note: The following are available from: Almost All Digital Electronics, 1412 Elm St. S.E., Auburn, WA 98092 (206-351-9316):
- **Disk containing source and object code: $19.95 (includes free copy of MPASM, PIC assembler, and MPSIM, PIC simulator)**
- **Programmed IC2: $29.95**
- **Hard-to-find parts kit: $49.95 (includes printed-circuit board, all switches with buttons, L1, C1, C2, RLY1 and U2)**
- **Complete kit: $79.95 (includes machined case with panel decal)**
- **Assembled unit: $99.95**

Include $4.00 shipping and handling per order. Add and additional $4.50 on C.O.D. orders. Washington State residents add 8% sales tax

LISTING 1

```
INITIALIZE THE CPU AND I/O PORTS
INITIALIZE THE LCD DISPLAY
WHILE Lx OR Cx are ON
     DISPLAY "SWITCH ERROR"
WEND
(The computer cannot calibrate itself if Lx or Cx are on.  The unit
waits for the operator to clear the switches.)
DISPLAY "WAIT" (wait 10 seconds  for the oscillator to stabilize.)
CALIBRATE:
     DISPLAY "CALIBRATING"
     MEASURE F1
     SWITCH IN THE CALIBRATION CAPACITOR
     MEASURE F2
     SWITCH OUT THE CALIBRATION CAPACITOR
     COMPUTE C1=F2^2 / (F1^2 - F2^2) C2
     COMPUTE L1=1 / (4 p^2 F1^2 C1)
DO (loop continuously)
     IF Lx and Cx are OFF
          IF ZERO
               GOTO CALIBRATE (re-calibrate the unit)
          ELSE
               DISPLAY "READY" (ready to measure Lx,Cx,or be ZEROed)
               MEASURE and STORE F1
          END IF
     ELSEIF Lx ON AND Cx OFF
          MEASURE F2
          IF ZERO ON
               MEASURE and STORE F1
               DISPLAY "0.000"
          ELSE (ZERO OFF)
               COMPUTE Lx=(F1^2 / F2^2 -1) L1
               DISPLAY "Lx="
               DISPLAY VALUE in engineering units
          END IF
     ELSEIF Cx ON AND Lx OFF
          MEASURE F2
          IF ZERO ON
               MEASURE and STORE F1
               DISPLAY "0.000"
          ELSE (ZERO OFF)
               COMPUTE Cx=(F1^2 / F2^2 -1) C1
               DISPLAY "Cx="
               DISPLAY VALUE in engineering units
          END IF
     ELSE (Lx and Cx both ON)
          DISPLAY "SWITCH ERROR"
     END IF
LOOP
```

The unit can be re-calibrated by pressing ZERO when L_x and C_x are both off. This may be desirable when measuring very small values. In such cases, the unit should be allowed to warm up for about 5 minutes to allow the oscillator to thermally stabilize.

Making measurements

When the L_x and C_x switches are off, the microcontroller continuously measures f_1 to track any drift in frequency. When the L_x switch is depressed, the unknown inductor is placed in series with L1. The total inductance is then L1 + L_x. This causes the frequency to change to:

$$f_2 = \frac{1}{2\pi\sqrt{(L1 + L_x)\ C1}}$$

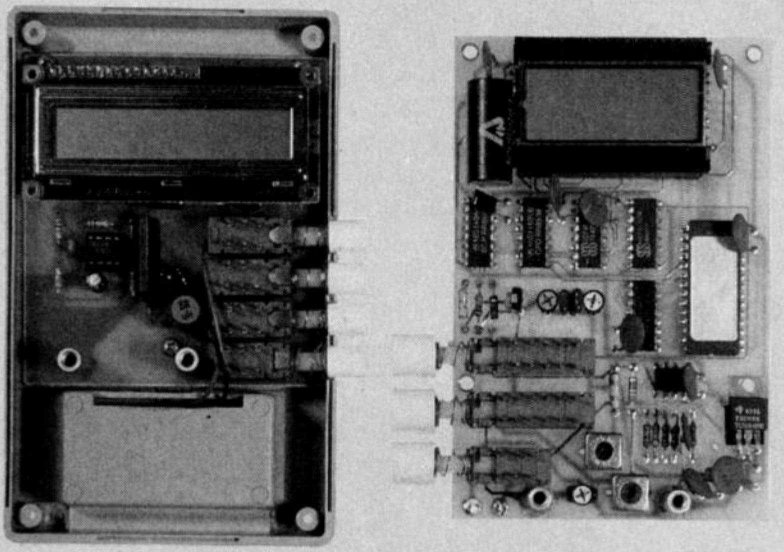
This equation can be solved, simultaneously with the equation for f_1 to produce:

$$L_x = \left[\frac{f_1^2}{f_2^2} - 1\right] L1$$

Similarly when the C_x switch is depressed the unknown capacitor is placed in parallel with C1. The total capacitance is then C1 + Cx.

$$f_2 = \frac{1}{2\pi\sqrt{L1\ (C1 + C_x)}}$$

A DESIGN THAT IMPROVES WITH AGE



THE NEW L/C METER is shown on the left, mounted in its case. The original version's PC board is shown on the right. Note how the PC board size and complexity have been reduced greatly.

In July of 1988, *Radio-Electronics* magazine (*Electronics Now*'s predecessor) presented the L/C Meter I. It measured inductance and capacitance by detecting the shift in frequency of a oscillator when an unknown is inserted into its tank circuit. At that time it was postulated that a microcontroller would be the best solution to the computation and display of the result. However, there were no inexpensive microcontrollers available back in 1988. Instead a ROM look-up table approach was used.

That was 1988, this is 1996 and the Micochip Technology's series of PIC microcontrollers allows the use of a microcontroller in this version of the L/C Meter. The result is increased resolution and range as well as intelligent display of the result in engineering units. The technique and the oscillator circuit are essentially the same as original L/C Meter, which had 12 ICs and an LCD display. This updated version uses only 3 ICs and features an intelligent LCD display. The original L/C Meter had to be manually calibrated, while the new unit is self-calibrating. Best of all, the new L/C Meter is significantly less expensive than the original. Ω

Which is solved for Cx, with the equation for f_1, to produce:

$$C_x = \left[\frac{f_1^2}{f_2^2} - 1\right] C1$$

Stray inductance and capacitance

The circuit traces on the printed-circuit board, the switches , and the test leads all contribute a small amount of stray inductance (L_s) and capacitance (C_s). These stray values add to the values of L1 or C1 when the L_x or C_x switches are pressed, slightly affecting the frequency of f_1. The unit is zeroed by pressing the ZERO switch, which causes the unit to re-measure f_1 with the stray values in the circuit.

To zero L_s the operator must short circuit the test leads, press L_x and then press the ZERO button. Similarly, for capacitors, the operator open circuits the test leads, presses C_x and then presses ZERO.

This zero operation is good until the L_x or C_x switch is turned off. If the L_x or C_x switch is again turned on the unit must be re-zeroed.

Floating-point math

From all of the above equations it would seem that there is some relatively high-powered math involved and there is. The lower half of program memory in the microcontroller contains a complete 32-bit floating-point math package. The math package includes ADD, SUBTRACT, MULTIPLY and DIVIDE instructions. It also contains conversions from integer to floating-point, floating-point to integer and integer to binary-coded decimal (BCD).

The computer measures frequency by counting the number of oscillator cycles for a period of 0.2 seconds. The result is an integer. This number is converted to floating-point and all calculations are done in floating-point. When the values of L_x or C_x are finally computed, the answer is converted to an integer and then to BCD for display.

The upper half of the microcontroller's program memory contains the functional software which is described in Listing 1 by a pseudo BASIC-like, high-level language.

Construction

The L/C meter is indeed simple and there is no particular order of assembly. Refer to Fig. 3, the parts-placement diagram. Note that there is only a ⅜-inch space under the display when it's mounted. Leave enough lead length on the taller parts so you can tip them at an angle to reduce their height. Figure 4 is a photograph of the board under the display. Note how the crystal and voltage regulator are installed at an angle.

Start assembly with the resistors. Then solder in the sockets for the IC's, the capacitors, and then the switches. The switch terminals should just barely stick through the printed-circuit board in order for the shafts to line up with the holes in the case. Be careful not to install the switches upside-down. Remove the little tin rivet from under the brass leaf of the ZERO switch only. This converts it from an alternate-action switch to a momentary-contact switch (see Fig. 5.).

Solder P1, the male, square-post header, at the top of the PC board. Install the contrast control, R6, on the back of the printed-circuit board otherwise you will not be able to adjust it with the display installed. Install the two ¾-inch spacers for the test jacks as shown in Fig. 5. This should complete printed-circuit board assembly. Solder J1 to the display unit. A single-sided printed-circuit board is used so don't forget the one

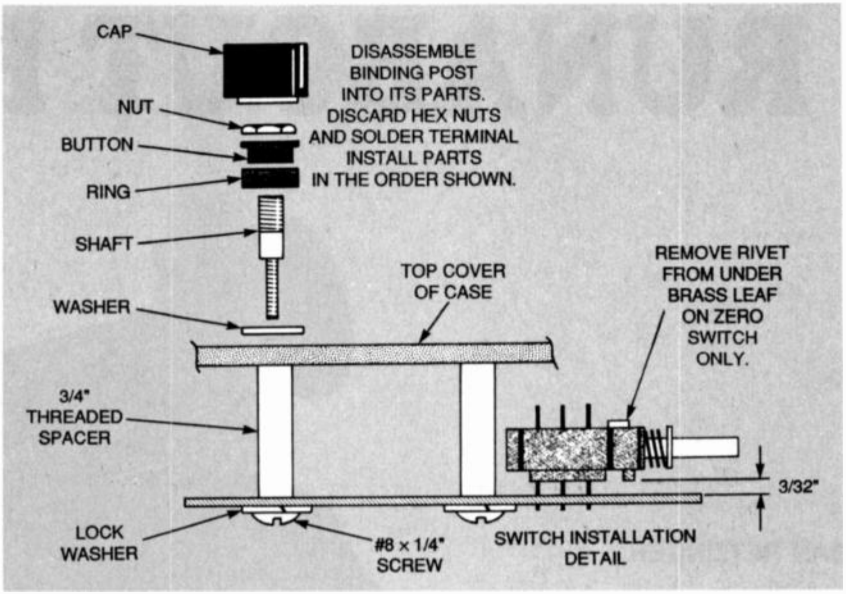


FIG. 5—MECHANICAL DETAILS. Remove the rivet from the Zero switch to convert it to a momentary-contact switch.

jumper wire needed as indicated on the parts layout. Decide which type of capacitor display you prefer. If you prefer to indicate nanofarads, solder jumper wire JU1 as indicated on the parts layout.

Pass the leads from the battery clip through one of the slots in the battery box of the case and solder them to the appropriate pads of the printed-circuit board. Plug in the display and turn on the unit. If you don't see anything on the display, don't panic, try adjusting R6, the contrast control. The unit will display WAIT for 10 seconds followed by CALIBRATING for two seconds followed by READY. If it does, you're up and running. Adjust the contrast control so the background is just barely visible. Install the printed-circuit board in the bottom of the case using three No. 4 sheet metal screws. Install the top cover of the case and install the binding posts as shown in Fig 5. Test leads should not exceed 4 inches in length with a banana plug at one end and alligator clip at the other.

If your finished unit doesn't work, remove the printed-circuit board and carefully inspect to see you have soldered everything that should be soldered, and that you have not created any inadvertent solder bridges. It is very unlikely you will have any problems; however, if you purchased your kit from the source in the parts list they will try to fix it free except for a $4.00 return postage and handling fee.

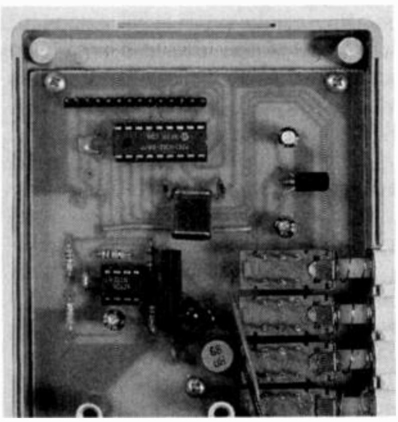


FIG. 4—THE AREA UNDER THE DISPLAY has a maximum clearance of ⅜ inch. Note how the crystal and voltage regulator are tilted to decrease their heights.

For those who wish to make their own printed-circuit board a full size PC-board foil pattern is provided. The switches called out in the parts list should fit without problem. When the original L/C Meter was designed, a large volume of surplus switches was obtained. These are supplied with the new L/C meter kits from the source listed at the end of the Parts List. For those with the capability to program their own PIC16C61 the code can be downloaded from the Electronics Now BBS (516-293-2283 N81). Look for LCM.ZIP. The code can also be purchased from the source listed in the parts list and includes a free copy of MPASM, the PIC assembler, and MPSIM, the PIC simulator.

Operation

The typical stray inductance is .04 to .06 µH and the typical stray capacitance is 5 to 7 pF. When measuring inductors less than 5 µH or capacitances less than 50 pF, it is advisable to zero the unit first. For larger values, the strays are insignificant to the result. It is difficult to retain a reading of 0.000 pF because of the extreme sensitivity of the meter. Your body capacitance influences the reading. Try zeroing the capacitance and then move your hands around the test leads without touching them. You will find you can adjust the reading a few hundredths of a picofarad.

To measure inductance, place the unknown across the test leads and depress L_x. The inductor must have DC continuity, or the unit will display NOT AN L. To measure capacitance place the unknown across the test leads and press C_x. If the unknown is out of range the unit may break into spurious oscillation and display random or rapidly changing values.

The oscillator tends to drift a few hertz during the first few minutes of operation. When measuring very small values the unit should be allowed to warm up for about five minutes and then re-calibrated and zeroed.

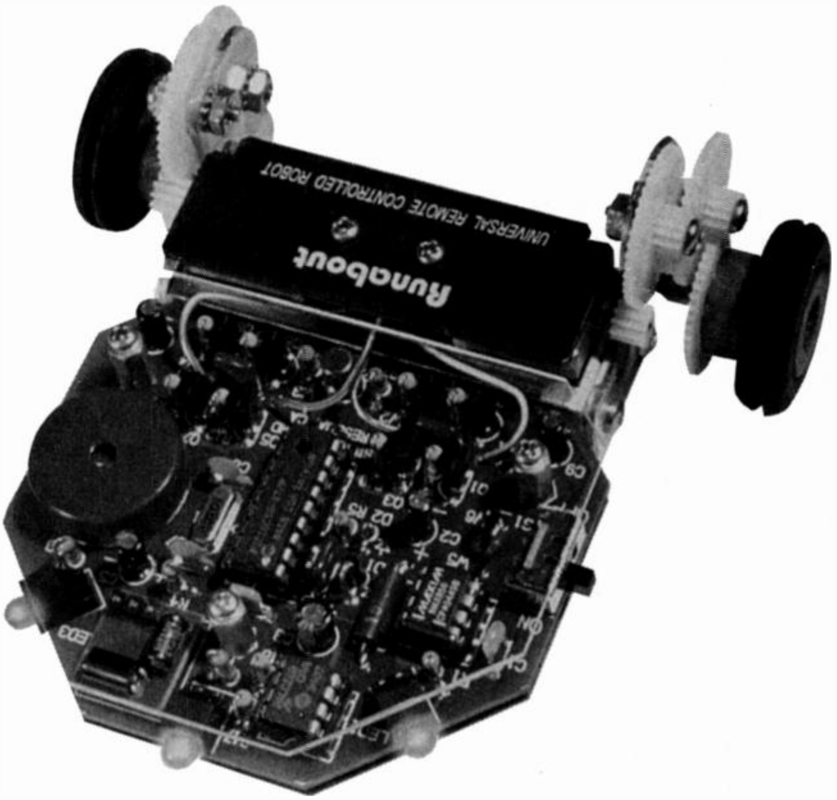
Accuracy and resolution

The L/C meter accuracy is specified at 3% of reading. This is vastly superior to units specified as percent of full scale. For example a unit on a 1-mH range, specified at 1% of full scale, would have a maximum error of 10 µH which could be as much as a 100% error when measuring a 10 µH inductor. Our L/C meter would have a maximum error of 3% for the 10 µH inductor.

The author measured about

(Continued on page 108)

RUNABOUT ROBOT



DAN RETZINGER

The Runabout robot's 17 functions are controlled by a universal TV remote control.

SOME TIME AGO, SOMEONE LOOKED around his living room and noticed that a number of remote controls were accumulating on the coffee table—one for the TV, one for the VCR, one for the cable box, and one for the stereo. No doubt that observation led to the invention of a device now readily available in many retail stores, namely the universal remote control.

The universal remote control is a device that you can program to operate almost any TV, VCR, or cable box. It doesn't matter what brand TV/VCR/cable box you own. You simply look up a code in the instruction manual, enter it into your universal remote, and the corresponding device can be controlled.

With universal remote controls now being so readily available and inexpensive (in the $10 to $20 range), it is tempting to use one to control yet another device. This article describes the Runabout, a small desktop robot that can be controlled from almost any universal remote control.

Features

The Runabout can be controlled with virtually any infrared universal remote control. The mode used to control the Runabout is the same mode that controls any Sony brand television. Therefore, you need only program your universal remote for a Sony TV, and it will control the Runabout. Also, if you have a Sony brand television, your non-universal Sony remote will also operate the Runabout.

The Runabout is controlled by 17 keys on the remote including channel-up, channel-down, volume-up, volume-down, number keys 0 through 9, and a few others. Various keys tell the Runabout to move forward or reverse, turn right or left, or stop. Some keys enable the Runabout to produce sound effects through a built-in piezoelectric speaker mounted on the Runabout's PC board. Other keys flash Runabout's three LED "headlights."

The Runabout also has an on-board 16-kilobit, non-volatile memory that enables it to remember movement sequences. There are six selectable memory banks, each with 127 steps of memory. This means you can have the Runabout repeat its movement and produce sound effects automatically. You can store six sequences each with up to 127 steps and, with the press of a button, the Runabout will replay the sequence. Sequences are stored and remembered even if power is temporarily turned off or the batteries die.

The on-board infrared receiver is sensitive enough for a control range of up to 25 feet. You can select two speeds—a high range and a low range. The Runabout requires only two AAA batteries for operation.

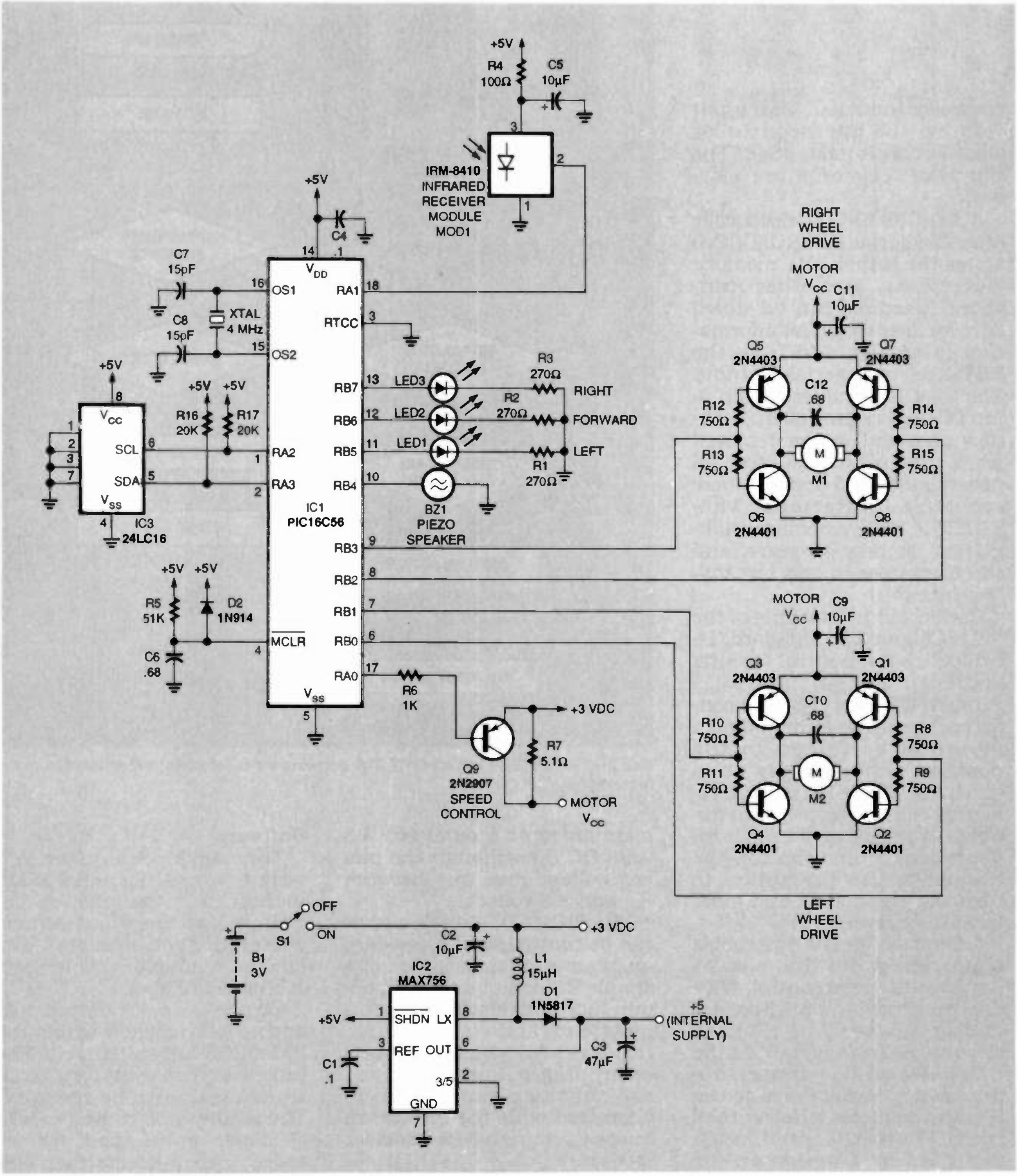


FIG. 1—RUNABOUT SCHEMATIC. The "brain" of this device is a Microchip Technology PIC16C56 eight-bit CMOS microcontroller with built-in EPROM.

The circuit

Figure 1 is the schematic diagram of the Runabout circuit. The "brain" of this robot is IC1, a Microchip Technology PIC16C56 eight-bit CMOS microcontroller with built-in EPROM. The PIC16C56 is housed in an 18-pin DIP package that contains a central processor, clock, EPROM, RAM, a timer, and 13 TTL/CMOS-compatible input/output (I/O) lines.

Control information from the universal remote control is received by an infrared receiver module, MOD1. The IR receiver module outputs a low-level TTL-compatible signal whenever it receives a pulse of infrared light from the remote control. Therefore, whenever a button is pushed on the universal remote, the receiver module outputs a serial bit-stream unique to that particular button.

The receiver module then feeds the bit stream to microcontroller input RA1. That input controller input RA1. That input informs the microcontroller what action to take. (See "The Universal Remote Control" sidebar).

A 24LC16 16K-bit electrically erasable serial EEPROM (IC3) stores the Runabout's memory. Movements, and other Runabout functions can be stored here for later recall. All information is sent to and from the EEPROM in a serial fashion. The 24LC16 is housed in an 8-pin DIP and retains all information even with power removed from the circuit. As with all non-volatile RAM devices, there are some limitations. This EEPROM will remember information for only 40 years, and can be written to only one million times!

Connected to four pins of the PIC16C56 are two standard "H-bridge" motor-control circuits made up of transistors Q1 through Q8. The H-bridge configuration allows either pin of a motor to be forced to the positive motor supply or to ground. The Runabout's motors can be stopped, run forward, or reversed. Through independent motor control, the Runabout has the ability to turn left, right, stop, and move forward or reverse.

Transistor Q9 is a switchable shunt across R7 that acts as Runabout's speed control. With the transistor on, a full 3 volts is available to the motor H-bridge circuits (high range). With the transistor off (low range), approximately ½-volt drops across R7 and reduces the motor's speed. The speed control switch is toggled by a button on the universal remote control.

A Maxim MAX756 (IC2) boosts the battery voltage (+3 volts) to +5 volts necessary for the PIC16C56 and the serial EEPROM. The MAX756 is a high-efficiency, CMOS, step-up, DC-DC switching regulator. Housed in an 8-pin DIP, an internal MOSFET power transistor permits high switching frequencies. The output is

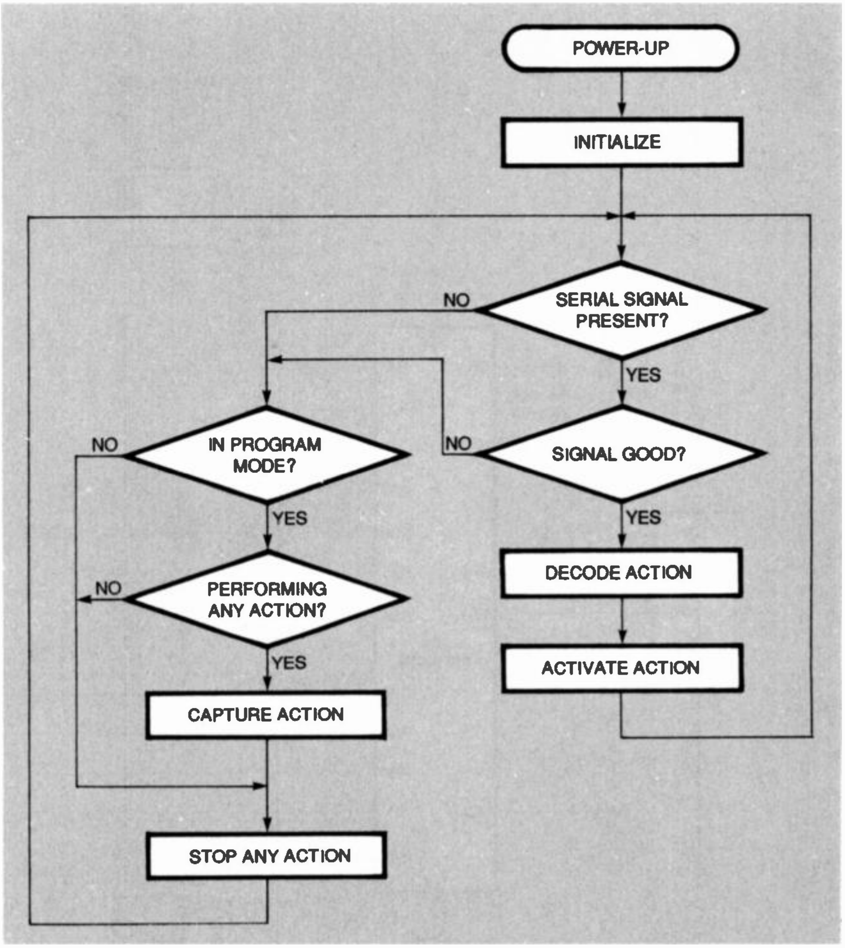


FIG. 2—SIMPLIFIED FLOWCHART. The software waits for serial information from the receiver.

maintained at a regulated +5 volts DC even though the battery voltage may vary between +1 and +3 volts.

The PIC16C56's clock circuit can be controlled by a standard quartz crystal, a resonator, or a simple RC combination. To obtain high-frequency accuracy, a quartz crystal was selected. Good frequency stability is necessary to keep Runabout's internal software routines synchronized with the bit stream output from the IR receiver module.

Three LED's are connected to separate ports on the PIC16C56 (RB5, RB6, AND RB7). These act as the Runabout's headlights, and each can be controlled individually. A piezo speaker connected to RB4 (pin 10) produces sound effects. Components R5, D2, and C6 provide a stable reset signal to the PIC16C56 whenever power is applied to the robot.

Software

The main function of the software is to wait for serial information from the receiver, decode it, and carry out actions dictated by the serial bitstream. A simplified flow chart is shown in Fig. 2.

On power-up, the output pins and various registers within the PIC16C56 are initialized. The processor then waits for a serial transmission to be received. The validity of a received code is checked, and if good, it's decoded. The processor then carries out the proper action by activating motors, sounding the piezoelectric speaker, flashing the LEDs, entering or exiting the program mode, or running one of the stored programs.

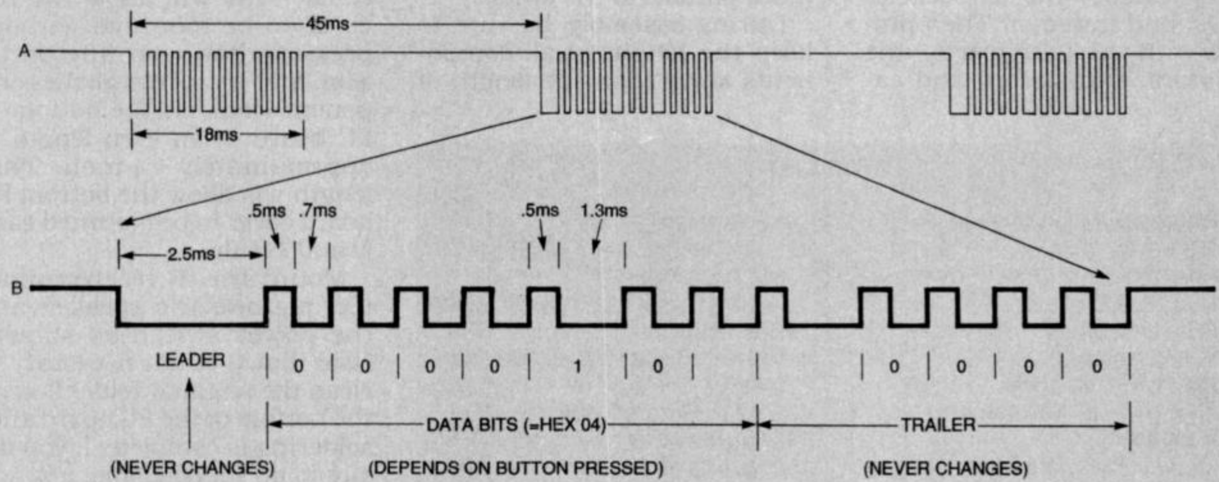
When the serial transmission ceases (when the button is let up on remote), the processor determines whether it's in its program mode, and if it is, it

THE UNIVERSAL REMOTE CONTROL

Today's TVs, VCRs, and other consumer electronics are commonly controlled by wireless remote controls. The remote typically has an infrared LED, which transmits pulsed light to a phototransistor or photodiode in the receiver unit. A unique serial code is produced for each key pressed on the remote control. Manufacturers of consumer electronics have devised many different infrared serial pulse encoding schemes to control their products.

The manufacturers of universal remote controls have successfully developed products that can emulate almost all serial control schemes used by electronics manufacturers. To use a universal remote control for a particular brand TV, you set up the remote with a two- or three-digit code from the manual supplied with the remote (the manual has many brands listed in tables). The remote control will then emulate all the original manufacturer's control codes. Universal remote controls usually have a few mode-change keys, so you can instantly re-assign the control to operate other devices (VCR, cable box, etc).

A typical serial control code for the up-channel button for a Sony brand TV is shown below. An expanded portion of the signal is also shown. The low levels in the waveform correspond to the presence of IR light, and the high levels represent no light. With the key held down, the code repeats continuously every 45 milliseconds. Within each code burst is a series of long and short pulses that defines binary data bits. As shown, a 0.5-millisecond high followed by a 0.7-millisecond low translates to a zero bit while a 0.5-millisecond high followed by a 1.3-millisecond low defines a one. The code translates to hexadecimal 04. Ω



checks if any actions are currently being performed. If an action is being performed while the processor is in its program mode, it is stored in serial memory. If the processor isn't in its program mode, any actions controlled by the processor are stopped.

The "capture action" step shown in the flow chart is where information is sent to the serial EEPROM (24LC16). The information sent is simply a series of bytes corresponding to the actions carried out. A time-code byte is also sent to the memory. Upon playback, the bytes are accessed in the order stored.

Building the Runabout

All of the necessary components including the PC board, gears and motors, top acrylic cover, and sheet metal pieces to build the Runabout as pictured are available from the source given in the Parts List. Foil patterns are provided if you wish to make your own PC

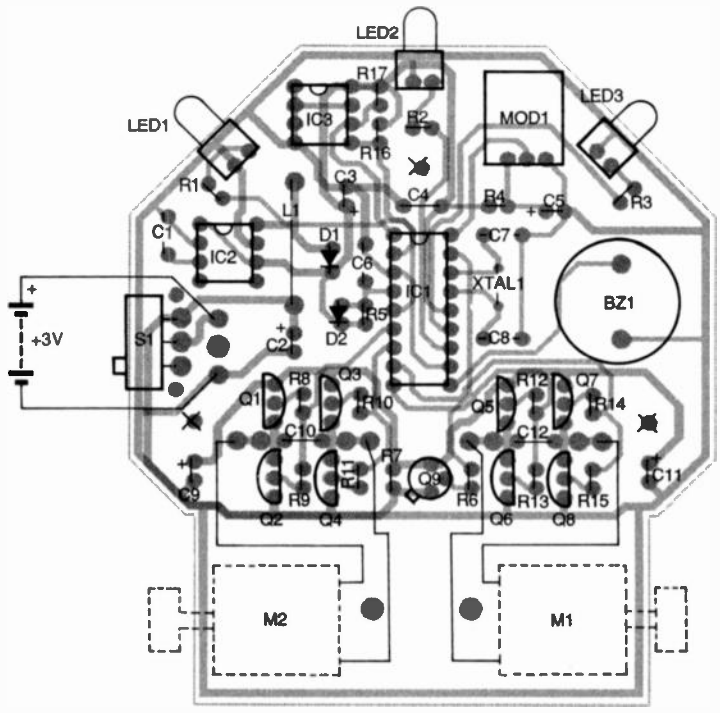


FIG. 3—PARTS-PLACEMENT DIAGRAM. The circuit board holds the electronics and serves as the Runabout's chassis.

board. Pre-programmed PIC16C56's are available from the same source and the HEX code is posted on the Gernsback BBS (516-293-2283) as part of a file called RUNABOUT.ZIP.

The circuit board

The circuit board not only holds the electronics, but acts as the Runabout's chassis. Therefore, it must be assembled first. Figure 3 is the parts-placement diagram. Start by installing the components with the lowest profile—the IC sockets, LEDs, and inductor. Then proceed with the taller parts—the resistors, transistors and capacitors. To conserve space, the resistors are mounted vertically, with one leg bent 180 degrees down parallel to the other.

During assembly, be sure to keep the height of all components lower than the length of the standoffs that hold the top acrylic cover— refer to the mechanical assembly instructions. This will allow the top cover to be mounted without pressing down on any parts. Similarly, try to trim all the component leads on the bottom of PC board to an even length of approximately 1/16-inch. That length will allow the bottom PC board cover to be mounted easily and evenly.

Mount the IR receiver module, piezoelectric speaker, and the power switch as shown. Note that it is not necessary to clean the residual solder flux off the bottom of the PC board after soldering is complete. If you desire to do so, do not let any solvent touch the speaker or power switch—these components can be damaged by the solvent.

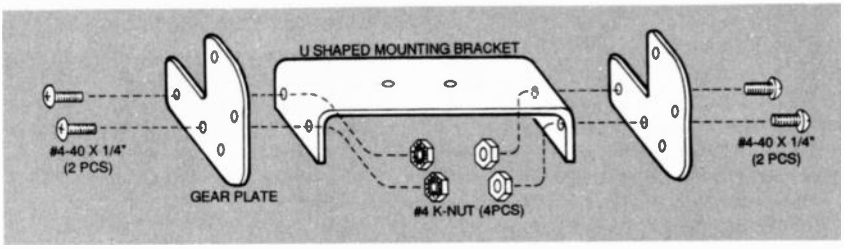


FIG. 4—THE MAIN ASSEMBLY that holds the gears and wheels is composed of two side gear plates and one U-shaped bracket. Detailed mechanical drawings can be purchased from the source given in the Parts List.

PARTS LIST

All resistors are 1/4-watt, 5%.
R1–R3—270 ohms
R4—100 ohms
R5—51,000 ohms
R6—1000 ohms
R7—5.1 ohms
R8–R15—750 ohms
R16–R17—20,000 ohms

Capacitors
C1, C4—0.1 µF, 50 volts, ceramic
C2, C5, C9, C11—10 µF, 16 volts, radial electrolytic
C3—47 µF 16 volts, radial electrolytic
C6, C10, C12—0.68 µF, 50 volts, ceramic
C7, C8—15 pF, 50 volts, ceramic disk

Semiconductors
IC1—Pre-programmed PIC16C56-XT/P microcontroller (Microchip Technology)
IC2—MAX756CPA voltage converter (Maxim)
IC3—24LC16 serial EEPROM (Microchip Technology)
Q1, Q3, Q5, Q7—2N4403 PNP transistor
Q2, Q4, Q6, Q8—2N4401 NPN transistor
Q9—2N2907 PNP transistor
D1—1N5817 Schottky rectifier diode
D2—1N914 signal diode
LED1–LED3—green light emitting diode, right-angle PC-mount package

Other components
MOD1—Infrared receiver module, Everlight No. IRM-8410
XTAL1—4-MHz crystal, low-profile case
BZ1—piezo speaker, Murata-Erie No. PKM22EPP-40
M1, M2—hobby motor, Mabucci No. 020SA-09170
S1—SPST slide switch, PC-mount side actuated
B1—Two 1.5-volt AAA alkaline batteries
L1—15 µH molded inductor

Miscellaneous: Runabout PC board, battery holder for two AAA cells, one 18-pin and two 8-pin IC sockets, two 1-inch grommets (wheels), two 9/16- × 5/8-inch spacers (wheel hubs), gears and mounting hardware, six 3/8-inch No. 2 standoffs, one KF brand 7/8-inch "Domed-Glide" No. 6277 (front skid), acrylic plastic top cover, ABS black plastic bottom cover, screws and nuts, solder

Note: The following parts are available from Silicon Sound, PO Box 371694, Reseda, CA 91337-1694, 818-996-5073:
• Complete Runabout robot kit with all parts including PC board, programmed PIC16C56, all gears, hardware, and top acrylic and bottom plastic covers—$99.00
• Assembled and tested Runabout robot—$139.00
• Pre-programmed PIC16C56 microcontroller—$17.00
• Complete set of eight plastic gears for Runabout—$15.00
• Full function universal remote control (can control your TV/VCR/Cable Box)—$15.00
Please add $4.50 for shipping and handling. California residents add 8.25% sales tax.

Mechanical assembly

If you wish to make the Runabout from your own parts, you will need to do some sheet-metal work. As shown in Fig. 4, the main assembly that holds the gears and wheels is composed of two side gear plates and one U-shaped bracket These were fabricated from 6061 aluminum sheet stock, 0.08-inch thick. It is not critical that you follow the original plans exactly, as long as you follow the general layout. Many of the mechanical parts including gears and motors can be purchased from the various manufacturers listed in Table 1.

Plastic gears were used for the Runabout, but metal gears will work just as well. Start by mounting the two gear plates to the mounting bracket. Mount the gears with No. 4-40 machine screws and nuts, as shown in Fig. 5. Threaded holes in the mounting bracket hold

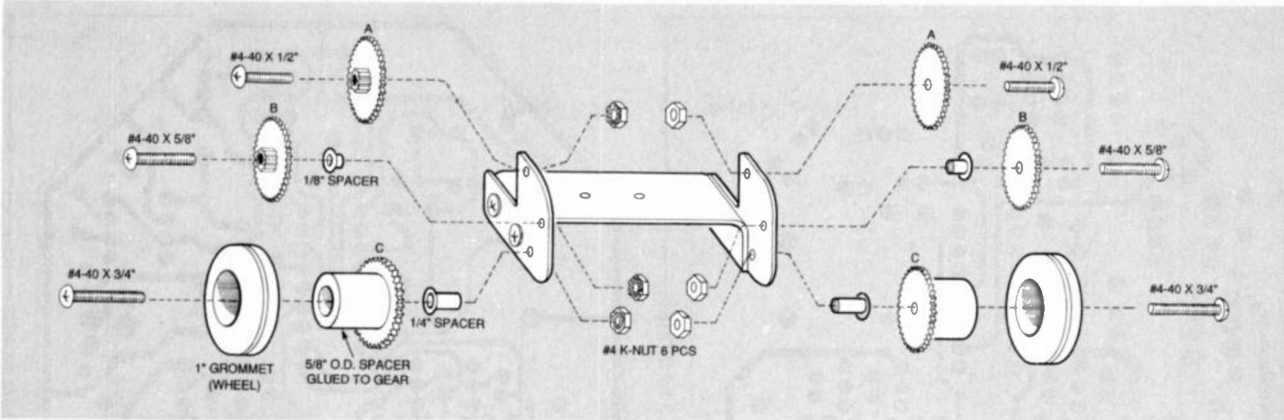


FIG. 5—GEARS ARE MOUNTED with No. 4-40 machine screws and nuts. Threaded holes in the mounting bracket hold the gear screws, with nuts locking the screws in place.

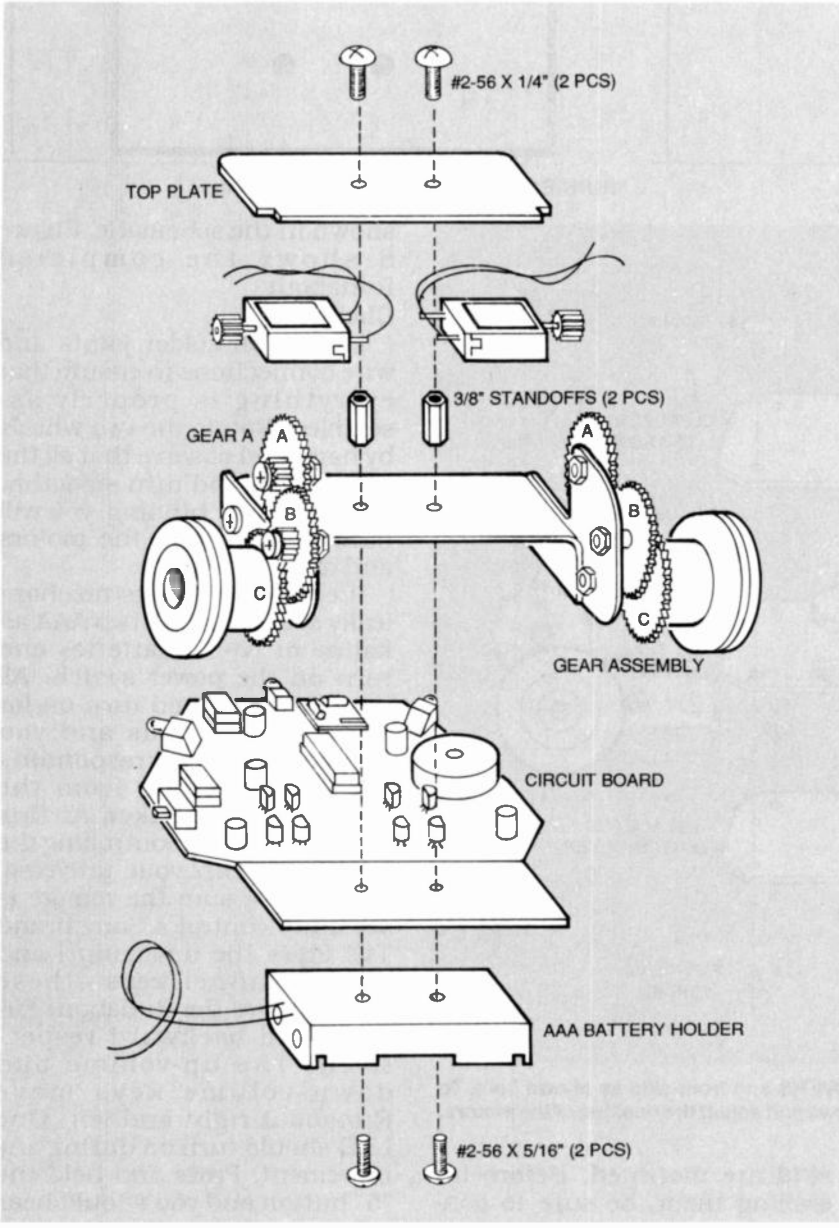


FIG. 6—THE GEAR ASSEMBLY mounts to the PC board as shown. The two screws on the top plate hold the two motors in place.

the gear screws; the nuts lock the screws in place. All gears must mesh smoothly.

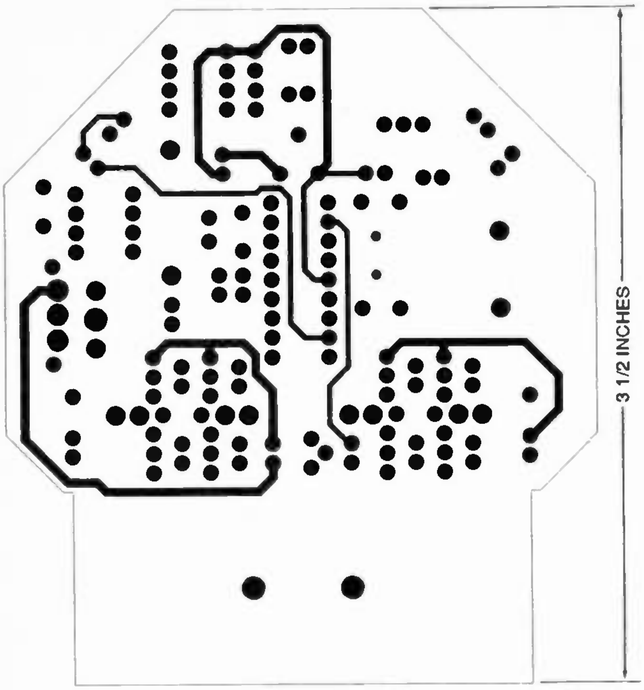
Figure 6 shows how the completed gear assembly mounts to the PC board, and how the two motors and battery holder are held in place. The two standoffs in the center are key to the assembly. The two screws on the top plate form a compression clamp for the two motors, holding them in place. To align the two motor gears to the other gears, loosen the top screws and adjust the position of the motors so they mesh with gear "A", as shown in Fig. 7.

If you use your own motors, you might need to make some adjustments in the overall dimensions as shown. As long as you end up with a two-wheel drive system, with motor current below approximately 300 milliamperes (the H-bridge transistor limit), you should be able to make a working robot.

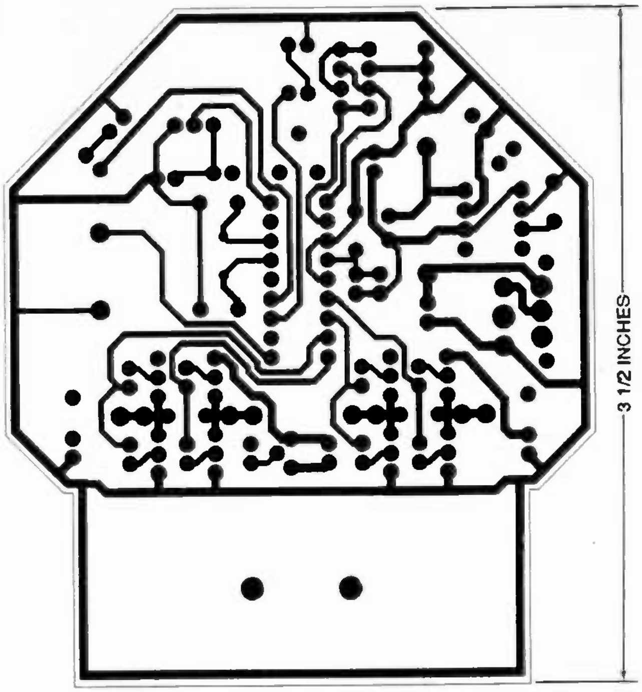
The Runabout's gear ratio is about 57:1, which means that the motors must turn 57 times for each revolution of the wheel. This gives the Runabout a slow and even motion. You do not have to stick to this ratio; you can eliminate a gear on each side plate if you desire a faster robot.

As shown in Fig. 5, the wheels are made from two large rubber grommets. These can be purchased in many different sizes from most electronics retailers. See Table 1 for sources.

The front "skid" is actually a nail-on-glide intended for use as a foot on the leg of a chair or table. Most hardware stores carry various types of these de-



RUNABOUT PC BOARD COMPONENT SIDE.



RUNABOUT PC BOARD SOLDER SIDE.

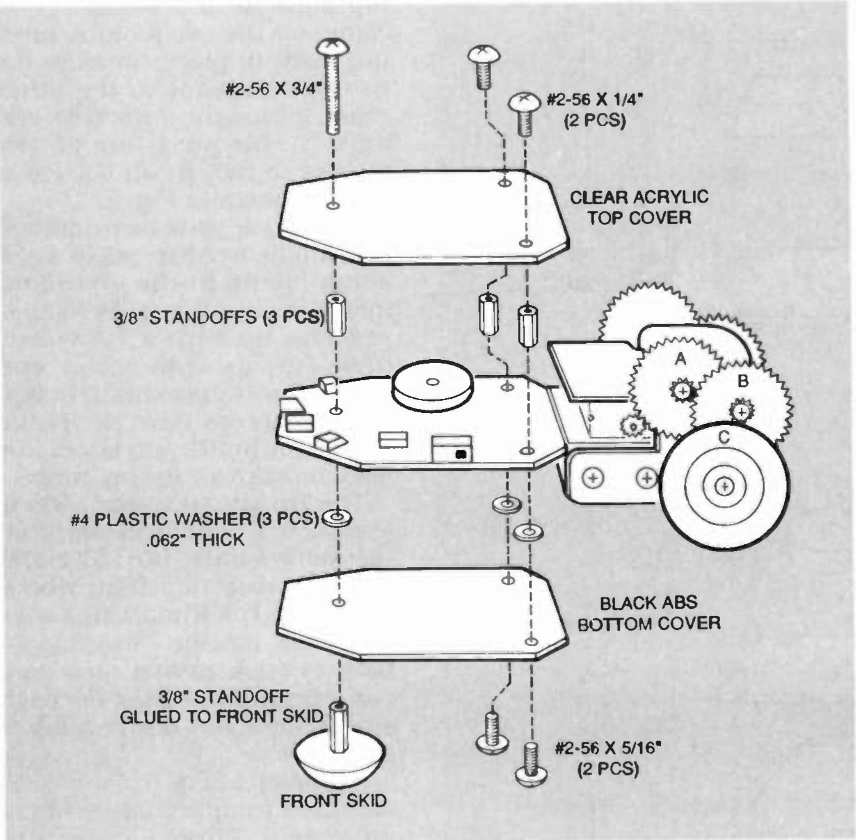


FIG. 7—MOUNT THE TOP AND BOTTOM COVERS and front skid as shown here. To align the two motor gears, loosen the top screws and adjust the position of the motors.

vices. Instead of a skid, you could fabricate some type of wheel for the front of Runabout.

Figure 7 shows how the top and bottom covers and the front skid are mounted. Before installing them, be sure to connect the motor wires to points W1 through W4, and connect the battery holder wires as shown in the schematic. Figure 8 shows the completed Runabout.

Checkout

Inspect all solder joints and wire connections to ensure that everything is properly assembled. Rotate the two wheels by hand and observe that all the gears mesh and turn smoothly. If the gears are binding, you will have to reposition the motors and/or gears slightly.

If everything looks mechanically sound, install two AAA alkaline or Ni-Cd batteries and turn on the power switch. All three LEDs should turn on for about 0.2 seconds and you should hear a corresponding two-tone beeping from the piezoelectric speaker. At this point you can try controlling the Runabout with your universal remote. (Be sure the remote is set up to control a Sony brand TV.) Press the up-channel and down channel keys—these should move the Runabout forward and backward respectively. The up-volume and down-volume keys move Runabout right and left. One LED should turn on during any movement. Press and hold the "5" button and you should hear a beeping from the piezo element.

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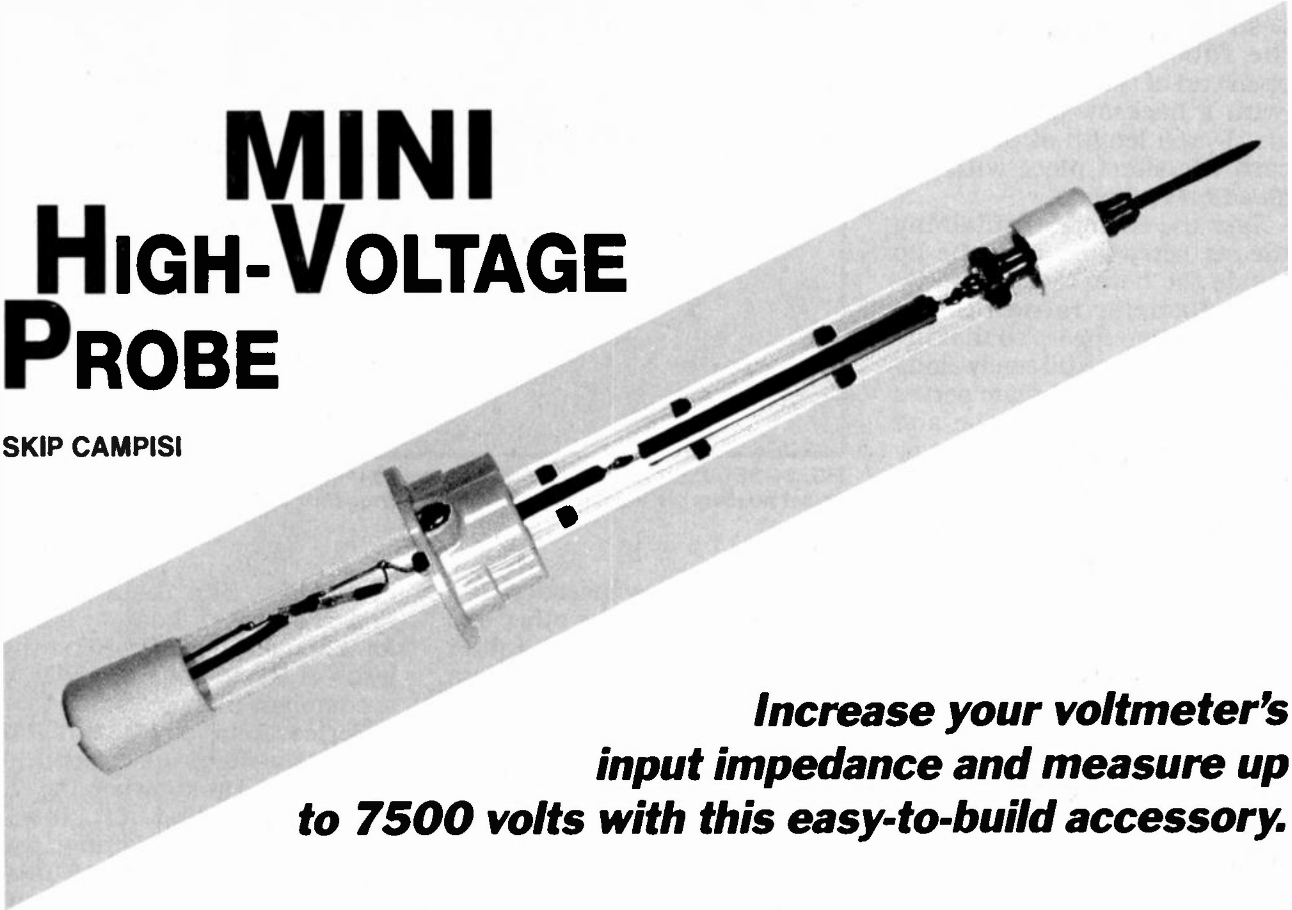


MINI HIGH-VOLTAGE PROBE

SKIP CAMPISI

Increase your voltmeter's input impedance and measure up to 7500 volts with this easy-to-build accessory.

THE MAXIMUM ALLOWABLE VOLTAGE specification on the typical digital voltmeter (DVM) usually never exceeds 1000 volts. Even the DVM's 10-megohm input impedance every so often loads down a high-impedance circuit giving false readings. That's why you either need a $100-plus, store-bought, high-voltage probe or the Mini High-Voltage Probe that you can build in one weekend for about $10 to $20. So save the money and read on.

The Mini High-Voltage Probe has an input impedance of 110 megohms, or 11 times that of a standard DVM, and it can handle 5000-volts AC or 7500-volts DC peak. The prototype illustrated in this article and a common, service-type DVM were used to test a 5500-volts AC transformer, and the probe performed perfectly. Its accuracy is within 1 percent, which is typical considering the components used in the probe's construction.

About the circuit

The schematic diagram of the probe (Fig. 1) reveals its simple circuit. It is a standard voltage divider made up of resistors with a 1-percent tolerance. Resistors R1 and R2 are the key elements here. They are rated at 15,000 volts and 10,000 volts, respectively. The 7500-volt DC peak specification for the assembled probe **must not be exceeded under any circumstances!** Play it safe and purchase a factory-built unit if you require higher voltage measurements, especially if you wish to do TV servicing.

The values for series resistors R3 and R4 are in parallel with the 10-megohm resistance of the DVM, thus providing a 1000 to 1 voltage divider. Voltage measurements made by the probe should be multiplied by a factor of 1000. If your DVM uses a different input impedance than the standard 10 megohms, you can adjust the R3-R4 series combination as needed.

Construction

The body of the probe is made from an antenna wall feed-through tube available from Radio Shack. The tube is made of clear plastic with an outside diameter of ¾ inch, and a bore of ⅝ inch. It has two flanged end plates, one of which is glued in position. Remove the other end plate by loosening the Phillips

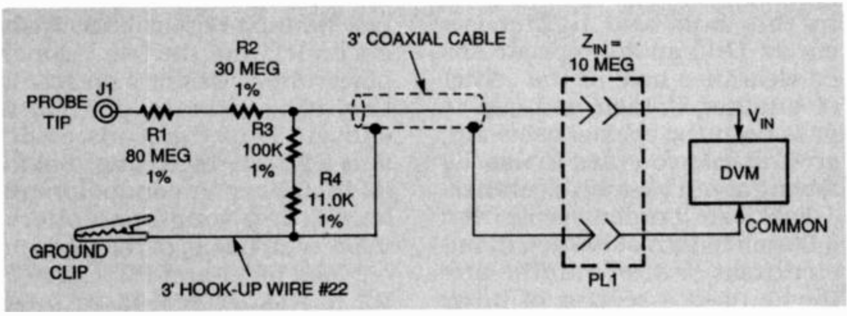


FIG. 1—SCHEMATIC DIAGRAM for the Mini High-Voltage Probe.

head set screw and slide it off the tube. Measure from the open end of the tube and cut off (with a hacksaw or razor saw) an 11-inch length of tube. Discard the short piece with the glued-on end plate.

Take the end plate containing the set screw and note the lip inside the bore. Use a ¼ to ⅜-inch diameter rat-tail file to smooth down the lip so that the end plate can be slid easily along the tube. This end plate serves as the hilt on your probe and keeps your hand safely away from the high-voltage business end of the probe.

WARNING: ***Do not be tempted to paint the clear plastic tube—insulation integrity could be compromised!***

Now prepare five ⅜-inch rubber faucet washers (obtainable at plumbing supply stores or hardware outlets) by enlarging their center bores. The standard ⅜-inch washers have an outside diameter of ⅝ inch with a flat outside edge. Check to be sure that they slide easily into the probe body before drilling. Using drill bits twisted with your fingers (no power tools), you can do a neat and quick job by "stepping up" drill bit sizes in increments of 1/64 inch or 1/32 inch to attain the final sizes. Drill two washers to a bore of 7/32 inch, one washer to ¼ inch, and two washers to 9/32 inch. Install J1, a panel-mount RCA phono jack, in the washer drilled with a ¼-inch bore. Do not over-tighten the nut, or the washer will spread out and bind in the probe's body—a nice slide fit is desirable. Secure the nut on J1 with a dab of silicone sealant.

Drill a ¼-inch hole dead center in the end of a ¾- inch, plastic, chair-leg end cap. Install J2 (panel-mount RCA phono jack) in this hole and tighten securely. Drill an appropriate sized clearance hole in the center of another ¾-inch end cap to pass both the coaxial cable and ground lead you plan to use, allowing about 1/16-inch clearance.

Fabricate a probe needle from a 3-inch length of ⅛-inch diameter brass or steel rod (the prototype used a section of brass welding rod). Round off one end

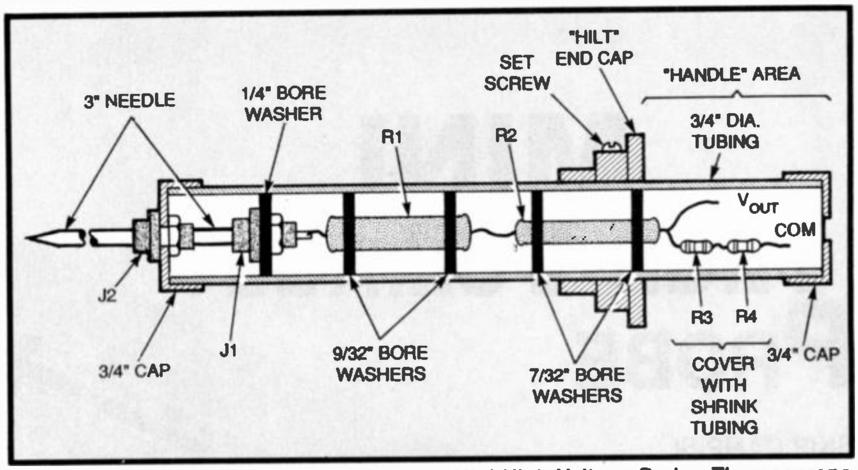


FIG. 2—DETAILED ASSEMBLY VIEW of the Mini High-Voltage Probe. The neoprene faucet washers are identified as ⅜-inch; however, their actual outside diameter is ⅝ inch.

of the rod for easy insertion into the jacks, and file the other end to a blunt needle shape, rather than a sharp point, to suppress arcing and corona discharge. This work can be done by hand, or, more rapidly, chucked in a lathe or power drill. Finish up with fine steel wool and metal polishing paste for a nice finish. Tooth paste works fine in a pinch!

Insert the rounded end of the probe needle into J2, mounted on the ¾-inch cap. Leave about 1¼-inch protruding from the front of J2. The probe needle should be a tight fit to keep it from sliding when used. If the fit is too loose, remove the needle and flow solder into the jack's center conductor pin for a better fit. If necessary, you can solder the needle directly to the pin. Install the assembly of J1 (mounted in its washer) on the rounded end of the needle, leaving J1's center-conductor lug accessible. No connections are to be made to J2's center conductor, or either jack's ground lug.

Refer to the parts location diagram (Fig. 2), then install the two 9/32-inch-bore rubber washers on R1, and the two 7/32-inch bore rubber washers on R2, in the approximate positions shown. Trim the leads on R1 and R2 to ½-inch long. Solder R1 to J1's center conductor eyelet. With a long-nose pliers, make wire hooks of the leads on one end of R1 and R2. Connect R2 to R1's other lead by interlocking their wire-hook leads and solder. Slip the assembly into the probe's body to check for a smooth slide fit. Bend the leads of R1 and R2 carefully to accomplish this.

Series connect R3 and R4, and put a slight offset bend in R2's free lead as shown in Fig. 2. Solder the free end of R3 to R2 near the bend and arrange the leads as shown. Cover R3-R4 with a piece of heat-shrink tubing. Likewise, cover R2's lead with heat-shrink and leave about ½-inch of exposed wire at the end. Select a 3-foot length of flexible coaxial cable such as RG-174 or audio cable, and solder its center conductor to the junction of R2-R3. Solder the braided shield to R4's free end, along with a 3- foot length of insulated #22 stranded hookup wire.

Feed the two cables through the probe body followed by the entire resistor/probe tip assembly. If the ¾-inch cap containing the probe tip is not a tight fit on the tube, secure it with a dab of silicone sealant.

Install a cable tie on the two cables right before they exit the tube, and slide a plastic washer up the cables to the tie thus providing strain relief for the cable and wire. Slip the previously completed "hilt" over the cables and onto the tube and position it so that the end of R2's body can just be seen at the junction of R2-R3 (Fig. 2). Tighten the set screw snugly, using care not to crack the tubing. Slip the remaining ¾-inch plastic cap over the cables and onto the probe's body.

Solder an alligator clip to the end of the 3-foot hook-up wire, which is the probe's ground lead. Select the connector which mates to your DVM (a dual banana plug is typical) and connect it to the end of the 3-foot coaxial cable, the braided shield going to the ground, or common terminal. This completes construction of the probe, which is now ready for testing.

PARTS LIST

Resistors
R1—80 megohms, 1%, 7.5-watt, 15,000-volts, metal-film Caddock #MG780 (Johnson #160-CAD-80M)
R2—30 megohms, 1%, 3.5-watt, 10,000-volts, metal-film Caddock #MG735 (Johnson #160-CAD-30M)
R3—100,000 ohms, 1%, ¼-watt, metal-film (Johnson #151-100K)
R4—11,000 ohms, 1%, ¼-watt, metal-film (Johnson #151- 11.0K)
Connectors
J1, J2—Jack, RCA phono, panel mount
PL1—Dual banana plug
Miscellaneous
1—Tube, antenna through-wall lead-in (Radio Shack 15-1200)
2—Cap, plastic chair leg, ¾-in.
5—Washer, neoprene, faucet (sink) ⅜-in. (⅝-in. O.D.)
3-ft.—Coaxial cable, flexible, any impedance
3-ft.—Wire, #22 stranded, insulated, hook-up
1—Alligator clip

All four resistors are available from: Johnson Shop Products, P.O. Box 2843, Cupertino, CA 95015; Tel: 408-257- 8614.

Testing and operation

Check for proper operation of the divider circuit on a low-voltage DC source. Plug the probe into your DVM, making sure that the braided shield is connected to the DVM common or ground terminal. Connect the probe ground clip to the negative terminal of a nine-volt battery and touch the probe needle to the positive terminal. The DVM should indicate about 9.0 millivolts as a satisfactory reading. Now measure the battery voltage directly (without the probe) using your DVM and ordinary test leads.

Multiply the probe's reading by 1000, and compare it to the battery voltage direct reading (without the probe). The two readings should match within about ±2% or better. If not, go no further before finding and correcting your problem! When the readings agree, you may check the high-voltage performance of your probe.

WARNING: *To avoid the risk of electrical shock and possible damage to the probe or other equipment, follow these instructions exactly!*

As a general precaution before proceeding with any high-voltage check with any high-voltage probe, always inspect the insulation integrity of your probe and cables first. Make sure there are good connections to the plug and ground clip. Check that the wire to the ground clip is not worn or frayed. Plug the probe into the DVM, observing proper polarity (ground to ground), and turn on the DVM.

Begin by using a high-voltage AC transformer rated less than 5000-volts AC, with the power OFF. Connect the probe ground clip to one of the transformer's terminals, and by means of a short clip lead, connect the probe needle to the other terminal, keeping the leads separated to avoid drawing an arc. Without touching the probe's body, apply power to the transformer and look and listen for any arcs or "sizzling" at any points in your set-up.

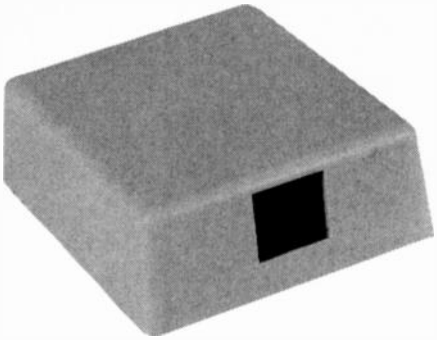
If you have a problem, repair it *before* attempting to handle the probe during actual use. If everything looks satisfactory, note the actual reading on your DVM, and if this reading appears correct, you are ready to make high-voltage measurements with your home-brew probe!

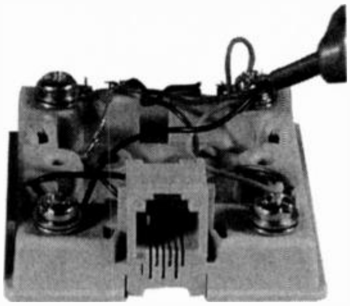
To measure high-voltage DC, first connect the ground clip to chassis ground, then touch the probe needle to the high voltage terminal. If possible, make the high-voltage connection before turning on the high-voltage supply: This will prevent arcing to the probe needle, which could damage the probe or the equipment under test. Remember to multiply all of your readings by 1000, and hold the probe by the handle behind the hilt.

Be cautious

Never grasp the probe ahead of the hilt near the divider section! *Never* connect the ground clip to a voltage referenced above or below earth ground—serious electrical shock and instrument damage could result. The clip has to be either transformer isolated from ground, or at ground potential for safe operation. Of course the probe can be used for a low-voltage, high-impedance measurements by DVM, also—just remember to use the 1000 multiplication factor. Ω

JAMES MELTON





A specialized two-lead semiconductor is a complete project that will protect your modem communications from interruptions.

PHONE-LINE PRIVACY MODULE

MODEMS ENABLE COMPUTER owners to communicate with other computer owners, and access fax machines and network services all over the world. You can download more information about almost any subject than is found in your local library in less time than it takes to get there! You can send orders for merchandise, requests for information, or send your opinion to a radio station right from your keyboard.

With all this convenience comes a problem: You can be interrupted during the middle of all this high-speed, compressed-data, multiple handshake communications by the simple act of your two-year-old child picking up a phone in another part of the house and saying "Hi Granny" into the mouthpiece! Even five minutes lost can be aggravating.

One obvious solution is to have two phone lines—and the accompanying two bills from the phone company. A better solution would be an automatic way to ensure that the person, modem, or machine using the phone line has exclusive use of the line. Such an arrangement is possible without the resources of NASA and the national budget. In fact, the exclusive use of the phone line can be arranged at your house or business just by adding a single semiconductor in series with each phone that might interfere with modem operation.

Phone basics first

Although the "how" of operating a phone across the phone network is so simple as to be second nature to everyone (remember that two-year-old child), the behind-the-scenes operation is more complicated. Consider the operation of a phone line that runs from the telephone company's CO (central office) to your home.

Start with the phone on-hook (hung-up is the common expression) waiting for a call to be made. When all the phones on the same line are on hook, the phone line from the CO is an open loop. There will be a voltage of between 30 and 50 volts DC standing on the line, and no current will be flowing.

When a phone goes off-hook, a switch inside the telephone connects the phone instrument to the phone line, and presents a terminating load of approximately 600 ohms. This 600-ohm load causes a DC current to flow in the loop between your home and the CO. This DC current signals the CO that you wish to make a call. The amount of current flowing depends on the distance the phone is from the CO, since the current has to travel many miles through the phone lines to your house. The farther away your home is from the CO, the lower the loop current, and consequently, the lower the voltage seen at your home telephone. Typically, the off-hook voltage might vary between 12 and 18 volts.

Equipment at the CO places an audio dial tone signal on the line going to your house to let you know that connection to the CO has been made and you can now proceed with dialing. The CO listens for the DTMF (digital-tone, multiple-frequency) signals from the phone's key pad, and the call is routed at the CO to a destination. The equipment at the CO then waits for you to break the connection by hanging up, which it determines when the loop current no longer exists.

For incoming calls, the CO places an AC ringing voltage from 90 to 130 volts AC onto the DC voltage standing on your open-loop line. A capacitor in the telephone provides a closed loop for the ring signal when the phone is on hook. The capacitor passes the AC through to the ringing circuitry, and your phone rings. When you pick up the phone, you complete the DC loop as mentioned previously, and the CO knows you have picked up the phone. The CO discontinues the ringing signal, interconnects the originator's phone to yours, then monitors the loop current, waiting for you to hang up.

One-component project

To isolate the modem from the phones and achieve uninter-

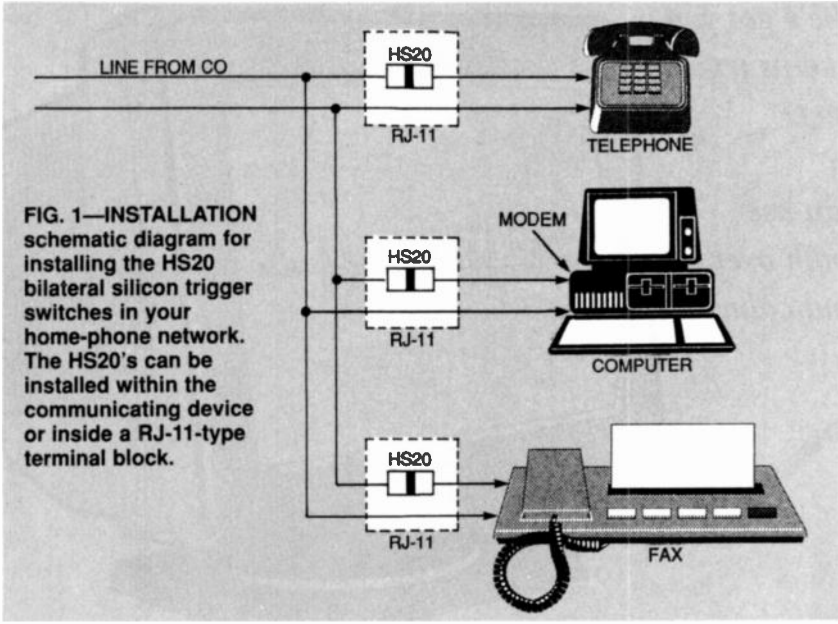


FIG. 1—INSTALLATION schematic diagram for installing the HS20 bilateral silicon trigger switches in your home-phone network. The HS20's can be installed within the communicating device or inside a RJ-11-type terminal block.

rupted communications requires the installation of HS20 bilateral silicon trigger switches manufactured by Teccor Electronics. Normally, the HS20 is used in commercial light dimmers as part of the triggering circuit for a triac. It prevents current from flowing until the voltage has built up to a definite, repeatable value, then fires (or begins conducting) at a point in the AC waveform that allows for positive triggering of the triac. However, those performance characteristics are ideal for this application. All you have to do is install one semiconductor in each of the phones that you want to safeguard from jamming your modem's communications.

Basic plus one part

Here is how your home phones will operate after the installation of the HS20 bilateral silicon trigger switches: With the modem and the phone line on-hook, 30 to 50-volts DC is standing on the line, and is present at the modular plug for each phone. If your modem goes off-hook, it closes the loop, and the HS20 sees the 30 to 50 volts across it.

Because the HS 20 is manufactured to trigger at 20 volts, it triggers, and becomes a very low resistance (about a 2-volt drop) part of the loop circuit. Should the other phone(s) in the circuit now try to access the line, nothing will happen. The voltage on the circuit, with the modem accessing the line, has dropped to somewhere between 6 and 18 volts. This voltage is not enough to fire the trigger switch at the phone's site, and the HS20 remains in a high-impedance (resistance) state. You do not have loop current flowing in the line to your voice phone, and you have not interrupted the modem's reception or transmission.

The HS20 works equally well the other way: If you are on the voice phone first, no other phone equipped with a trigger in the loop can interfere. The other phone will be silent, and cannot hear your phone conversation. Also, you cannot use your modem.

Installation

You can determine from the schematic drawing in Fig. 1 that the HS20 can be placed anywhere in each telephone's line so as to effect only that device. The RJ-11 block (Fig. 2) is the best place to install the HS20 in series with one wire of the inner pair of the modular jack. Unless you have more than one phone line, the inner pair of the modular cord will always be the pair from the CO. In some cases, it might be easier to open the phone's plastic case and locate the inner pair of wires, and solder the HS20 into one of the lines.

It does not make any difference which of the two wires of the line is used, and you do not have to stay on the same wire from one device to the next. The HS20 is also not polarity sensitive, so either lead of the semiconductor can be connected to either line in the loop. Again, you need to put one HS20 in the line for each device you want to protect including the modem. Any phone connected to the line without the HS20 in its line will be able to butt-in on your conversation, or on your data or fax transfer.

One HS20 bilateral silicon trigger switch is required for each phone and modem you intend to protect; the minimum quantity is two semiconductors for a home with one modem and one phone. If you are having trouble obtaining the HS20 bilateral silicon trigger switches from electronic parts suppliers, you can purchase them from SolarWorks, 2747 Wentworth Drive, Grand Prairie, TX 75052 for $4 each, plus $0.50 postage and handling per order. Ω

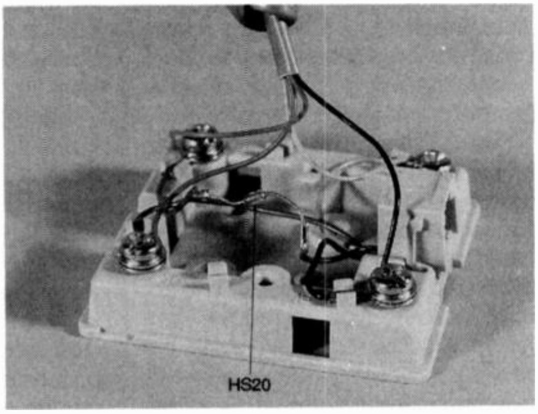
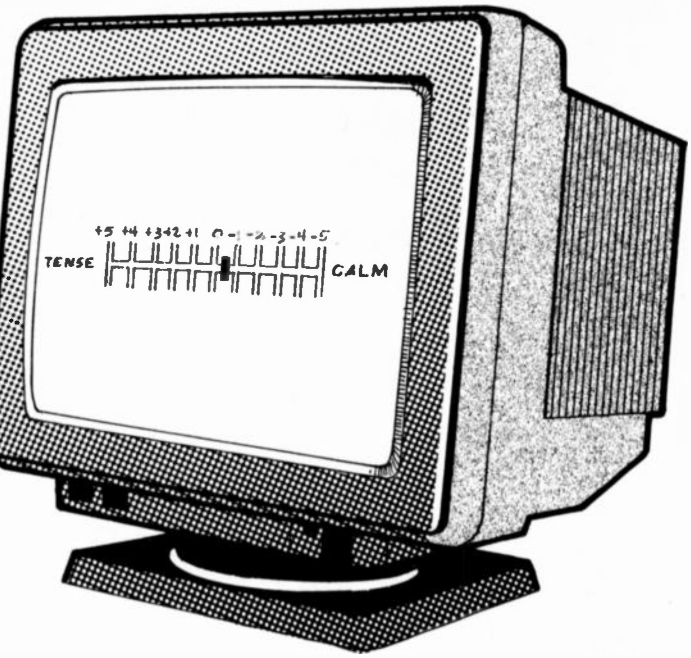
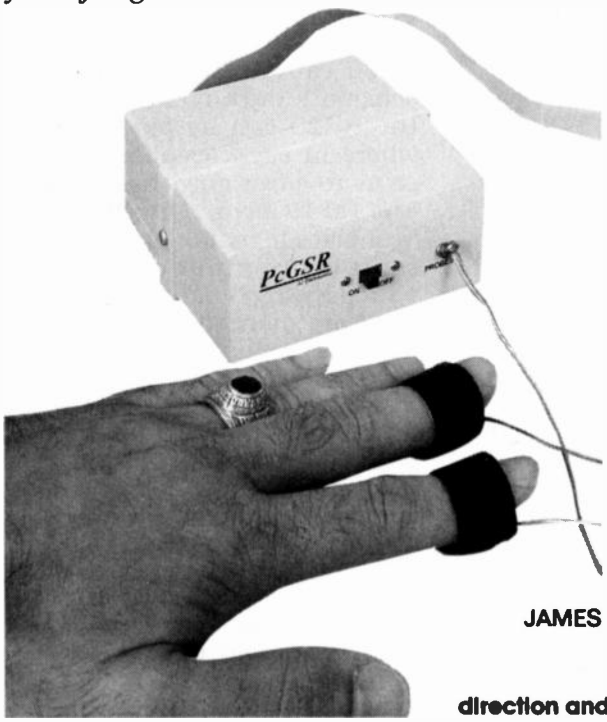


FIG. 2—INSIDE VIEW of a RJ-11 type terminal with the HS20 bilateral silicon trigger switch installed. Communications emanating from a phone or modem plugged into this block will not interfere with other similarly connected devices.

Stressed out from your job? Life's got you in a tizzy? Is your stomach in knots trying to find parts for that last project? With this simple device and an IBM or compatible PC, you can use biofeedback techniques to smooth over some of life's rougher edges and calm your jangled nerves.





Biofeedback MONITOR

JAMES J. BARBARELLO

Stress reduction through biological feedback is a time-tested and relatively simple process. It consists of measuring a person's level of stress while thinking of various things. The current stress level is fed back to the person in real time, usually by some form of audio tone, lights, or other display. You can then discover the mental exercises that aid in reducing stress, and eventually use those exercises in everyday situations without biofeedback assistance. In a sense, biofeedback devices can be thought of as a set of mental training wheels. Once you get the hang of controlling your stress levels, you no longer need to rely on artificial support.

Note: If you have either a serious or medically-related stress problem, you should only attempt biofeedback or other types of treatment **under the direction and guidance of a doctor or other medical professional**. But for those of us who just want to reduce everyday tension, or simply relax, a self-administered biofeedback program is both safe and beneficial.

To make our monitor work, we obviously need a way to measure a person's stress level. Galvanic skin response (GSR), which is the measurement of the electrical resistance of the skin, changes with various levels of stress. Therefore, a GSR sensor whose output can be examined and fed back in real time would make an effective basis for a biofeedback system.

Over the years, there have been many such devices with a sensor based on a resistance-to-frequency conversion technique. The stress-level monitor was in the form of discrete circuitry, a microprocessor, or a computer of some type. In today's high-speed, Windows-based PC world, the computer-based resistance-to-frequency approach has a few drawbacks. First, that system depends on the microprocessor clock speed, and must be adjusted from computer to computer. Second, the sensor's frequency varies directly with the galvanic skin resistance. That causes an annoying disparity between the feedback rate at calm levels (very slow) and tense levels (very fast). Lastly, the sampling is interrupted periodically by the PC as it does "overhead" stuff (like keeping the clock updated). That is even more pronounced if you use it in an MS-DOS environment under Windows. The result is random variations in the sensor output that can cause shifts in the displayed stress level.

The *Stress-A-Bater* biofeedback monitor discussed here is a low-cost, PC-based home biofeedback system that eliminates the drawbacks of resistance-to-frequency GSR sensors. It uses an analog-to-digital (A/D) converter that measures GSR by referencing it to a fixed, known resistance. Common parts are used throughout, and no special construction techniques are required. The Stress-A-

Bater is powered by a single 9-volt battery and connects to an IBM or compatible PC through any available parallel port.

How It Works. The schematic in Fig. 1 shows how simple the Stress-A-Bater's hardware is. There are only three integrated circuits: an ADC0831 A/D converter (IC1), a CD4066 quad analog switch (IC2), and a 78L05 5-volt regulator (IC3).

Let's begin with a quick description of the A/D converter. (For more information on A/D converters in general, see "Build an 8-Channel A/D Converter" in the June, 1995 issue of **Popular Electronics**.) Integrated circuit IC1 converts an analog voltage into an 8-bit binary number between 0 and 11111111 (255 decimal). The reading is zero when the input voltage on pin 2 ($V_{IN}+$) is equal to the voltage on pin 3 ($V_{IN}-$). A value of 255 is reached when the input voltage is equal to the sum of the voltages on pin 3 and pin 5 (V_{REF}). That arrangement allows IC1 to measure input voltages that span a range less than 5 volts. In order to convert an input voltage to a digital number, pin 1 (CHIP SELECT) is brought low and a clocking signal is supplied to pin 7. The most significant bit (D7) appears on pin 6 (DATA OUT) on the falling edge of the second clock pulse. Each following bit (D6, D5, etc.) appears on pin 6 with the falling edge of each additional clock pulse. When all eight bits have been read, pin 1 should again be brought high to prepare for the next conversion.

The input to IC1 is a two-resistance voltage divider. Resistors R5–R8 form the upper part of the divider. Those resistors are selected by IC2, a quad bilateral-analog switch. That device contains four identical switches, each with an input, an output, and a control. When a switch's control signal is low, a low-resistance connection (about 50 ohms) is made between the input and output. Thus, any single or parallel combination of the four resistors (R5–R8) can be selected with the appropriate control signals to IC2 pin 5, 6, 12, or 13. By selecting one of the 16 possible on/off combinations for the switches, the resistance in the top portion of the voltage divider can be adjusted between about 56,000 ohms and 1 megohm.

The lower part of the voltage divider is the resistance of a person's skin. One of the GSR probes connects to the input of the A/D converter, and the other probe is connected to ground. When the probes are attached to a person's fingers, a resistance (GSR) is seen between pin 2 of IC1 and ground. Since the selected resistors and the GSR probe together form the voltage divider, the input voltage at IC1 generated by the voltage-divider circuit is directly proportional to the galvanic skin resistance across the probes.

The V_{IN-} and V_{REF} voltages are generated by voltage-divider resistor pairs R1/R3 and R2/R4. Using the values shown in Fig. 1 for R1-R4, the reference voltage are approximately 1.6 volts for V_{IN-}, and 2.6 volts for V_{REF}. With those voltage levels, IC1 provides a 0 output at 1.6 volts, and a 255 output at 4.2 volts (1.6 + 2.6). The resolution of IC1 is the input voltage range divided by the number of possible binary output steps. That is , or about 10-mv/step. As an example, with only R5 selected and a GSR of 100,000 ohms, the input to IC1 will be:

$$V_{IN+}=5\times(R_{select}/(R_{select}+R_{probe}))$$
$$=5\times(100{,}000/(100{,}000+100{,}000))$$
$$=2.5v$$

The V_{IN+} equation can be rearranged to:

$$R_{probe}=5\times(R_{select}/V_{IN+})-R_{select}$$

Using the 10-mv (0.1-volt) resolution we previously calculated, we can see that the next change in output will be when the input voltage changes to either 2.49 volts or 2.51 volts. Using 2.51 volts in the R_{probe} formula above gives us a GSR of:

$$R_{probe}=5\times({}^{100{,}000}/_{2.51})-100{,}000$$
$$=99{,}200 \text{ ohms}$$

The resistor values chosen for R5–R8 let us see changes in GSR of about 1%. The Stress-A-Bater can operate at that

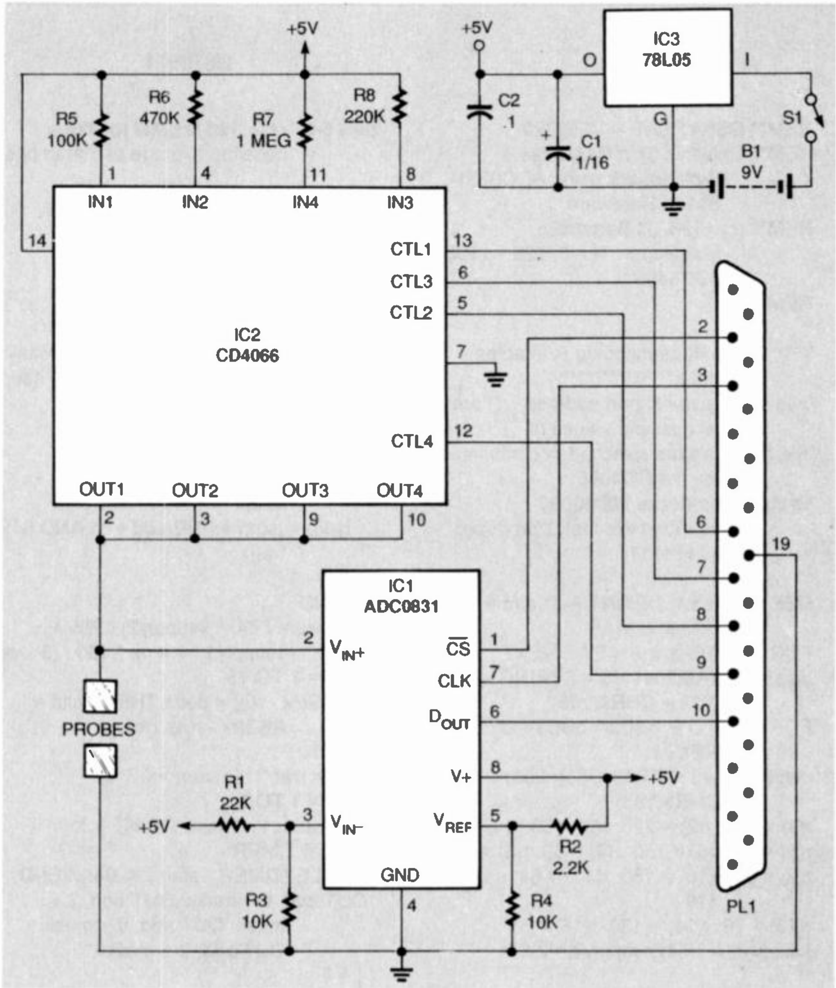


Fig. 1. The circuit for the Stress-A-Bater's hardware is very simple. The 3-wire output of the ADC0831 makes it very easy to interface the A/D converter to many different types of computers.

LISTING 1

```
REM** GSR41.BAS -- V960220
REM** Galvanic Skin Response
        Biofeedback using ADC0831-
        Based Hardware
REM** (c) 1996, JJ Barbarello,
        Manalapan, NJ  07726 -- (908)
        536-5499
REM**
'
'******** Do Housekeeping (Variables,
        etc.) **************
'add is the parallel port address.  r() are
        all possible values of
'the four resistors switched in combination
        by the CD4066.
'xsupply1 produces 00000000.
        xsupply1+xsupply2 produces
        11111111
'
DEF SEG = 64: DEFINT A-T: add = 888:
        DIM a(7), r(15)
FOR i = 0 TO 7: a(i) = 2 ^ i: NEXT
disp$ = CHR$(204): d$ = STRING$(4,
        205) + CHR$(206)
FOR i = 1 TO 9: disp$ = disp$ + d$:
        NEXT i
disp$ = disp$ + STRING$(4, 205) +
        CHR$(185)
r(1) = 100: r(2) = 220: r(3) = 69: r(4) = 470
r(5) = 83: r(6) = 150: r(7) = 60: r(8) = 1000
r(9) = 91: r(10) = 180: r(11) = 64: r(12) =
        319
r(13) = 76: r(14) = 130: r(15) = 57
xsupply1 = 1.54: xsupply2 = 2.61
'
'******** Housekeeping Done, Program
        Starts Here *********
'
programloop:
COLOR 7, 1: CLS : LOCATE 1, 21:
        PRINT "PcGSR Biofeedback
        Monitor (Version 4.1)"
LOCATE 2, 1: PRINT STRING$(80, 223);
COLOR 7,0: FOR i= 8 TO 12: LOCATE i,
        6: PRINT SPACE$(69): NEXT i
LOCATE 8, 6: PRINT CHR$(218);
        STRING$(67, 196); CHR$(191)
FOR i = 9 TO 11: LOCATE i, 6: PRINT
        CHR$(179); TAB(74);
        CHR$(179): NEXT i
LOCATE 12, 6: PRINT CHR$(192);
        STRING$(67, 196); CHR$(217)
COLOR 2, 1: LOCATE 16, 26: PRINT
        "Press <Esc> To End
        Monitoring";
COLOR 7, 1
'
'******** Initialization Begins
        **************************
'Take a reference reading with the 100K
        resistor.  From that, calculate
'the probe resistance, rx.  From that, see
        which of the 15 ref resistor
'combinations come closest to start at mid
        range.  Set the mask as the
'resistor number * 16 (ex: r(4) mask is
        4*16 or 64) to be sent to port
'pins 6-9.  Use that resistor to take a
        baseline average of 5 readings.
'
baseline = 0: jsum = 0: delta = 9999:
        mask = 16: rref = 15
LOCATE 10, 28: PRINT "Initializing .";
OUT add, 1 + mask
start! = TIMER
WHILE (TIMER - start!) < .1: WEND
OUT add, 0 + mask: OUT add, 2 + mask:
        OUT add, 0 + mask: OUT add,
        2 + mask
j = 7
 WHILE j > -1
  OUT add, 0 + mask: OUT add, 2 +
        mask
  jsum = jsum + (INP(add + 1) AND 64)
        * a(j)
  j = j - 1
 WEND
vx = ((jsum / 64) * xsupply2) / 255 +
        xsupply1: rx = vx * 100 / (5 - vx)
FOR i = 1 TO 15
 IF ABS(rx - r(i)) < delta THEN delta =
        ABS(rx - r(i)): rref = i
NEXT i
mask = rref * 16: jsum = 0
FOR i = 1 TO 5
 OUT add, 1 + mask: PRINT " .";
 start! = TIMER
 WHILE (TIMER - start!) < .04: WEND
 OUT add, 0 + mask: OUT add, 2 +
        mask: OUT add, 0 + mask:
        OUT add, 2 + mask
 j = 7
  WHILE j > -1
   OUT add, 0 + mask: OUT add, 2 +
        mask
   jsum = jsum + (INP(add + 1) AND 64)
        * a(j)
   j = j - 1
  WEND
 baseline = baseline + jsum / 64: jsum =
        0
NEXT i
baseline = baseline / 5: IF baseline = 0
        THEN baseline = 1
'
'******** Main Monitoring Starts Now
        ********************
'f is map for appropriate resistor(s).  1 +
        mask brings CS* high.
'2 + mask pulses Clk hi, with resistor
        selected and CS* low
        (enabled).
'0 + mask pulses Clk lo, with resistor
        selected and CS* low.
'jsum is 64 or 0.  At end, divide results by
        64 to get 1 or 0.
'
start:
jsum = 0: jsumtotal = 0
FOR i = 1 TO 5
 OUT add, 1 + mask
 start! = TIMER: WHILE (TIMER - start!) <
        .08: WEND
OUT add, 0 + mask: OUT add, 2 + mask:
        OUT add, 0 + mask: OUT add,
        2 + mask
 j = 7
  WHILE j > -1
   OUT add, 0 + mask: OUT add, 2 +
        mask
   jsum = jsum + (INP(add + 1) AND 64)
        * a(j)
   j = j - 1
  WEND
jsumtotal = jsumtotal + jsum / 64: jsum =
        0
NEXT i
jsum = jsumtotal / 5
'
'******** Print Results Of The Scan
        **********************
'
COLOR 8, 0
LOCATE 9, 15: PRINT "+5   +4   +3   +2
        +1   0   -1   -2   -3   -4   -5"
COLOR 7, 0: LOCATE 10, 9: PRINT
        "TENSE"; TAB(16); disp$;
        TAB(68); "CALM"
COLOR 9, 0: delta = ((jsum - baseline) /
        baseline) * 100 + 25
SELECT CASE delta
  CASE IS <= 0
   delta = 0: COLOR 4, 0
  CASE 0 TO 24
   COLOR 4, 0
  CASE IS > 49
   LOCATE 10, 66: PRINT CHR$(219); "
        CALM": GOTO donemonitoring
END SELECT
x$ = "t240l12n" + STR$(64 - delta): PLAY
        x$
LOCATE 10, 16 + delta: PRINT
        CHR$(219);
a$ = INKEY$: IF a$ = "" THEN GOTO
        start
IF ASC(RIGHT$(a$, 1)) <> 27 THEN
        GOTO start
'
'******** Done Monitoring.  Decide What
        To Do Next *******
'
donemonitoring:
COLOR 10, 1: LOCATE 16, 26
 PRINT SPACE$(3); "Monitoring Session
        Ended"; SPACE$(3)
COLOR 15, 1: LOCATE 18, 20
 PRINT "<Enter> for Another Session,
        <Esc> to End...";
optionselect:
a$ = INPUT$(1): a = ASC(a$)
SELECT CASE a
   CASE IS = 13
    GOTO programloop
   CASE IS = 27
    VIEW PRINT: CLS : LOCATE 18, 1:
        END
   CASE ELSE
    BEEP: GOTO optionselect
END SELECT
```

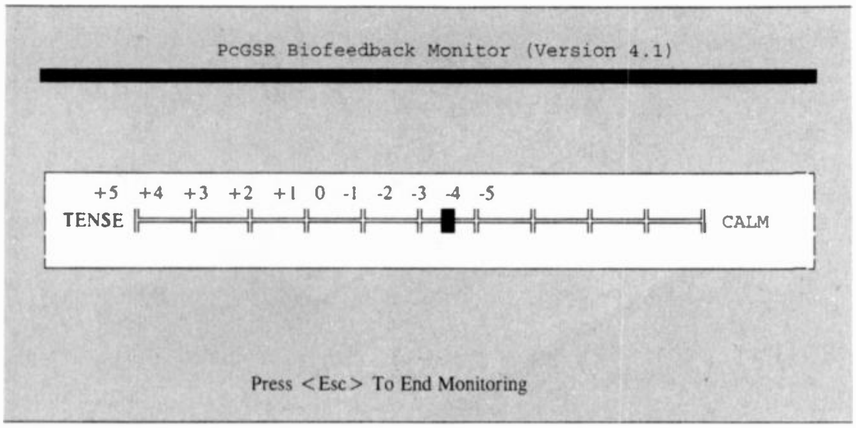


Fig. 2. The QBasic program for the Stress-A-Bater displays this moving dot across a horizontal scale showing how much stress a person is under. A beeping also sounds from the computer's speaker; the more tense you are, the higher the pitch of the beeping.

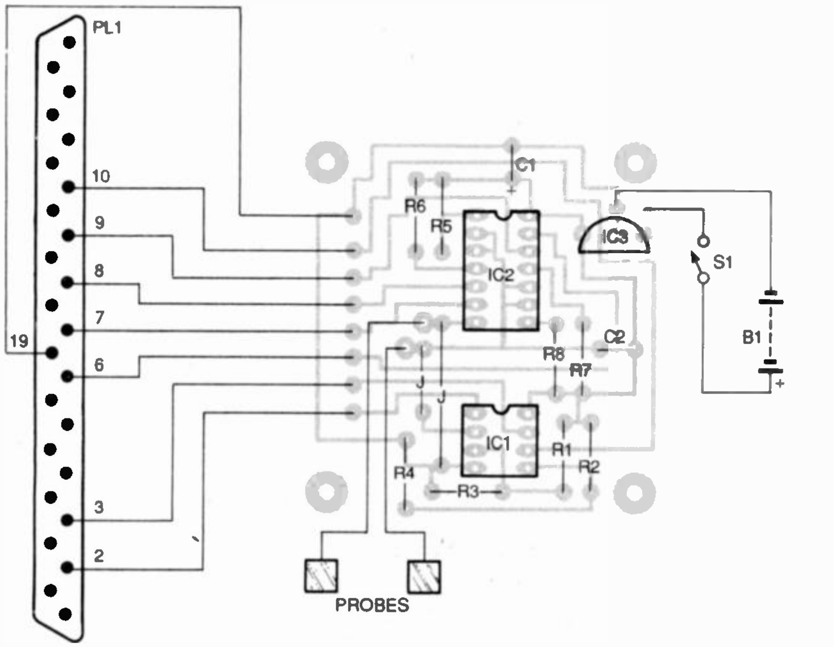


Fig. 3. Here's where the components are located on the PC board. Single-sided board design makes assembly easy—there is no worry about placed-through holes or solder connections on the top side of the board.

good a level of resolution because of IC1's ability to operate over an input range smaller than 5 volts, and the ability of IC2 to selectively set the fixed resistance in the input-voltage divider.

The control lines from IC2 for selecting the voltage-divider resistors, along with the control and data lines from the A/D converter, are connected with a length of ribbon or round cable to a male DB-25 connector. That allows the Stress-A-Bater to be hooked up to the printer port of an IBM or compatible PC for computer control and monitoring of biofeedback sessions.

Power from a 9-volt battery is regulated by IC3 to 5 volts. That 5-volt source powers IC1 and IC2, and also connects to all the voltage dividers (R1, R2, and R5–R8). It is very important to include C2 in the circuit. If C2 is left out, electrical noise will interfere with the A/D converter, causing erratic and unstable readings.

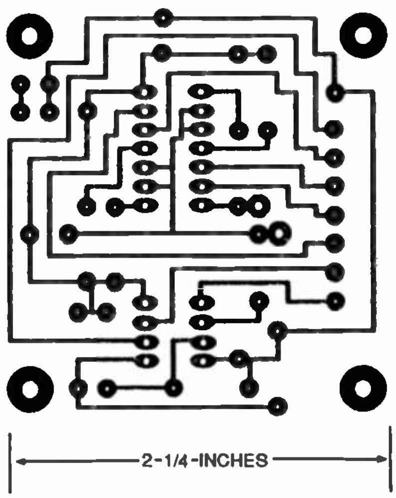
The Computer Program. Listing 1 is the source code for a simple biofeedback program that can be run under Microsoft QBasic. An enhanced version of the program, with better resolution, data logging, and results graphing is available from the source given in the Parts List. Each of the lines beginning with an apostrophe (') is a remark line. They have no program function—merely documenting certain aspects of the program. If you are typing in the program, you do not need to enter the remark lines.

The "Do Housekeeping" and "Housekeeping Done . . ." sections set up program variables and do initial formatting of the screen. Of special interest are the following statements:

```
add = 888
xsupply1 = 1.54
xsupply2 = 2.61
```

The variable *add* specifies the address of the parallel port you intend to use. The program listing sets that variable to 888, which is the decimal address number for LPT1. If you are going to use a different parallel port, you must change the value for the *add* variable to the proper address of the port to be used. The variables *xsupply1* and *xsupply2* are the voltages present at pins 3 and 5, respectively, of IC1. Based on the actual values of the resistors you use in the device, the voltage values will most likely be slightly different than what is mentioned here. You will need to measure those values, change the values assigned to *xsupply1* and *xsupply2*, and re-save the program before using it.

The "Initialization Begins" section uses the starting GSR of the person attached to the Stress-A-Bater to establish an initialization "baseline". As mentioned in the remarks lines for that section, an initial reading is taken after the 100,000-ohm resistor is



Here's the foil pattern for the Stress-A-Bater. Only 2 jumper wires are needed on this single-sided board.

switched into the circuit. That reading is used to calculate the person's current GSR across the probes. The program then figures out which of the available resistor combinations come closest to the person's current GSR. Finding the person's current GSR resistance reading will set the input voltage to IC1 at about mid range. Once that has been done, five readings are taken within a quarter second to obtain an average. That average is then used as the starting baseline. That approach minimizes any instantaneous GSR variations such as hand movement or changes in position of the probe's contact surfaces against the skin.

The "Main Monitoring" section uses a similar approach to obtaining monitoring samples. The variable *mask*, set during the "Initialization Begins" section, is the value that selects the appropriate resistor combination. To repeat what the remarks in the program listing say, that value is added to whatever data is to be sent out each time to the Stress-A-Bater to make sure that those resistors stay connected in the proper configuration. Just like in the initialization section, five samples are taken and averaged to minimize excess variations.

The averaged GSR value is displayed in the "Print Results Of The Scan" section. A typical screen display in Fig. 2 shows the stress measurement cursor positioned midway between 0 and -1 (moving towards the calm portion of the scale). In addition to the visual display, there is a continuous audio tone whose pitch is directly proportional to the displayed stress level. Lower stress levels lower the pitch of the tone, and higher stress levels raise the pitch. After the tone pitch is played, the following two lines check to see if you want to end the monitoring session:

```
a$ = INKEY$: IF a$ = "" THEN GOTO
        start
IF ASC(RIGHT$(a$, 1)) <> 27 THEN
        GOTO start
```

If no key, or a key other than the escape key (whose ASCII value is 27) is pressed, the program loops back to the label *start:* (in the main monitoring section) for the next sample. If the escape key was pressed (or the CALM level has been reached), the program goes to the "Done Monitoring" section. Here, you can press the enter key to start another monitoring session, or press the escape key to end the program.

Construction. Building the Stress-A-Bater is simple when using a single-sided PC board. After fabricating the board or obtaining one from the source mentioned in the Parts List, follow the placement diagram in Fig. 3 for location of the components. The orientation of polarized components C1 and IC1–IC3 should be followed carefully. Attach the black lead of a 9-volt battery clip to the hole marked "–", and the red lead to one lug of S1. The other lug of S1 is connected to the hole marked "+". The two jumper wires may be formed from twc excess capacitor or resistor leads. Solder all the parts into place.

Before connecting PL1 and the probes, decide what type of case you will be using to house the Stress-A-Bater. One inexpensive alternative is a case for holding 3½-inch floppy disks. Such cases can be found almost anywhere for around a dollar and are just the right size to house the PC board

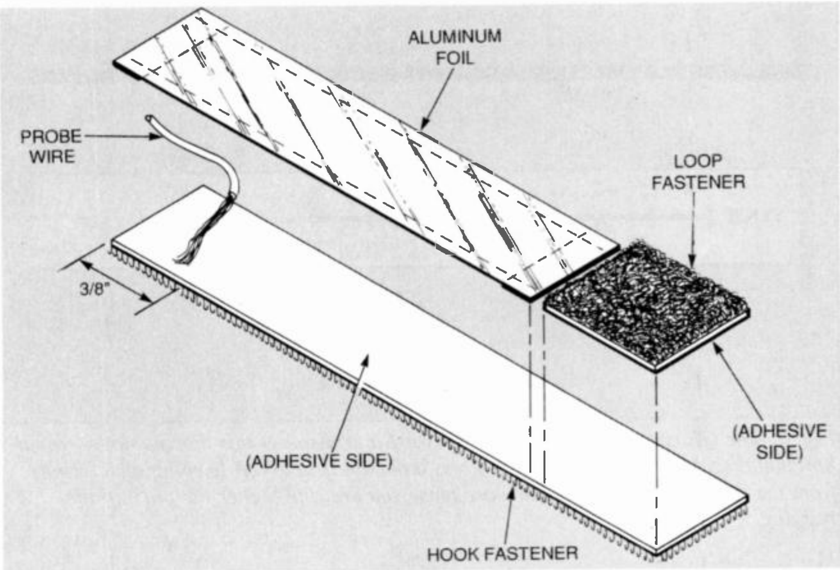


Fig. 4. Self-adesive Velcro-style hook-and-loop fasteners make assembly of the skin probes very simple. You could substitute a single layer of heavy-duty aluminum foil for the 2 layers of regular aluminum foil for the contact itself. With either type of foil, be sure to fold over the edges for added resistance to wear and tear on the probes.

PARTS LIST FOR THE STRESS-A-BATER BIOFEEDBACK MONITOR

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1—22,000-ohm
R2—2,200-ohm
R3, R4—10,000-ohm
R5—100,000-ohm
R6—470,000-ohm
R7—1-megohm
R8—220,000-ohm

CAPACITORS
C1—1µF, 16-WVDC, electrolytic
C2—0.1-µF, ceramic-disc

SEMICONDUCTORS
IC1-ADC0831 analog/digital converter, integrated circuit
IC2—CD4066 CMOS quad bilateral switch, integrated circuit
IC3—78L05 5-volt regulator, integrated circuit

ADDITIONAL PARTS AND MATERIALS
B1—9V battery
PL1—DB25 male connector and hood
S1—SPST switch
9-volt battery snap, printed-circuit board, hook-and-loop fasteners, household aluminum foil, 24-gauge two-conductor cable, 9-conductor multi-conductor or ribbon cable (see text)
NOTE: The following items are available from: James J. Barbarello, 817 Tennent Road, Manalapan, NJ 07726: Printed circuit board (GSR-PC), $10; Enhanced software with source code and executable file on 3.5-inch disk (GSR-S), $12; Complete kit includes printed-circuit board, all parts, case, wire, and enhanced software (GSR-K), $35. NJ residents must add appropiate sales tax.

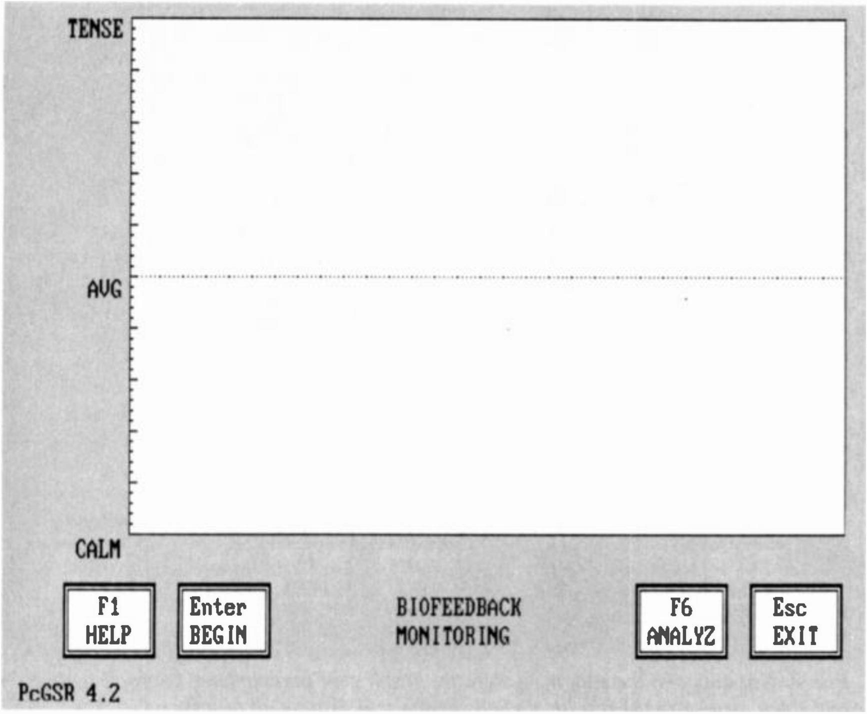


Fig. 5. The enhanced software from the source listed in the Parts List gives you greater detail in analyzing your indidividual stress-reduction sessions. Several different people can use the same program to store their individual sessions on disk for future reference.

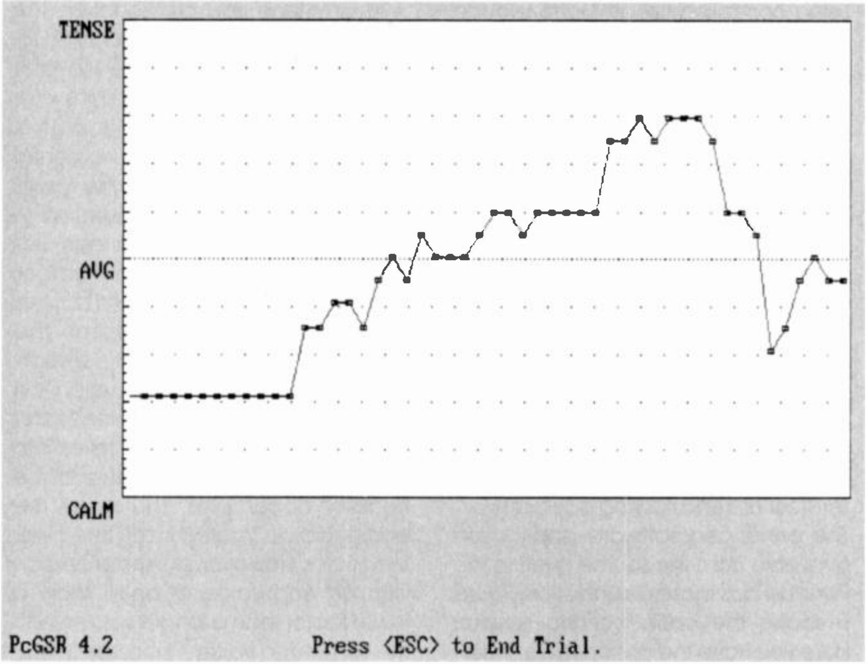


Fig. 6. After a session is done, the enhanced software graphs shows how you did. Time runs right to left, with the first reading of the session to the right, and the last reading of the session to the left. You can see in the example that the person started calming right away, but then tensed up and took a while to relax again. That may have been caused by readusting the sitting position.

and battery. One example is a Radio Shack 26-273 disk case. The PC board is mounted in the case with #4-40 × ½-inch machine screws and nuts. To hold the battery in place, a "Z" shaped bracket is bent from light aluminum and secured to the case with another #4-40 × ½-inch machine screw and nut. Two more #4-40 × ¼-inch machine screws are force-threaded into a pair of 3/32-inch diameter holes drilled in either side of the case to hold the two case-halves together. Choose where the computer and probe cables will exit the case and cut the appropriate openings. Pick a spot on the case where the on-off switch will be mounted and drill the needed holes.

You'll need a male DB-25 connector, along with a suitable length (4 to 6 feet) of seven conductor cable with ground wire, or a 9-conductor cable for PL1. You could also use a ribbon cable with a DB-25 male insulation-displacement connector (IDC) on one end as an alternative. The individual conductors on the free end of the ribbon cable can be separated for connection to the PC board. Thread the cable through the opening you made for it in the case, and wire the corresponding pads on the PC board to the cable wires using Figs. 1 and 3 as a guide.

Thread 4 to 6 feet of two-conductor cable for the probe cable through the appropriate opening in the case; 22-gauge or 24-gauge stranded audio-speaker "zip-cord" wire works well. If you're using that size zip-cord wire, a ⅛-inch diameter hole in the case will fit the wire just fine. Make sure there is sufficient wire in the case to allow it to be opened and closed easily when it comes time to change the battery. Tie two knots in the wire, one on either side of the case wall. Slip the knots snugly towards the case wall to form a strain relief. Solder the wire's conductors to the probe pads on the PC board. Either conductor may be soldered to either pad. Mount the PC board, the battery, and the switch to the case. Make sure the switch is in the off position.

The final construction step is to build the two skin probes and attach them to the unconnected end of the two-conductor wire. Get a piece of adhesive-backed hook-and-loop fastener. The hook portion contains evenly spaced rows of hooks, while the loop portion appears fuzzy. Cut one hook piece to 3 by ¾ inches, and one loop piece to ⅝ by ¾ inches. If you have large fingers, you might want to make the hook piece a bit longer than 3 inches. Remove the paper backing on both pieces, and following the layout in Fig. 4, stick the adhesive-backed sides of the loop piece onto one end of the adhesive-backed side of the hook piece. Separate the two conductors of the probe cable about 6 inches and tie a knot at the junction to ensure that the cable does not unzip any further. Strip 1 inch of insulation from the free end of one of the probe conductors. Curl the stranded wires into a circle and push them into the adhesive of the hook piece. Cut two pieces of common household aluminum foil to ⅝ by 1 inches. Place the two pieces together and fold over all four edges ⅛ inch so the final dimensions are 2⅜ by ¾ inches. Place the aluminum foil strip onto the exposed adhesive of the hook piece, covering the stranded wires. Build the second probe the same way.

Operation. Using the Stress-A-Bater is straight forward. Have your computer fired up and sitting at a DOS prompt. Connect the unit to whichever parallel port you will be using, and turn the unit on. Wrap one probe around the tip of the index finger of your left hand (if you are right handed), and secure it by overlapping the loop end of the probe. The wire should be under your fingerprint and stick out away from your hand. Apply the other probe to your middle finger in the same way.

Rest the hand with the probes on a solid surface so that there is no muscle tension in your hand or forearm. Keeping your hand still, start the program in Listing 1 with QBasic on your PC. After a few seconds, the initialization process will end, and the Stress-A-Bater will be reading your stress level. Watch the indicator and listen to the beeps. Concentrate on trying to lower the pitch of the beeps and move the indicator to the right (more calm). At first, you may find that the harder you concentrate on moving the indicator right, the more it will move to the left (more tense). That is perfectly normal at first. You just haven't created an effective biofeedback loop between the indicator and your thought processes.

To create that loop, start by becoming aware of your breathing pattern. Try taking long, deep breaths. Do that for a few minutes, and the indicator should begin moving to the right as you start to relax. That is the beginnings of a biofeedback loop. Continue doing that until you can no longer move the indicator any further to the right. Pressing the escape key or moving the indicator all the way to the right will end the session.

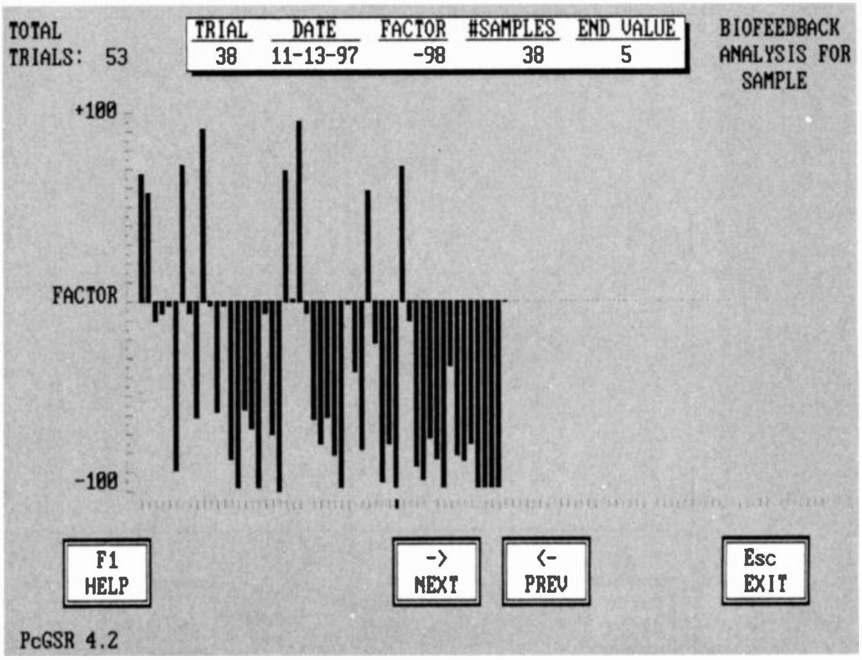


Fig. 7. Not only can the enhanced software graph your performance for each session but it can also store the results of each session and display all of them.

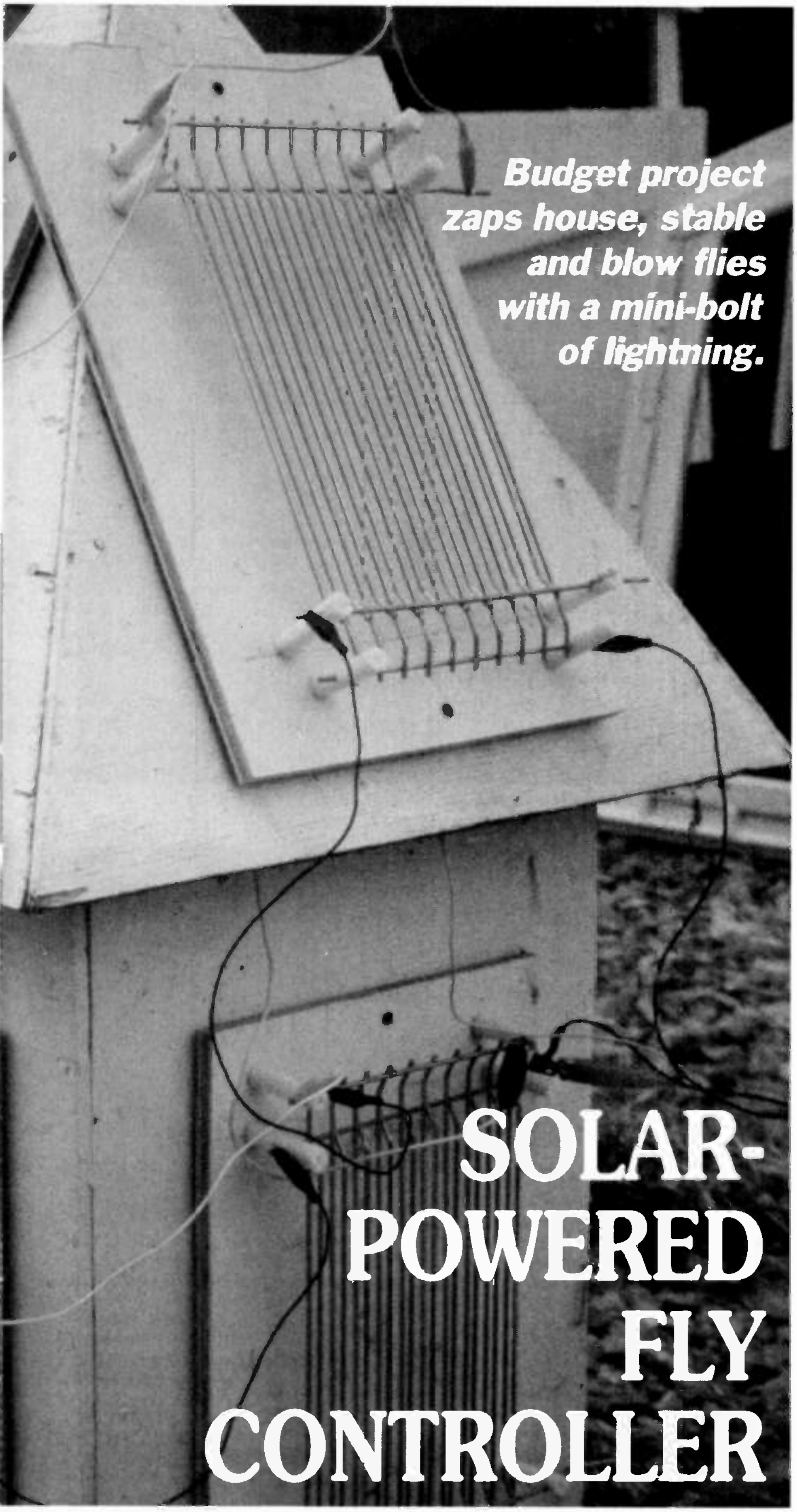
Once you become proficient at using controlled breathing to reduce tension, try moving on to visualization. In that process, you mentally picture scenes or bring forward thoughts that cause calming. As you discover one or more pictures or thoughts, use the Stress-A-Bater to help reinforce your ability to call them up and have them produce a calming effect on you.

The Stress-A-Bater will be most effective if you use it consistently over a long period of time. For instance, you might like to set aside 10 to 15 minutes each day for biofeedback sessions. If you choose to do that, you will probably want to keep a record of your various sessions, and have a better view of trends during each session. The enhanced software application available from the source gven in the Parts List has those capabilities. Figure 5 shows the main working screen. Here you have the option to get additional help on using the program, begin a biofeedback session, analyze your stored data from previous sessions, or exit the program. If you had just completed a monitoring session, an additional option to save the result of the session would also appear.

Figure 6 shows the results of a monioring session. The latest indication appears on the left of the graph as the previous results move to the right. To end the session, you press the escape key. You can then save the results to a named file.

At any time you can analyze the contents of your file. The display in Fig. 7 shows a file containing the results of 53 sessions. Up to 1000 sessions can be recorded in each individual's file. The cursor on the bottom horizontal indicator row is pointing to the results of session 38, which are detailed in the box at the top of the screen. Besides indicating the session number, the box also shows the system date of that trial, the session factor, the number of samples during the session, and the value that existed when the session was ended. The session factor is based on a formula that takes into account the ending value and the number of samples. The lower the ending value (more calm), the lower the factor. However, a shorter session with an end value of 5 will show a lower factor than a longer session with the same end value. This gives a relative measure of how long it took to come to a specific calm state. The best result is a session factor of -100.

The example in Fig. 7 shows that there were periodic excursions into the plus zone, indicating that whoever was using the Stress-A-Bater had trouble reaching a calm state during those sessions. The analysis function can help pinpoint stress causing events on different days that would not otherwise be obvious. Ω



SOLAR-POWERED FLY CONTROLLER

Budget project zaps house, stable and blow flies with a mini-bolt of lightning.

LAWRENCE PICKENS

FLIES ARE A GREAT ANNOYANCE AND a health problem for man and beast. Flies breed in garbage cans, dumpsters, compost piles, and kennels, just to name a few sites. Most comon solutions to eliminate flies have their own problems. For example, chemical insecticide sprays can be applied to surfaces, and poisoned fly bait can be spread around the garbage cans, but both are environmentally unsafe, and they are not effective against every species of fly. Also, the poisons must be re-applied at regular intervals, compounding the pollution problem.

What is needed to keep the fly population down at breeding sites is a continuously working device that is environmentally safe; effective against house flies, stable flies and blow flies; and that requires limited maintenance. The Solar-Powered Fly Controller presented here is an effective fly-zapping device that you can build. It has a high-voltage electric grid that electrocutes flies that alight on it. Its advantage over commercial electric flying-insect traps is that it is driven by battery or solar power. Commercial units are powered by line current and are unsuited for use in backyards or other outdoor areas that are remote from power lines.

The controller's circuit is turned on or off either manually or automatically. A photoelectric cell automatically turns the controller off at night and during dense cloud cover that usually brings rain.

The controller remains in the off state until the ambient light is sufficient to cause the unit's phototransistor to restore power to the controller. The controller provides high-voltage pulses at one or two-second intervals in order to conserve battery life. The solar power feature provides power to drive the controller and keep the battery in an excellent charge state. The controller develops a peak-to-peak, high voltage of at least 3,000 volts that can jump across a 3-mm gap when a fly

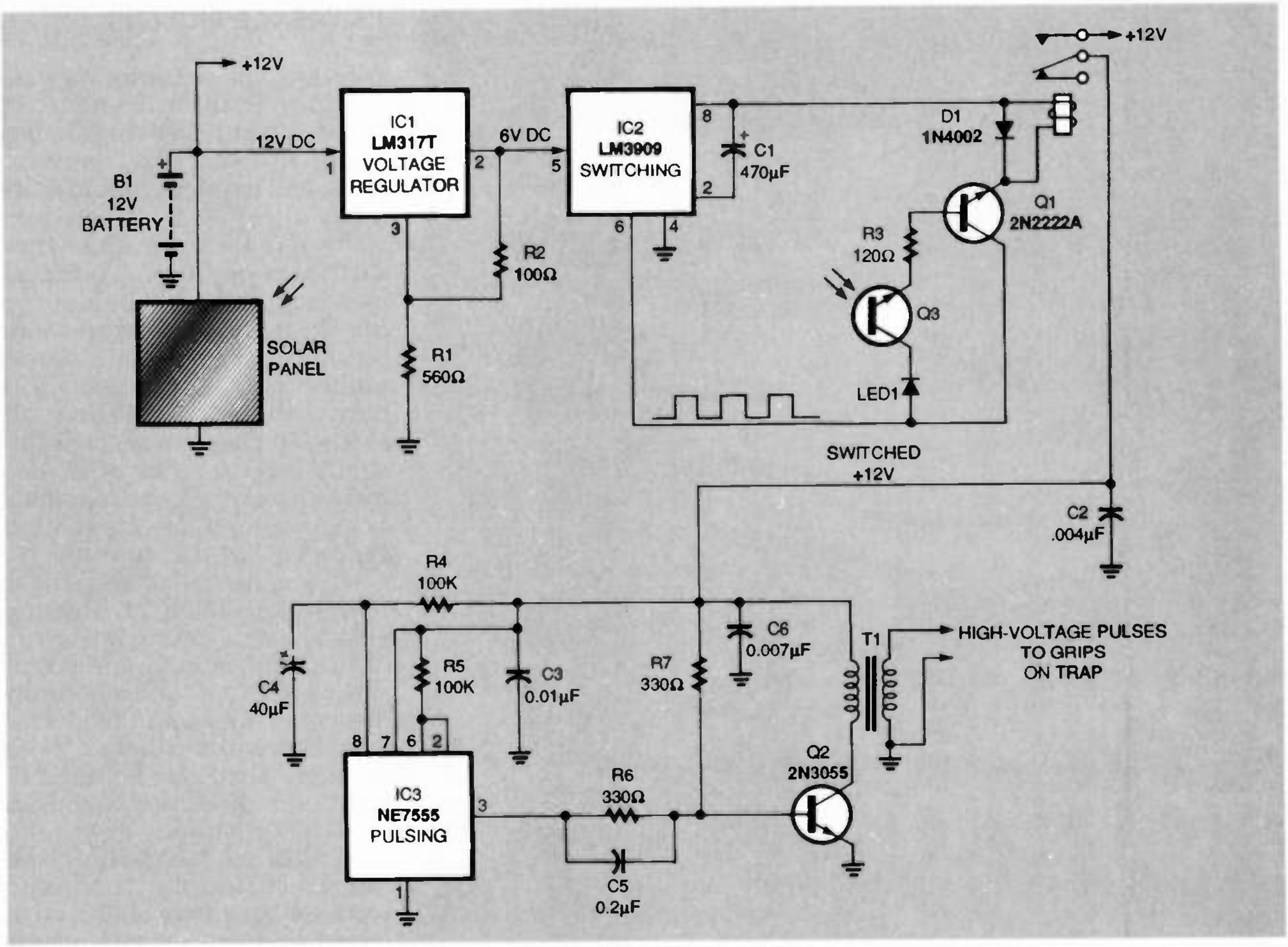


FIG. 1—SCHEMATIC DIAGRAM of the solar-powered fly controller is surprisingly simple.

alights in the gap. The high-voltage discharge current is below 8 mA which is considered safe for humans. Nevertheless, it is wise for humans to stay clear of the grid because an accidental shock may cause a person to involuntarily jump or slip into an obstacle and injure themselves.

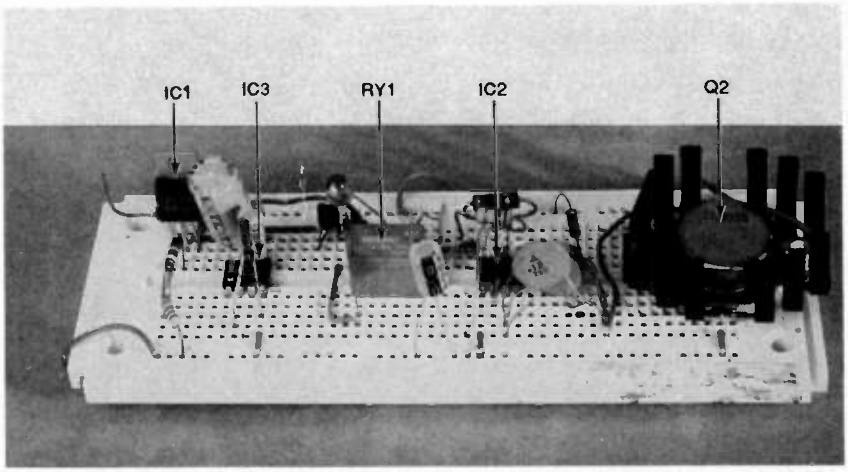


FIG. 2—PARTS PLACEMENT for the Solar-Powered Fly Controller is not critical. The ignition coil, T1, grids, and power source are located off the circuit board. Once the circuit is tested and functioning normally, move part by part to a matching PC board and solder in place.

The circuit

The circuit for the solar-powered fly controller is shown in Fig. 1. It consists of a switching circuit, pulsing circuit, and a high-voltage output circuit. The external power components are a 1- to 5-watt solar panel and a 12-volt motorcycle or camcorder battery. The output of the high-voltage ignition coil connects to a network of paralleled electrodes, called a grid, upon which flies land and are destroyed.

Voltage input to the LM3909 LED-flasher/oscillator (IC2) is kept at 6 to 9-volts by a LM317T voltage regulator (IC1). The exact voltage is not critical as long as it is regulated. The LM3909 produces a series of pulses that are coupled to a 2N2222A transistor (Q1) to form a switching circuit. An output of positive pulses from IC2 to the 2N2222A transistor boosts the pulse current so that it closes a 5-volt relay (RY1) for approximately 0.1 second at intervals of 1 to 2 seconds. Diode D1 shunts out

PARTS LIST FOR SOLAR-POWERED FLY CONTROLLER

All resistors are 1/4-watt, 5% units.
R1—560 ohms
R2—100 ohms
R3—120 ohms
R4, R5—100,000 ohms
R6, R7—330 ohms

Capacitors
C1—470 µF, 25 volts, electrolytic
C2—0.004 µF, 25 volts, electrolytic
C3—0.01 µF
C4—40 µF, 25 volts, electrolytic
C5—0.2 µF
C6—0.007 µF, 100 volts

Semiconductors
D1—1N4002 diode
IC1—LM317T voltage regulator
IC2—LM3909 LED flasher
IC3—NE7555 or NE555 timer
LED1—Red LED
Q1—2N2222A switching transistor, NPN
Q2—2N3055 power amplifier, NPN
Q3—KTN2222 infrared phototransistor, NPN (Radio Shack 276-145 or equiv.)

Additional Parts And Materials
B1—12-volt deep-cycle battery
RY1—5-volt relay, single-pole, double-throw (Radio Shack 275-240 or equiv.)
1—12 volt type "T" or "CD" automobile ignition coil
1—13.8-volt, 1-watt photo-voltaic panel
1—6-inch modular solderless breadboard (Radio Shack 276-174 or equiv.)
1—6-inch modular PC board (matches solderless breadboard, Radio Shack 276-170 or equiv.)
Weather-tight automobile battery storage case, TO-3 heat sink, conductive-foil tape, wire, glossy- white boards or plastic panels, lumber for trap construction

Sources of some materials
Automobile ignition coil obtainable from J. C. Whitney Co., 2233 S Throop St., Chicago, IL, 60608 or most automotive parts store.
Solar panels obtainable from Edmund Scientific Co., 101 Gloster Pike, Barrington, NJ 08007-1380; from H & R Co., 18 Canal St., P.O. Box 122, Bristol, PA 19007-0122; and Integral Energy Systems, 109 Argail Way, Nevada City, CA 95959.

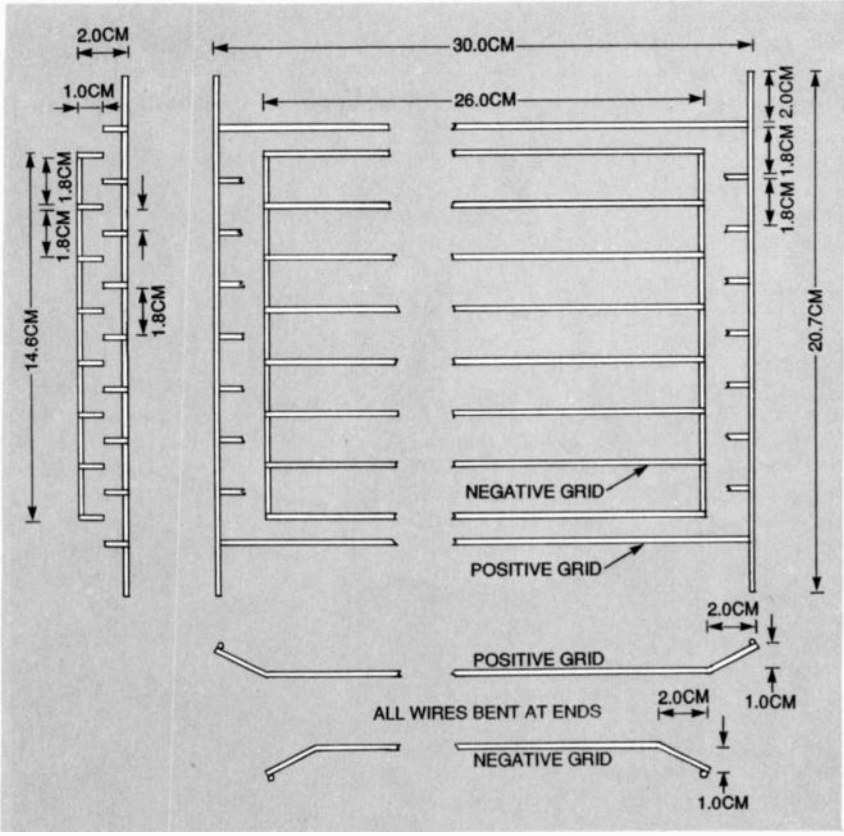


FIG. 3—THE GRID for the solar-powered fly controller is fabricated from stiff wire that can be assembled with solder, braising material, or by welding. No. 12 solid copper wire without insulation is a good choice. It forms easily and solders well with a 100-watt iron. (Note: 2.54 cm equals 1.0 inch.)

high-voltage spikes produced by the switching voltage across the relay's coil. The switching circuit is turned off at night or during periods of heavy cloud cover by phototransistor Q3 whose internal resistance increases as the ambient light diminishes. This reduces the positive bias on Q1's base, causing the transistor to cut off. LED1 serves as a voltage dropping device.

Single-pole, single-throw relay RY1 provides brief pulses of the 12-volt battery voltage to IC3, an NE755 timer that is wired as a free-running audio-frequency pulse generator. The pulses are amplified by a 2N3055 power amplifier transistor, Q2. The output of Q2 drives an automobile ignition coil, T1, to generate the high-voltage pulses for the external grid. The output voltage at the secondary winding of T1 is approximately 12,000-volts peak-to-peak.

The circuit is powered by a 12-volt rechargeable lead-acid or nickel-cadmium battery. A 1-watt or better solar panel of the type used to keep automobile batteries charged should be used to eliminate the need to recharge the battery frequently. Many different solar panels are available on the surplus market where the price is considerablly less than buying new for catalog suppliers.

Building the controller

The parts for the controller first are assembled on a soldereless breadboard with the 12-volt battery, solar panel and ignition coil off the board. Install C6 as close to the T1 primary winding as possible. Power the unit up and be sure the circuit is functioning. Check for a spark at the center terminal of the ignition coil.

Remove the parts one at a time and mount them on a matching PC board. Figure 2 shows the author's layout on a solderless board. Put the wired

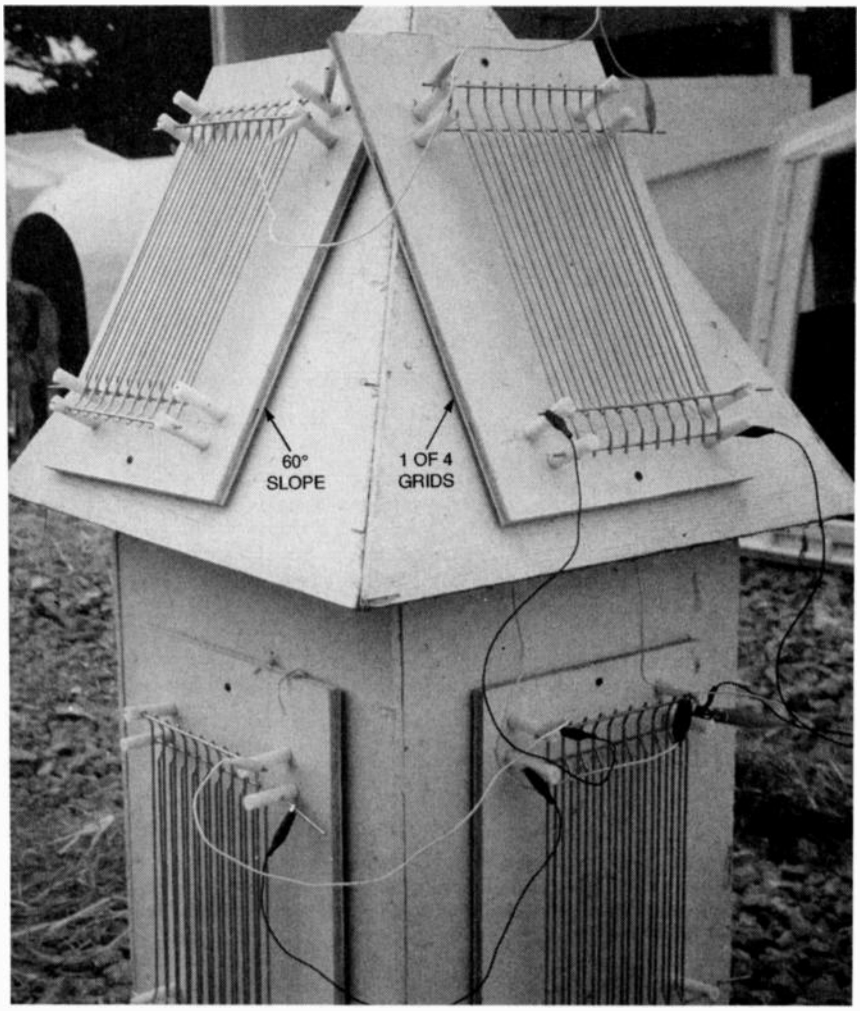


FIG. 4—THE GRIDS ARE MOUNTED on a box form, called a trap, (each controller can support up to four grids), that houses the controller and rechargeable battery. The solar cells may be mounted on a short mast and sloped to catch the maximum sunshine available.

FIG. 5—VIRTUALLY ANY automobile ignition coil can be used for T1.

PC board aside until it is needed.

The high-voltage grid

The grid is made up of two comb-like elements (Fig. 3) which are spaced 5 mm apart from edge to edge. (Note: 25.4 mm equals 1.0 inch.) The grid elements can be constructed from 16 gauge wire (i.e. a coat hanger), from conductive foil, or from a combination of foil and wire. A good alternative is #12 bare, solid, copper wire used by electricians to wire houses.

The grid should be mounted on high-gloss white wooden or plastic panels and the panels should be mounted either vertically or with a sixty degree slope from the horizontal (see Fig. 4). Porcelain standoffs electrically isolate the grid from the panels that could become conductive when wet. The terminal for the case of the transformer T1 (if it has one) is grounded to earth as is the negative input of the primary and secondary windings. One terminal of the grid is connected to the same common ground. The high voltage line from the secondary winding is attached to the other grid terminal. One controller circuit can easily power four grids.

Operation of the trap

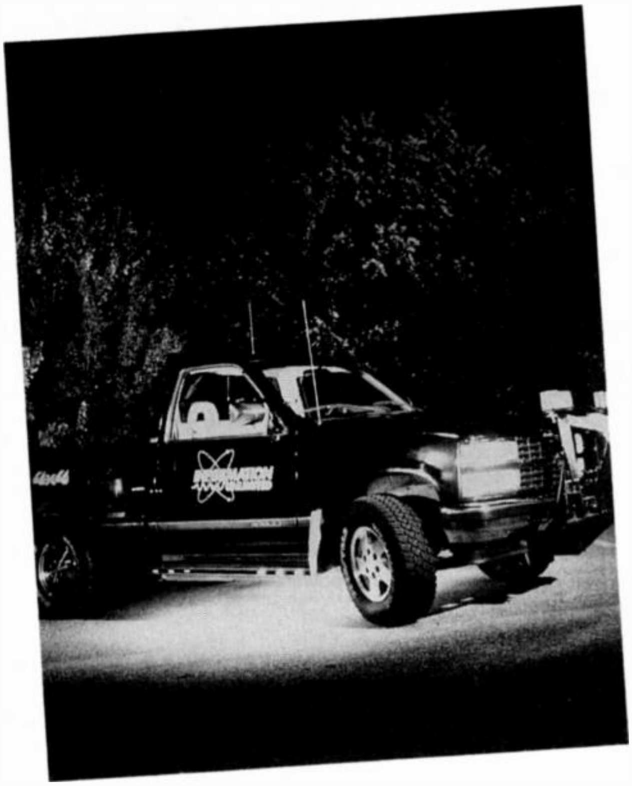
To eliminate flies, place four grids on a specially constructed stand as shown in Fig. 4. This configuration is called a trap. The slope of the grids mounted at the top of the trap is sixty degrees from the horizontal. The grids are mounted on adjacent surfaces of the trap. Place one trap to the north, and one to the east of places where flies gather. Good spots are at the eastern ends of buildings which house animals, near dog kennels, and near garbage cans or dumpsters. For best results, check the traps once a day and remove any insects or debris which have become lodged in the grids and are shorting the grid.

Safety concerns

Although the current available at the controller's grids is very small, the voltage is high enough to jolt a person. Therefore, power to the controller should always be turned off before handling any part of the circuit or grids. Also, the device should not be used where children can reach it. A high-voltage warning sign will keep curious adults away.

The solar-powered fly controller shown in the photographs has been in use for five years to control flies around kennels, garbage cans and in animal pastures. Several controller circuits and traps have been assembled and put to use at indoor and outdoor locations. None had any down time because of malfunction. If sufficient sunlight and an adequately sized solar panel are present, the batteries will remain charged for the life of the trap. Ω

AUTOMOTIVE NEON



Build this driver circuit to illuminate your car's license plate, light up its underside for a glamorous "spaceship" look, or just create portable neon or argon light displays.

ROBERT IANNINI

JOIN THOSE PEOPLE WHO enjoy customizing their cars by adding a lighted frame to their license plates or illuminating the undersides of their cars in red, green, or violet to give it a "hovering spacecraft" look. This article focuses on the construction of a complete illuminated frame system for your car's license plate, but the battery-powered gas tube driver circuit described here will permit you to light up individual gas tubes mounted on the underside of your car.

The driver circuit will light up neon-filled tubes that glow with a rich ruby red or argon-filled tubes that can be prepared to glow in brilliant green, violet, or pink. If neither of those projects interest you, maybe you would be interested in making up battery-portable illuminated wands, signs, or arrows for parties, festivals or perhaps you'll build it just as unusual eye-catching home decoration?

The driver circuit

The driver circuit ionizes and sustains the illumination of neon or argon gas-filled tubes up to four feet long bent into any shape desired. The tube will remain illuminated as long as power is applied to the circuit. However, the driver circuit permits the tube's illumination level to be adjusted to maximize brightness or reduce brightness to conserve power depending on which is more important.

The driver circuit is a pulse-width modulation circuit that can illuminate a neon or argon gas tube in either a continuous or flashing mode. In that mode, the tube will blink on and off at an adjustable rate that permits it to act as an emergency beacon. The circuit is also suitable for driving battery-portable gas tubes fashioned as signs or wands for carrying around at carnivals or using as decorative conversation pieces.

A note of caution

It is illegal in *all* states to drive a car with an illuminated license plate frame that flashes while the vehicle is moving. However, the frame can serve as an attention-getting emergency beacon if the vehicle is stopped.

Also, it is illegal in at least one state to have an illuminated license plate frame on a car unless the gas tube is so masked that only the light reflecting from the plate is visible to the driver of any vehicle that is following behind the car with the lighted frame.

How the driver works

Refer to the schematic Fig. 1. An industry standard bipolar 555 timer, IC1, is configured as a duty cycle clock to control the on and off time of the circuit's high-frequency oscillator. With C2 switched into the circuit by switch S1, the output at pin 3 of IC1 will be a square wave with a duty cycle or pulse rate that is fast enough to sustain continuous illumination of the gas-filled tube.

Adjusting trimmer potentiometer R1 changes the brightness of the gas tube by altering the on-to-off ratio or the duty cycle of the squarewave that appears at the output of pin 3 of IC1. The squarewave output of IC1 appears at the base of NPN transistor Q1, which functions as a buffer amplifier. The output of Q1 then appears at the base of grounded-emitter NPN transistor Q2, which functions as the feedback element in a free-

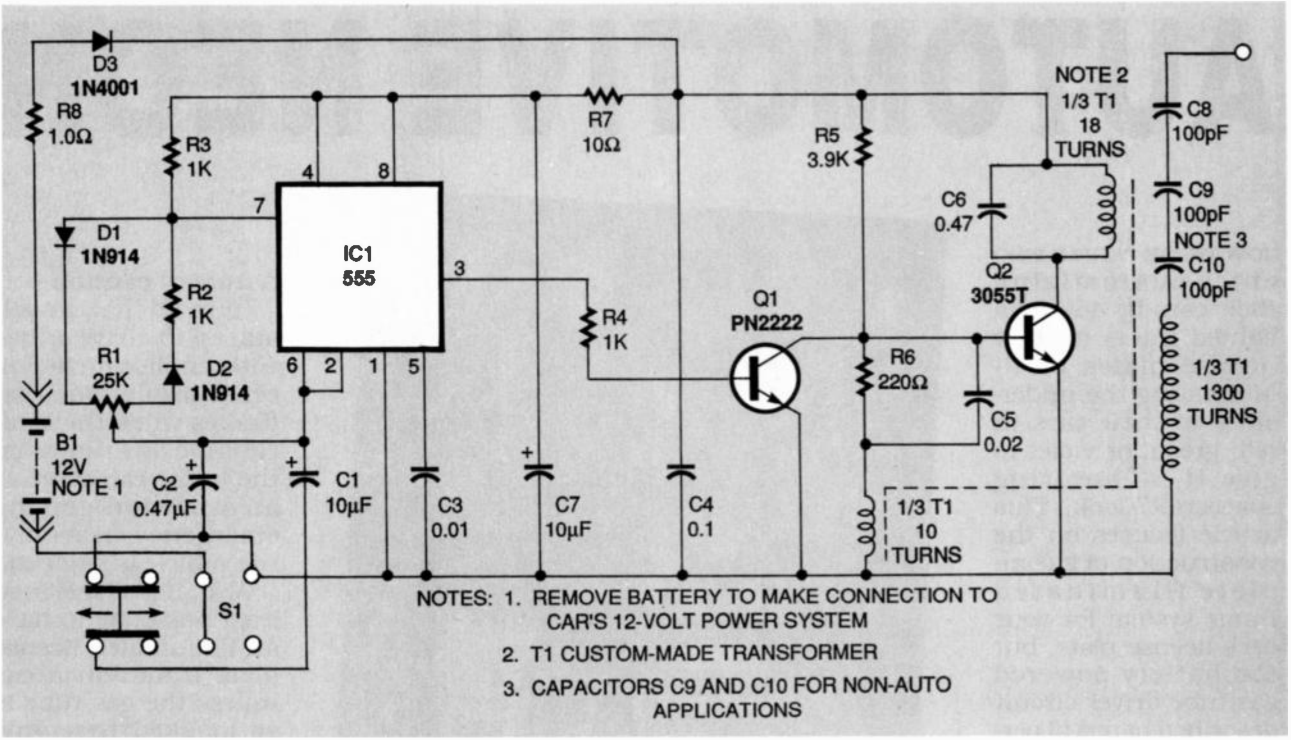


FIG. 1—DRIVER CIRCUIT SCHEMATIC. The circuit can be powered either from a battery pack or vehicle's 12-volt power system.

running oscillator circuit. Transistor Q1 acts as the switch to turn transistor Q2 on and off by clamping the transistor's base to ground.

The oscillator oscillates at a frequency of 25 to 30 kHz, and the output voltage at the top of the 1300-turn coil of T1 is approximately 2500 volts, peak-to-peak, sufficient to ionize the gas in the tube. The duty cycle pulse of IC1, as buffered by transistor Q1, controls the base of transistor Q2. The tank circuit that determines oscillator frequency, consists of capacitor C6 and the 18-turn primary coil of transformer T1.

Changes in the duration of the "on" cycle change only the brightness of the gas tube but do not affect the frequency of the oscillator. High-voltage ceramic capacitors C8, C9 and C10 correct for differences in the length of the gas tube being driven.

If switch S1 is set to the *flashing* mode, capacitor C1 is placed in parallel with capacitor C2, and the sum of their capacitive values will shorten the repetition rate of the squarewaves appearing at pin 3 of IC1. This will cause the tube to flash on and off at a rate slow enough to be seen as flashing (less than 50 pulses per second). The flashing time rate can be changed to a visually comfortable level by adjusting trimmer potentiometer R1.

Building the driver circuit

Whether you plan to operate the driver only from the battery pack or directly from an automotive 12- to 14-volt supply, it is recommended that provision be made to operate the circuit from the battery pack for testing.

If the illuminated frame is to be used on a vehicle (regardless of power source), attach a heatsink to the copper tab on the TO-220 case of transistor Q2. Omit capacitors C9 and C10 if you intend to install the system in a vehicle.

The driver circuit can be built on perforated board by point-to-point wiring method. Cut a 3¼ × 1⁵⁄₁₆-inch rectangle of pre-punched circuit board (0.042-inch diameter holes in a 0.1-inch grid. With the exception of the high-voltage capacitors C8, C9 and C10 and transformer T1, all components are readily available items.

If you do not want to wind your own miniature transformer, you can purchase one from the source given in the Parts List. The neon or argon frame and plate cover assembly referenced in this article is also available from the same source. Also the high-voltage capacitors C8, C9, and C10 are available in a kit.

Refer to Parts Placement diagram Fig. 2. Before starting assembly work, cut out a rectangular relief hole in the circuit, as shown by the dotted line, to make wiring slide switch S1 easier. If you intend to install the system in a car, attach a heatsink to the tab of transistor Q2 before inserting it.

Insert all components in the approximate positions shown on Fig. 2. Insert all components in the approximate positions shown. Insert all axial-leaded resistors and diodes marked with an asterisk vertically to conserve circuit board space. A snap-on heatsink suitable for a TO-220 package is, but a satisfactory substitute can be made by cutting and folding a piece of 0.062-inch thick sheet aluminum 1 × 1½ inches. Drill a small hole in its center for mounting it to the hole in the heat tab of transistor Q2 with a nut and bolt.

Carefully fold back one lead of all axial components shown as vertically mounted over the body of the component so that both leads can be inserted in holes spaced 0.10-inch apart. Observe the polarities of the diodes and electrolytic capacitors before inserting them and be sure that you have identified the pin functions of transistors Q1 and Q2 before inserting them in the board.

Insert and bend all leads first before doing any soldering so that extra lead lengths can be used to form the specified connections between components.

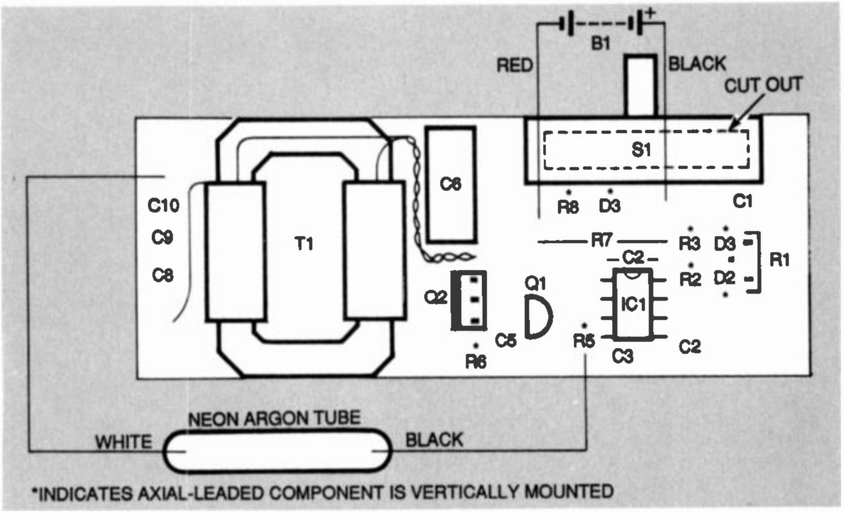


FIG. 2—DRIVER CIRCUIT PARTS PLACEMENT DIAGRAM. The circuit can be built by point-to-pont wiring on 0.1-inch grid perforated board. Transformer T1 is a non-standard component.

PARTS LIST

All resistors are ¼-watt, 10%, unless otherwise specified

R1—25,000 ohms, trimmer potentiometer, PC board mounting, carbon film
R2, R3, R4—1000 ohms
R5—3900 ohms
R6—220 ohms
R7—10 ohms
R8—1 ohm, ½-watt

Capacitors

C1, C7—10 µF, 35 volts, aluminum electrolytic, radial-leaded
C2—0.47 µF, 50 volts, aluminum electrolytic, radial-leaded
C3—0.01 µF, 50 volts, ceramic disc
C4—0.1 µF, 50 volts, ceramic disc
C5—0.02 µF, 100 volts, polyester
C6—0.47 µF, 100 volts, polypropylene, radial leaded
C8, C9, C10—100 pF, 3000 volts, ceramic multilayer, radial-leaded DIP (see text)

Semiconductors

IC1—555 timer, 8-pin DIP
Q1—2N2222, NPN bipolar transistor, TO-92
Q2—3055T NPN transistor, TO-220 package, National Semiconductor or equiv.
D1, D2—1N914 silicon diode
D3—1N4001 silicon diode

Other components

T1—transformer with 10-, 18-, and 1300-turn windings, (see text)
S1—slide switch, two-deck, three position (DP3T), PC mount, Mouser 10SL008 or equiv.

Miscellaneous: neon or argon gas tube frame assembly (see text); circuit board, (see text); circuit case (optional); 9-volt battery clip; eight-cell battery pack (optional); eight alkaline AA cells; No. 24 AWG insulated hookup wire; TO-220 heatsink, spade connectors, nut and bolt, solder

Note: Completely assembled systems, kits of parts, and individual parts for the neon/argon license plate frame with variable brightness and emergency flashing, are available from Information Unlimited: Box 716, Amherst, NH 03031, Telephone 1-603-673-4730; Fax 603 672 5406. Include $4 for shipping & handling per order. The following options are offered:

- Driver circuit transformer, T1 (28K087)—$9.50
- Printed-circuit board PC1—$4.50
- Kit of parts for system including all electronic components and PC board, but no gas tube or plastic frame (BATNEONK)—$19.50
- Ready-to-use aqua and purple neon tubes with plastic frames for flashing power supply (AQUA1)—$12.50; (PURP1)—$12.50
- Ready-to-install non-flashing purple license frame neon assembly (LICNPR)—$24.50
- Ready-to-install non-flashing green license-frame neon assembly (LICNGR)—$24.50
- High-brightness under-car neon assembly: Pink 4-tube kit (RG4K)—$124.50; Purple 4-tube kit (RG4L)—$124.50; Music driver for above kits (RG4M)—$39.50; Single tube kit (specify pink or purple) (RG1K)—$34.50

After soldering all components and trimming their leads, insert and solder the wires for the battery pack and vehicle's power system. Solder all the wires from transformer T1 to their specified terminal points. Connect and solder the hot and ground wires to the neon-tube frame assembly.

System assembly

Refer to assembly diagram Fig. 3. The neon or argon gas-filled tube has been bent to form a rectangle with an inside measurement of 11×5¼-inches so it can frame the license plates of all American and Canadian cars. The tube is embedded in RTV silicone within the lip around a transparent plastic cover that will protect the license plate.

Wires extend from both ends of the gas-filled tube for connection to the high-voltage output and ground wires of the driver circuit. Those wires can be soldered together or connected by soldering automotive spade-style connectors to their ends for more convenient connection and disconnection should it become necessary.

The battery pack needed for test purposes can also be the permanent power source, if desired. It consists of eight AA alkaline cells. If you intend to connect the system to a vehicle's electrical system, do it with approved automotive-style sol-

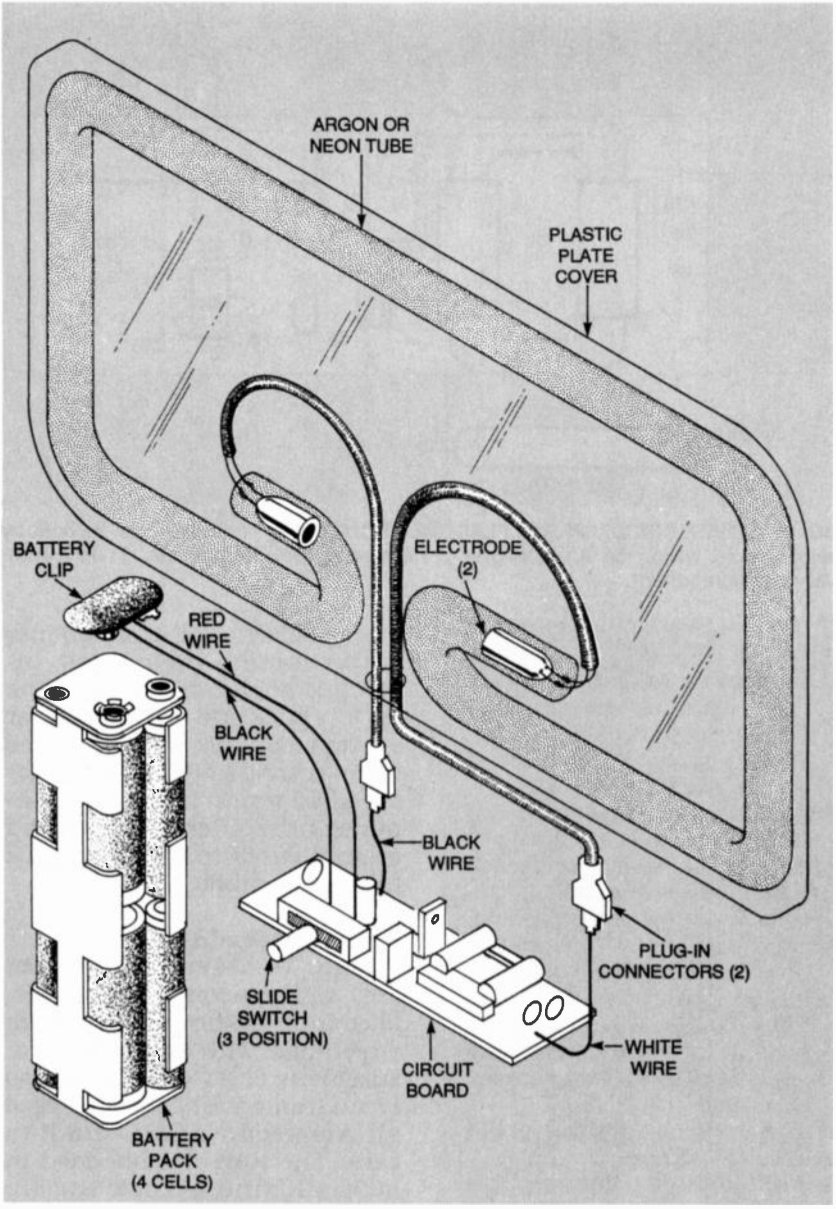


FIG. 3—NEON OR ARGON GAS TUBE LICENSE PLATE frame system showing driver circuit connections to the gas tube/ cover assembly.

derless connectors, and do as neat a job as possible.

After completing the driver circuit, it is recommended that the circuit be placed in a protective case to protect it from dust and moisture. A standard plastic project case is suitable. Drill or form holes in the case to permit the lever of slide switch S1 to be moved and permit the passage of external wires to the power source and the gas tube/ cover assembly.

Testing the system

Move the lever on the slide switch S1 to its full left OFF position. Place eight AA cells in the battery pack and snap the battery clip in position on the pack. Move the lever of S1 to the middle position and watch for ignition of the gas in the tube. Then move the switch to the right position and observe that the tube is flashing. If this does not happen, disconnect the battery power and examine the circuit for any error in parts placement or soldering and correct it.

The brightness of the glowing tube can be set by adjusting the wiper on trimmer potentiometer R1. This applies in both the continuous and flashing modes.

If the gas tube is to be run exclusively from the battery pack, you can expect about 10 hours of illumination from eight fresh alkaline AA cells before they must be replaced with a new set. Ω

STRIP CHART RECORDER

continued from page 45

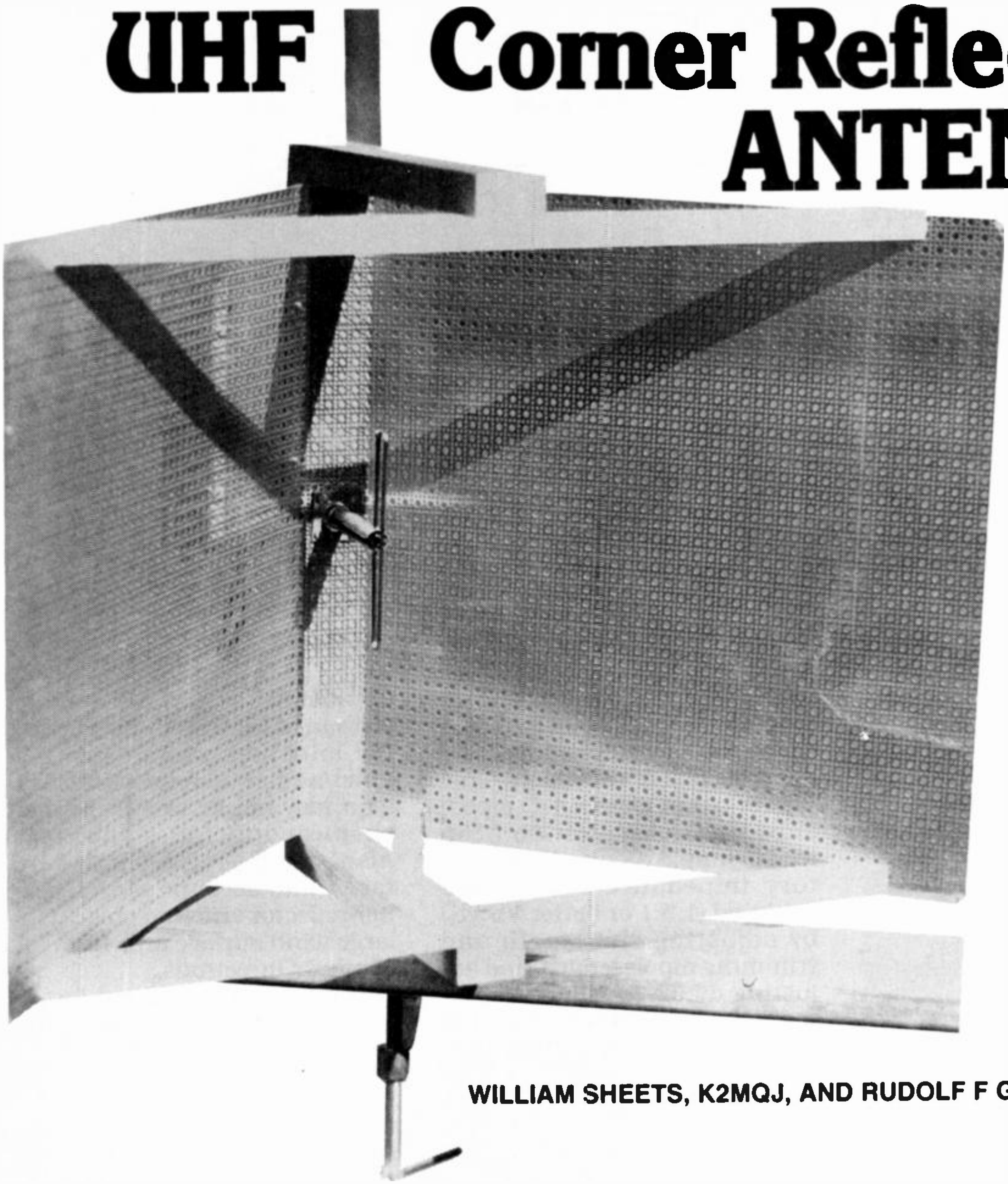
the recorder is to place a thermometer beside the temperature probe and mark pen positions and thermometer readings at various temperatures. Glue the marked-up calibration strip to a ruler or strip of plastic. You can then scale your charts by aligning the reference point on your ruler with the reference point on your chart.

Test the circuit by turning op-amp gain (R10) all the way up and setting S1 to Calibrate. The pen should move to the reference position and stop. If the carriage moves all the way to one side or the other, try reversing the wires going to the motor

If the carriage oscillates (hunts), gain is too high, so turn R10 down. When you get the drive working properly, switch to the thermistor, making certain that ambient temperature puts it within range of your chart recorder. Now verify the thermistor's resistance at different temperatures.

In addition to temperature, the author has recorded wind direction using a modified 10K potentiometer as a sensor. One planned experiment involves putting a probe in the ground and charting the relationship between soil temperature and tomato taste. If you come up with a novel project using an obsolete printer for a new purpose, let us know about it. A possible application idea is placing a signature on a check. There are other possibilities using otherwise obsolete computer components. Ω

UHF Corner Reflector ANTENNA



WILLIAM SHEETS, K2MQJ, AND RUDOLF F GRAF, KA2CWL

Obtain outstanding performance from a home-brew radiator built from readily-available parts and materials.

SCANNER ENTHUSIASTS, AMATEUR radio operators, and UHF experimenters are interested in simple antennas that are more effective than ground-planes and whips. You can build a high-performance UHF corner-reflector antenna that is compact and easy to tune using readily available materials.

A corner-reflector antenna provides good performance radiation for directional UHF work since it has 8 to 10 dB gain, is fairly easy to build, and has reasonable bandwidth of 5% to 20%. Also, the corner-reflector antenna exhibits a good radiation pattern and front-to-back signal ratio.

The corner-reflector antenna consists of a balanced half-wave dipole placed in front of a conducting surface that is folded with an angle of 90 degrees or less. As the angle gets smaller, the gain tends to increase but the antenna structure tends to get larger and the dipole feed impedance becomes lower. The dipole may be constructed with thick dipole elements to increase bandwidth. The spacing of the dipole from the reflector can be adjusted to optimize the feed impedance.

The gain of a corner-reflector antenna with a reflector surface of one to two wavelengths is typically 8 to 10 dB over an isotropic radiator. Antenna gain can be made 14 to 15 dB or more with a large reflector (greater than 5 wavelengths) and a narrow (45 degree or less) angle.

However this is mechanically impractical at frequencies below 1000 MHz.

Dipole operation

A dipole is a balanced antenna and should not be fed directly with coaxial cable. Doing so would cause the outer conductor of the coaxial line to act as part of the antenna, and a large amount of signal would be radiated or received by the outer conductor. For casual reception this may not matter much, but the directional radiation pattern of the antenna is destroyed and reception/transmission results are no longer predictable.

In order to derive a balanced feed for the dipole some sort of a transformer is necessary. For the corner reflector described here a slot-fed balun is used (see Fig. 1). This is accomplished by splitting the outer conductor (made from a brass tube) lengthwise for a quarter wavelength and connecting the inner conductor (a much smaller diameter tube or rod) to the end of one segment, and to one dipole element. The other segment is connected to the opposite half of the dipole. This type of balun gives a 4:1 impedance transformation and can feed a simple dipole. A satisfactory impedance match was achieved (1.5:1 or better VSWR) by adjusting slot length and trimming dipole length, and adjusting dipole-to-reflector spacing. Dipole-to-reflector spacing affects the dipole's impedance (see Fig. 2).

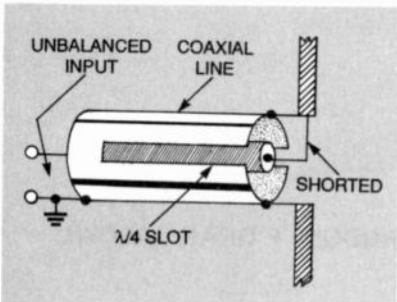


FIG. 1—METHOD FOR FEEDING a balanced dipole by a slot- fed balun.

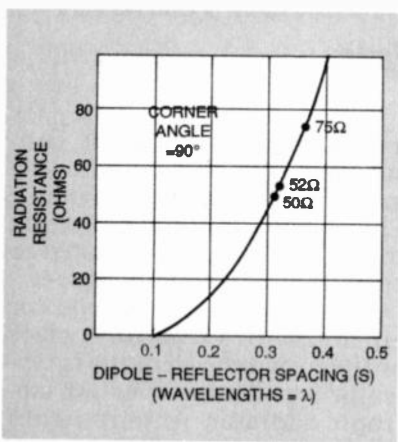


FIG. 2—PLOT OF RADIATION RESISTANCE in ohms vs. spacing of a dipole in wavelength from virtual apex of a 90° corner-reflector antenna.

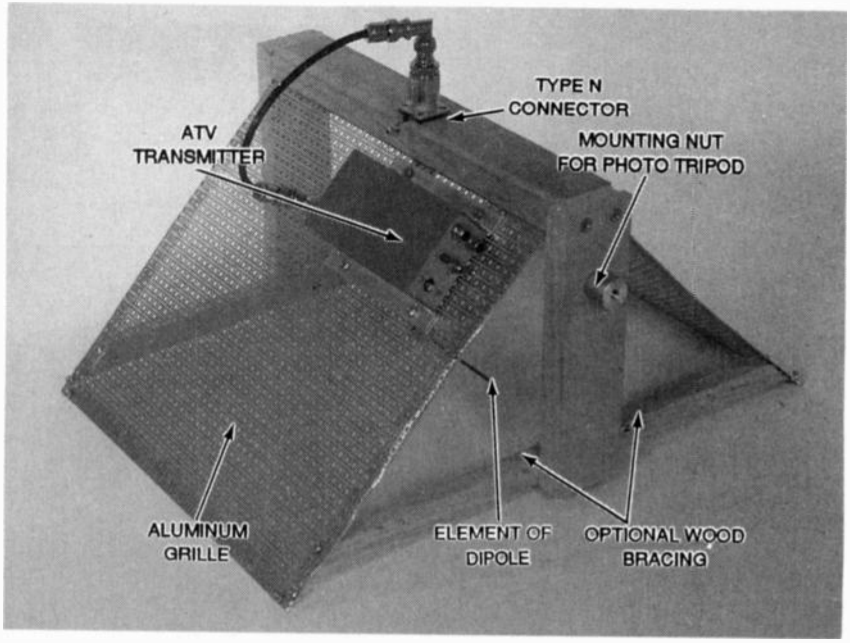


FIG. 3—THE BASIC PARTS of a corner-reflector antenna.

Construction

Fig. 3 shows some details of a corner-reflector antenna that you can build. Virtually all materials for the antenna are available at hobby shops and building supply centers. Total cost should be $20 or less. The corner-reflector antenna described here was designed for operation at 900-MHz. For other frequencies, the dimensions can be scaled from the information given in Table 1 and inserted into Fig. 4. However, at lower frequencies, the antenna is larger so some compromises have to be made to keep within practical mechanical size, weight and structural stability. A good idea from a performance standpoint is to keep the reflector as large as you can, up to a few wavelengths. This becomes impractical at 400 MHz, more so than at 1300 MHz, because of the antenna's overall size. As antenna size increases the extra gain may not be worth the mechanical difficulties and cost. Also, wind loading must be taken into account as this corner-reflector antenna presents a large wind surface area from all compass directions.

The antenna shown in Fig. 3 is fairly easy to construct with hand tools. Before you begin construction, review all the illustrations from Fig. 1 to Fig. 8, including Tables 1 and 2 to obtain a visual mechanical understanding of what is to follow.

Begin by cutting a 6.5-inch piece of ⅝-inch O.D. (outside diameter) brass tubing with a 0.015-inch wall thickness (available at well-stocked hobby shops). See Fig. 5. This length is the sum of half of a wavelength at the desired operating frequency, plus another 1 to 2 inches to allow for the connector and mounting flange as shown. Make sure the ends are squarely cut. A tubing or pipe cutter will provide a better cut than a hack saw. Cut a piece of ¼- inch tubing to a length about ⅛ inch shorter than the length of the ⅝-inch tubing. These brass tubes will form the dipole feed assembly and balun with the proper impedance.

Cut two slots lengthwise along one end of the ⅝ tubing, on opposite sides of tubing. Use a hacksaw or small saw and cut both slots at the same time with the saw passing through the center axis of the tube. The slot lengths should be ¼ wavelength at the operating frequency. For 923 MHz operation this cut should be approximately 3.2 inches. The slot width is not very critical.

Next, drill holes for the dipole elements as shown in Fig. 5. Leave about 1/16-inch space between the edge of the hole and the end of the tube. The dipole elements can be either 1/16 or ⅛-inch diameter brass rods or 3/32-inch diameter brass welding rod. Use a drill that is the same diameter as the dipole elements for a snug fit. Cut a length of brass rod that is to be used for the dipole elements to 1.05 wavelengths long at the desired center frequency. See Table 2 for data on the dipole length.

Carefully clean up and deburr the cut edges on the ⅝-inch and ¼-inch tubes. File the ends of the dipole element rods to remove burrs and sharp projections. Solder one end of the ¼-inch tubing to the center pin of a type N connector so that the center line of the tube is aligned with the centerline of the center pin on the type N connector. Allow ⅛-inch of space between the tube and the type N connectors flange as shown in Fig. 5. If necessary, build up the diameter of the center pin with some bare copper wire for a snug fit to ensure concentricity. Place the ⅝-inch tube over the ¼-inch tube, and check to see that the end of the center tube is flush with or is slightly shorter than the outer tube by approximately 1/16 inch, or less. Trim the center tube as needed. Clean the square flange on the connector with fine steel wool for soldering later.

Slip a ½-inch copper pipe coupling (use the kind that has no internal pipe stop) over the outer ⅝-inch tube. The commonly used ½-inch copper water pipe has a ⅝-inch outside diameter so a smooth slip fit should result. If OK, remove and drill a hole at one end to pass a #4 machine screw. See Figs. 6 and 7. A #33 drill is large enough, but a #28 drill was used to allow extra clearance. Polish the copper pipe coupling with fine steel wool to a bright finish. Using rosin core solder, solder a #4 brass nut to the coupling centered over the hole. Use a stainless steel #4 screw about 1-inch long to hold the brass nut in place while soldering. Solder will not stick to stainless steel.

Remove the screw after the solder joint cools.

TABLE 2
COAXIAL LINE IMPEDANCE WITH AIR DIELECTRIC

I.D./O.D.	Antenna Impedance (Ω)
2.0	41.5
2.1	44.5
2.2	47.25
2.25	48.6
2.3	49.9
23.33	50.7
2.5	54.9
2.67	58.8
2.75	60.6
3.0	65.8
3.5	75.1
4.0	83.1

Note: Shaded area indicates coaxial line impedances are within 10% of 50 ohms.

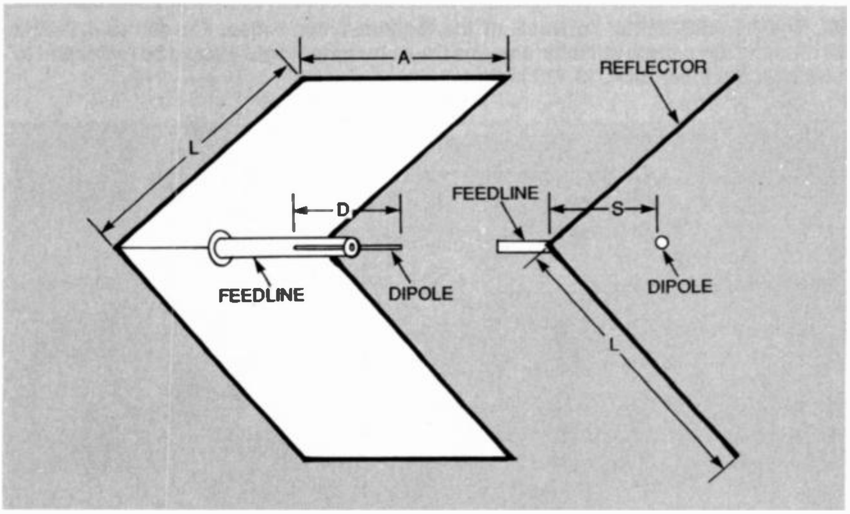


FIG 4—CORNER-REFLECTOR ANTENNA dimensions are determined by the frequencies used. Refer to Table 1 values.

TABLE 1—SUGGESTED CORNER-REFLECTOR DIMENSIONS FOR ELEMENTS IDENTIFIED IN FIG. AAA

CENTER FREQ. (MHz)	Dipole Spacing S (inches)	SIDE LENGTH L (inches)	CORNER LENGTH A (inches)	DIPOLE LENGTH D (inches)
420-450 (70 cm Amateur)	8.5	≥24	≥15	13.6
450-470 (2-way Commercial)	8	≥22	≥14	12.7
850-870 (2-way Commercial)	4.25	12	10	6.8
902-928 (33 cm Amateur)	4	12	10	6.4
928-960 (Commercial)	3.9	12	10	6.2
1240-1300 (23 cm Amateur)	2.9	12	10	4.6

Note: Dimensions are suggested starting points for minimum 8-dB antenna gain and are not exact value. The values are for practical sizes and are a compromise value given where necessary for mechanical construction reasons.

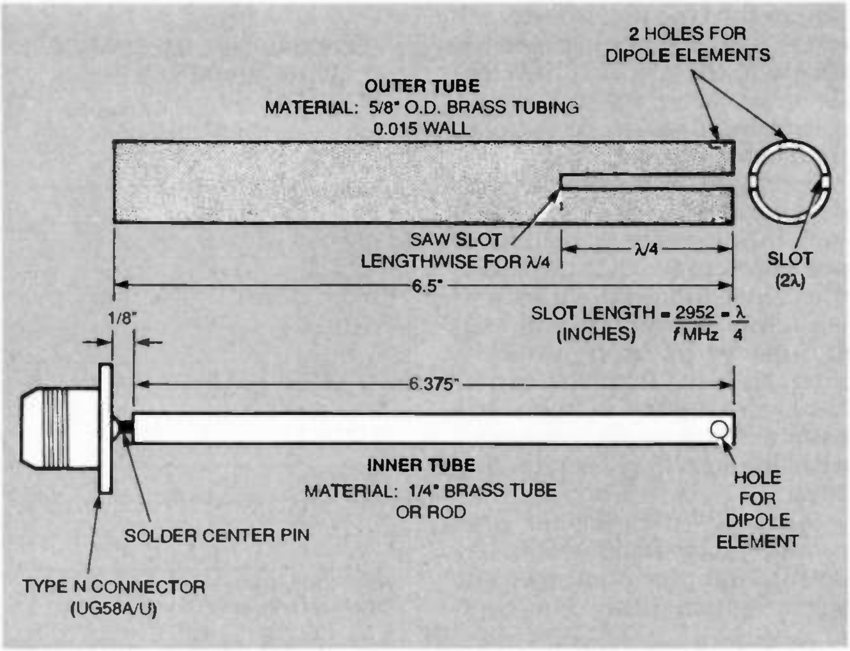


FIG. 5—PRE-ASSEMBLY DETAILS of the feedline/balun tubes. For 400 to 470-MHz operation of the corner-reflector antenna the outer tube length should be increased to 14 inches; the inner tube, 13.785 inches.

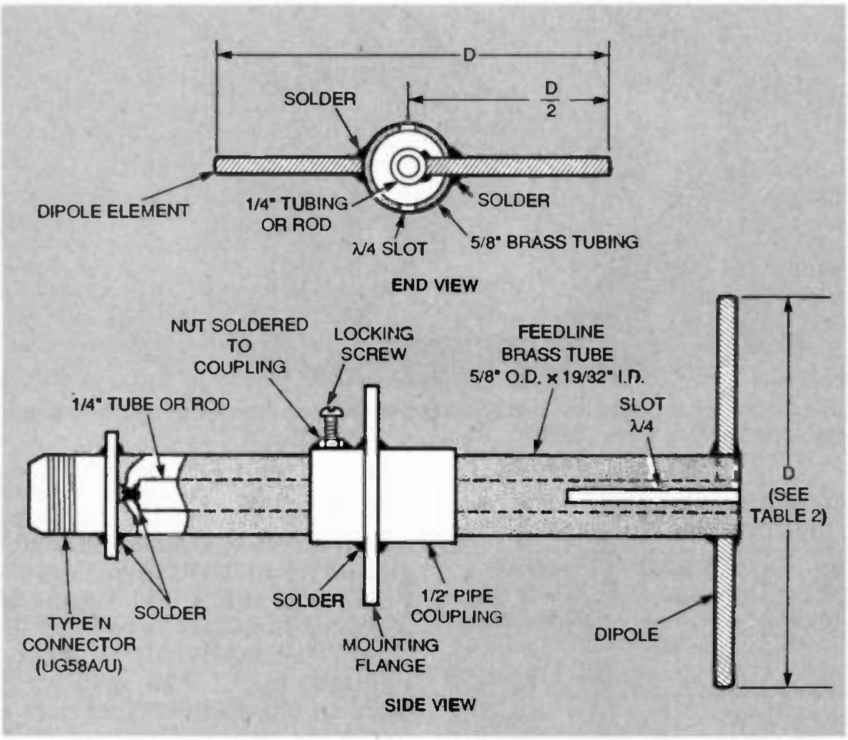


FIG. 6—TWO VIEWS OF THE DIPOLE AND FEEDLINE construction details. In the end view drawing note that the right dipole element connects to the inner and outer tubes and shorts them together. The left dipole element connects just to the outside tube. The ends of both dipole elements are equi-distant from the center of the inner tube.

Prepare a mounting flange from a 2 × 2-inch square plate made of copper, brass, or surplus PC board G-10 material. See Fig. 7. At its center, punch a hole in the flange to the outside diameter of the pipe coupling. Solder the coupling in place about the entire circumference. Make sure coupling is perpendicular to the plate. Slip the flange assembly over the ⅝-inch tube, the slit end opposite the nut as shown. Clean both ends

LIST OF MATERIALS

Parts specified for 800-1300-Mhz range. Lengths given in brackets are for 400-470-MHz range.

1—⅝-in. O.D. × 19/32-in. I.D. brass tubing, 0.015 nominal wall thickness, 6.5-in. long (14-in. long)
1—¼-in. O.D. brass tubing or rod, I.D. not critical, 6- ⅜-in. long (13⅞-in. long)
1—1/16-in. to ⅛-in. O.D. brass rod, or 3/32-in. brass welding rod, 15-in. long
1—Type N UG58A/U UHF connector, flange mount, or BNC UG290A/U RF connector, flange mount (either item preferably silver plated)
1—3-in. sq. ft material for reflector, 0.019-inch thick, perforated or grille aluminum recommended (see text)
1—4-40 brass hex nut
1—4-40 × ½-in. brass screw
1—4-40 × 1-in. stainless-steel screw
1—0.032 brass or copper plate, 2 × 2-in. square, or double sided G-10 material, 2 × 2in. × 0.062-in. thick
1—½-in. stop-less copper pipe coupling, sweat type
1—Wood, 1- × 2- × 12-in.
8—#6 × ½-in. sheet metal or wood screws
Also: Solder (both resin core and solid), fine steel wool, hardware as needed, miscellaneous wood blocks, ½ × ½-in. wood lengths for bracing as required, suitable plastic container for optional cover.
A catalog describing kits for ATV transmitters, ATV receiving converters and other projects useable with the antennas described in this article is available from North Country Radio, PO Box 53, Wykagyl Station, New Rochelle, NY 10804. Please include a #10 SASE and $1.00 to cover handling and postage.

E-mail: Ncradio200@aol.com
Compuserve 102033,1572 or
www.northcountryradio.com

Note: Materials illustrated and listed are for a corner-reflector antenna operating at about 900 MHz. Antennas for lower frequencies are larger and will require correspondingly larger or more materials. Brass tubing for inner and outer conductors can also be any other reasonable dimensions as long as they have approximately a 2.3 to 1 ratio of ID (outer) to OD (center). See Table 2 for other suitable sizes and corresponding impedances.

of the outer tube with fine steel wool to facilitate soldering in the following steps.

Insert the ¼-inch tube and type N connector assembly into the outer ⅝-inch tube placing type N connectors flange flush against outer tube (see Fig. 6). Check to see that pre-drilled holes for dipoles are aligned. You can insert the dipole elements and fasten them in place with tape to check for correct alignment. When the tubes are concentric, solder connector flange to ⅝-inch tube all around the edge. Use as little solder as you can for a neat job, and if possible use a hot 100-watt iron with a ¼-inch tip. A few wooden blocks drilled with ⅝ diameter holes will be useful for holding parts during assembly and soldering operations.

Clean all solder residues deposited in the previous step with isopropyl alcohol, flush with water and blow dry. Do this outdoors away from flame or sparks. Remove the dipole elements and make sure no electrical contact (short) between the outer and inner tubes exist.

Solder the dipole elements in place. The outer and inner conductor are shorted together by one dipole element. This is normal. Make sure they are aligned as shown in Fig. 6. Measuring from center of center tube, the dimensions of each side of the dipole should be equal in length and symmetrical.

You now have a half-wave, slot-fed dipole. Connect it to a receiver and check to see if it works as a receiving antenna. It should work as well as your whip antenna or better. Try orienting vertically and horizontally for best signal reception.

If you have the test equipment, use an RF source and a SWR or power meter to check the VSWR. It should be 2.0 or better. The dipole elements can be trimmed for lowest VSWR later. This will be affected by reflector spacing, slot length, and also presence of nearby reflecting objects. If the antenna pulls in no signals, check for shorts from burrs, solder drops, steel wool fragments, or other foreign material.

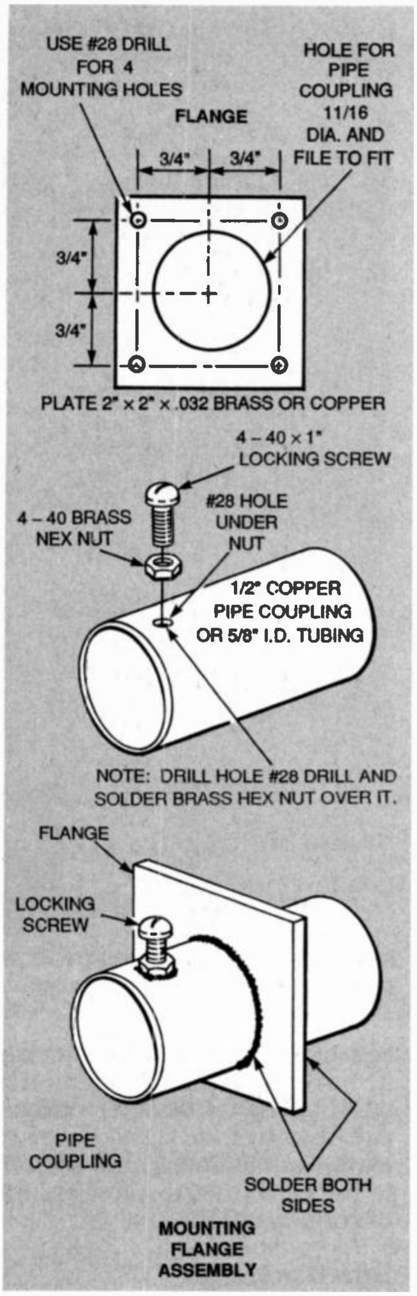


FIG. 7—DETAILS AND DIMENSIONS for the mounting flange assembly.

The reflector

Almost any perforated, stiff aluminum material can be used to make the reflector. A 0.019-inch thick perforated aluminum sheet was used. It is available in hardware stores for making grilles and covers for radiators, etc. The holes reduce the overall weight and wind resistance. Solid sheet aluminum, copper, wire mesh, or screening can be used since all you need is a conducting surface. Plywood or heavy cardboard covered with aluminum foil can also be used, if weatherproofing is not needed, for experimental or temporary use. Hardware cloth (aluminum or copper screening material) is also useful but hard to handle.

Referring to Fig. 3, you see that the reflector is made by bending a 1 × 2-foot sheet of perforated aluminum sheet. The exact reflector dimensions are not critical, larger being better. Instead of one 90-degree bend, two 45-degree bends were used leaving a 1⅝-inch valley that provides a surface for a good mechanical support. A piece of 1⅞ × ¾ × 12-inch wood is used to support the reflector and to mount the dipole in the center of the reflector. This piece of wood can also be used for mounting a bracket to hold the completed antenna to a mast or other support.

Bracing can be added to the reflector if desired as shown in the photo. Use wood, plastic, fiberglass, or other non- conducting material. Conductive materials in front of dipole will cause detuning and pattern distortion. If thin sheet metal is used alone for the reflector it is wise to cut the metal 1-inch larger in width and length and use this extra material to form a folded edge around the perimeter to stiffen the reflector surface. A block of wood can be used to form the bends, as the material is easily worked by hand. Make bends along perforated lines in the aluminum for sharp and true bends.

After the reflector is formed, cut a hole in the center of the valley fold as shown in Fig. 3 and fasten the flange on the dipole assembly to the reflector. The dipole should be parallel to the bend in the reflector. Initially set the dipole about 0.3 wavelengths from the reflector. Install a 4-40 screw in the nut previously soldered to the flange assembly to lock the dipole in place. Final adjustment can be made later by setting the dipole position for lowest VSWR, with an RF source and reflected power meter or SWR bridge. For receive only applications, no further adjustments are needed. You could try peaking the adjustments on a weak signal if you are fussy, but you will find that they are very broad and have little noticeable effect.

Next, mount the antenna in its final location. Make sure to mount the antenna for correct polarization. Polarization is same as dipole (e.g. vertical for vertical polarization). Vertical polarization is generally used for amateur and commercial two way FM, but horizontal is used for SSB amateur work and some amateur TV. UHF TV is generally horizontal or circular. As a compromise, the antenna could be mounted at 45 degrees to vertical.

You will find that the antenna has pronounced directivity, maximum pickup occurring along a line bisecting the reflector angle, in the direction the dipole faces. The pattern is clean and well defined. Pickup towards the sides or rear is much less. Therefore, face the antenna in the direction of desired reception. Two or more of these antennas can be used if multi-directional reception is desired, or a rotator can be used. Bandwidth depends on the VSWR desired, but this antenna should work well over a range of 10 percent or so. An antenna made for 900 MHz will easily work well from 800 to 1000 MHz, and reception at 450 MHz and 1280 MHz will be adequate, but not optimum. You should find this antenna easy to make and quite effective and may even wish to build several for different frequency ranges. Simply scale the dipole element length and reflector size as needed.

For outdoor use, it would be a good idea to cover the dipole and slotted feedline assembly with a plastic cover to keep out water and insects. Use a clear, plastic-food container that is microwave safe. If it does not heat up in a microwave oven, it probably has low RF losses and will not affect the antenna. The container can be slit and placed over the dipole with the slit facing down. The lid can be used to cover the open end of the tubing. Clear silicone seal can be used to seal edges and joints

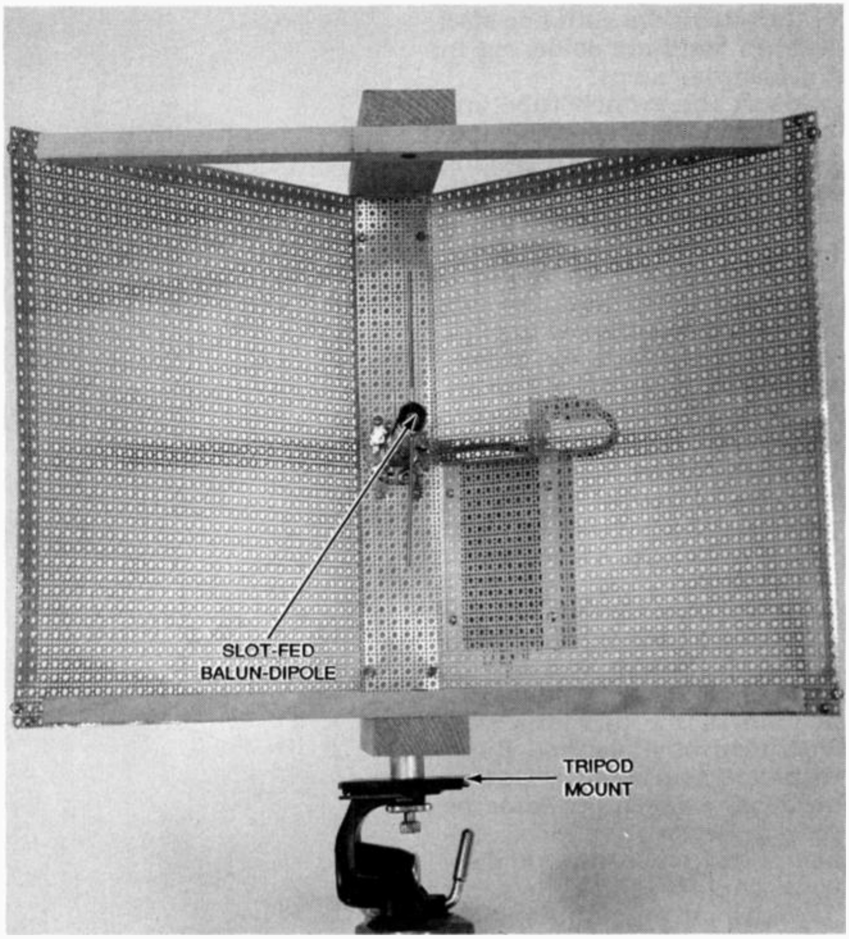


FIG. 8—THE CORNER-REFLECTOR ANTENNA fully assembled and mounted on a photographer's tripod for evaluation.

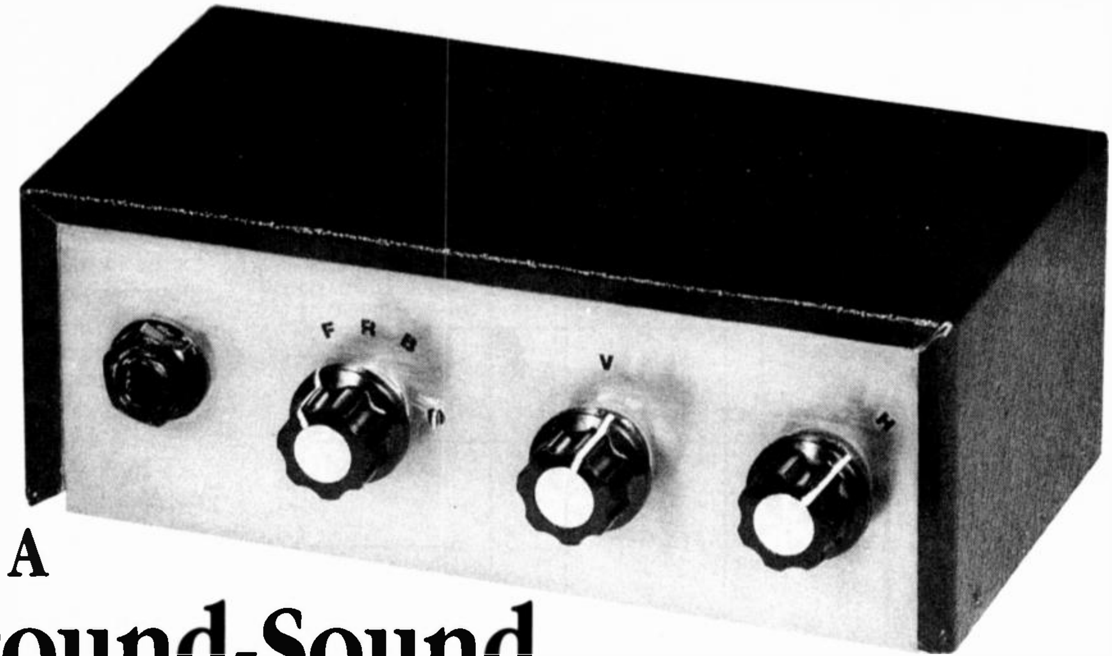
against leakage. Clear materials are preferred since pigments such as metal dust or carbon can be lossy for RF. Make sure to leave a small hole in the bottom of the container to allow escape of condensation.

How it performs

The corner-reflector antenna provides noticeable improvement over an omni-directional or ground-plane antenna. It can be used indoors as well. Fig. 8 shows the antenna mounted on a photographer's tripod for initial testing. The transmiter (or antenna) is mounted on the rear surface of the aluminum grille. This corner-reflector antenna is not intended for moonbounce, weak-signal SSB, DX contests or other such exotic amateur radio uses but it will be a darn good antenna for much scanner listening and routine ham use, or as a temporary, cheap antenna to use before investing in a larger Yagi or other expensive setup. With a low-loss feedline, an 8 to 10 dB antenna will give very good results both in transmission and reception.

The author has used two of these antennas for amateur TV transmission at 923 MHz, one antenna at the home station about 30 feet above ground, the other in a vehicle with a portable TV set and a receiving downconverter to allow reception of the 923 MHz amateur TV signals on VHF channel 3. A 1-watt transmitter was used at the house. Excellent pictures were received 8 miles away and, although snowy, a picture was seen at 17 miles. The tests were repeated at 1289 MHz with a pair of corner-reflectors designed for this frequency and similar results were obtained. The transmitters and receiving downconverters were described in articles published in the April and May, 1996. Ω

BY TED ROWEN



BUILD A Surround-Sound SWITCHBOX

Control where your home-theater or stereo system's audio is coming from and add surround sound with this handy little device.

Would you like a simple way to select which speakers in your audio setup are on? Better yet, would you also like to control those speakers in such a way as to produce a type of surround sound? If so, you should consider building the *Surround-Sound Switchbox* described in this article. It's a one-evening project that can make a great difference in the way you experience audio at home.

The Switchbox is designed to accommodate a stereo pair of speakers in the front of your listening room, and another "surround" pair in the rear of the room; that means you don't have to buy a truckload of speakers to use the unit. Also, while we're on the topic of buying, the components used in the author's prototype are readily available and inexpensive; in fact, depending on what materials you have on hand, you should be able to build this project for under $20.

The Switchbox is based on the surround-sound effect popularized by David Hafler. Basically, that is when a rear pair of speakers responds to the differential of stereo signals presented to a front pair. Those A+B and A−B signals are not apparent from speakers connected in a normal, parallel configuration. You'll probably be surprised to find that the Hafler effect can produce quite a startling audio ambiance. That is because a Hafler circuit extracts signals that are already present to create surround sound.

Circuit Description. The schematic diagram for the Switchbox is shown in Fig. 1. Because all components are passive, no power supply is required; only audio connections are made to the circuit. (To keep project cost down, a terminal strip was used to make many of the connections shown in the schematic. For that reason, there is only one jack shown.)

The circuit gets its audio input from the left and right outputs of a stereo amplifier. Those signals are fed to two terminals of a switching, stereo phono jack, J1. If headphones are inserted into J1 the audio from the amp will bypass the Switchbox and be fed directly to the headphones. An attenuator will need to be used with the latter (more on that later).

If no headphones are inserted into J1, the left signal is fed to two sections, S1-a and S1-b, of a 4P3T switch. The right signal is fed to the other two sections, S1-c and S1-d. When S1 is set to FRONT, the left and right audio signals will be sent to front-right and -left speakers that are connected to the Switchbox. Setting S1 to REAR will connect the audio signals to rear-right and -left speakers. Finally, the BOTH setting of S1 activates all four speakers.

When the circuit is set so that all speakers are working, another audio option is available from switch S2. Setting S2 to NORMAL will cause the rear speakers to work just like the front ones. However, the HAFLER setting on S2 connects the negative signals of the rear speakers to each other via a 50-ohm potentiometer, R1. Adjusting R1 allows for a variable, Hafler surround-sound effect.

Construction. Because all the components used in the Switchbox are panel-mountable, no circuit board was used in the author's prototype. You can easily do the same.

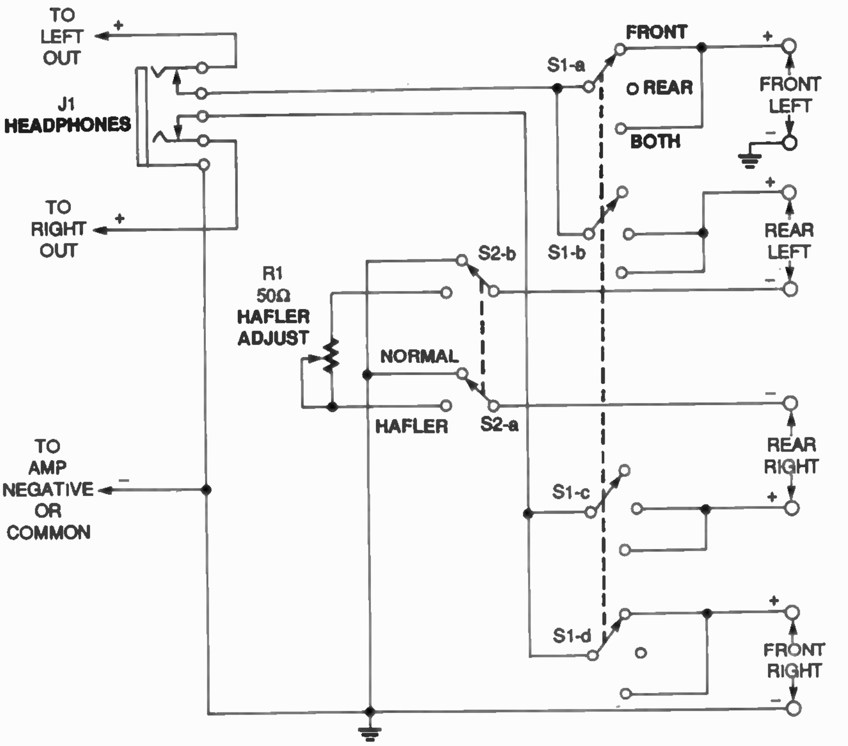


Fig. 1. The circuit for the Surround-Sound Switchbox requires no power source. It passively creates the Hafler effect using existing sum and difference signals.

Begin by finding a suitable enclosure. Drill holes in the panel of the case for the two rotary switches, potentiometer, and stereo jack. Then, mount the components.

Using different-colored lengths of insulated wire, carefully make the connections between the components shown in the schematic. Try to keep the wires as short as possible. In the author's prototype the connections to the speakers and amplifier were made using a twelve-terminal connecting strip. If you wish to do the same, make all the connections between the other components and the strip, and then fasten the latter to the case. The author's prototype used an open-back enclosure that allows easy access to the connecting strip. Depending on the case you use, you might need to make an opening for the strip.

Another option is to use RCA jacks for all audio connections, although that does increase the cost of the project. Depending on how much money you wish to spend, and on how often you will be connecting and disconnecting your Switchbox, you will need to decide if you wish to use jacks.

Before you close up the case, double-check your wiring. It's very easy to make mistakes when making so many point-to-point connections. If you have one, use a DMM that has an audible or visual continuity-tester mode. Connect the leads to various points across the switches and listen for the tone or watch for the needle movement that indicates the switches do what they are supposed to do.

Now, before you can use the circuit, you might need to build an add-on. If you recall, it was mentioned earlier that you will need an attenuator to use most headphones with the Switchbox. Commercial attenuators are available from sources such as Radio Shack; however, you can also build your own.

Figure 2 shows a simple circuit you can use. To build the attenuator, you have two options. You can either buy a jack and a plug and wire the resistors between them. Or, if you have a pair of headphones you'd like to use only with the Switchbox, you can simply cut the headphone wires and solder the four resistors in place. Be sure to insulate each connection and the entire assembly when you're done.

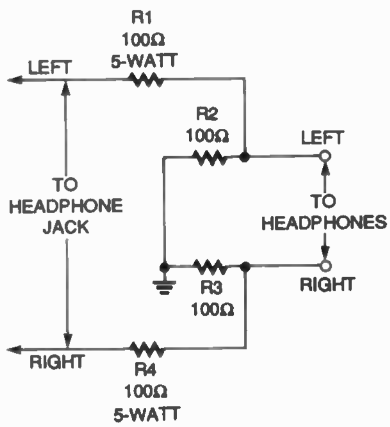


Fig. 2. To use most headphones with the Switchbox you will need an attenuator. Here's a simple add-on you can build in a few minutes.

PARTS LIST FOR THE SURROUND-SOUND SWITCHBOX

R1—50-ohm potentiometer, wire-wound
J1—Stereo phono jack, switching type
S1—4P3T rotary switch
S2—DPDT rotary switch
Suitable enclosure, knobs, twelve-terminal connecting strip, rubber feet, wire, solder, hardware, etc.

Using the Switchbox. If you are adding speakers to your system, which is probably the case with the rear ones you'll be using, make sure your amplifier can handle them. Remember that the actual load seen by the amplifier depends on the size and the phase of the signal. For the most part, using four 8-ohm speakers is your best bet. Avoid the use of 4-ohm speakers in the rear circuit as they will result in a 2-ohm load (which is too low) when connected in parallel.

Do not turn your amplifier on while your speakers and the Switchbox are not connected. Also, make sure you do not accidentally connect positive and negative leads from the amplifier together.

To use the Switchbox, turn the volume down on your amplifier and turn on its power. Then, turn S1 to each of its settings. As you do so, increase the volume and make sure each setting is activating the appropriate speakers. Finally, leave S1 on BOTH.

Turn S2 to the HAFLER setting. Adjust R1 to see how it varies the Hafler effect. With a little experimentation, your home-theater or listening room will definitely never be the same again. ■

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RUNABOUT ROBOT

Continued from page 74

If nothing happens when power is applied, check to see that +5 volts is present at pin 6 of the DC-DC converter IC2. Also check for +5 volts at the power pins of IC1 and IC3, and make sure the grounded pins of each IC are at zero volts.

If you have an oscilloscope available, check the serial bit stream from the infrared receiver module. Pin 18 of the PIC16C56 should toggle rapidly between 0 to +5 volts whenever a button is pressed on the remote. (This is also a good way to see the code sequence of each key.)

The idling (no movement) voltage at pins 6 through 9 of the PIC16C56 (motor control pins) should be at approximately zero volts. Whenever a motion key is pressed on the remote control (up/down volume or up/down channel), the voltage at these pins should increase to about +5 volts depending on the direction of movement.

Check the voltage at the top of both motor H-bridge circuits (the emitters of Q1, Q3, Q5, and Q7). These points should be at the battery potential of approximately 3 volts. Be sure the emitters of Q2, Q4, Q6, and Q8 are at zero volts.

If the Runabout operates, but turns when it should go straight (and goes straight when it should turn), you must reverse both wires on one of the motors. If it moves in reverse when it should go forward, and turns left when it should turn right (and vice versa), reverse both wires on both motors.

A common mistake when

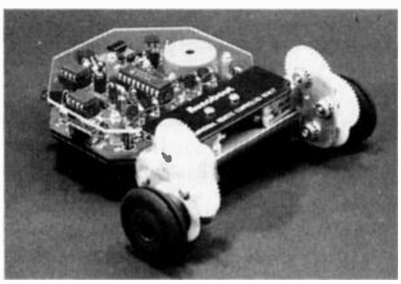

FIG. 8—THE COMPLETED RUNABOUT. The robot has a store-bought look to it, and is sure to entertain for hours.

TABLE 1—HARDWARE SUPPLIERS

Supplier	Products Available
Stock Drive products 2101 Jericho Pike New Hyde Park, NY 11040 (516) 328-0200	gears
Edmond Scientific 101 E. Gloucester Pike Barringotn, NJ 08007 (609) 573-6250	gears, motors
Digi-Key 701 Brooks Ave. South Thief River Falls, MN 56701 (800) 344-4539	infrared receivers
Radio Shack Stores (nation wide, check phone directory)	infrared receivers, motors
RAF Electronics 95 Silvermine Rd. Seymour, CT 06048 (203) 888-2133	spacers, standoffs
H.H. Smith Inc. 632 Arch St. Meadville, PA 16335 (814) 724-6440	large grommets, spacers, standoffs
Minor Rubber Inc. 49 Ackerman St. Bloomfield, NJ 07003 (201) 338-6800	large grommets
• In addition, check hobby and surplus stores for gears and motors.	

controlling the Runabout is made by pressing the wrong keys on the universal remote. For example, if you press the "VCR" or "Cable" key, you will no longer be sending proper information to control the Runabout. Most universal remotes instantly change to a new mode and send out new codes if the VCR or Cable key is pressed. Any time you notice an immediate non-operation of Runabout, press the "TV" key on your remote and try again. (If that doesn't work try re-programming the remote for a Sony brand TV.)

Operation

Table 2 lists all the functions programmed into the Runabout. For basic operation, the remote's channel and volume keys provide movement, while keys 0 through 9 produce sound effects and operate the LEDs. (Other keys not listed in Table 2 that you may have on your remote will not cause any action.) The Runabout responds only while the key is being pressed and stops when the key is let up (except in program-playback mode).

To enter the robot's program mode, press the "enter" key on your remote. Runabout will beep for approximately 1 second indicating that the program mode has been entered. Up to 127 movements, sound effects, and LED keypress commands will be recorded. After each action (key release), a short beep indicates that the action has been recorded. Press the enter key any time to exit (and save) your sequence, and then press the "power" key to play back a sequence. After the pre-programmed sequence ends, six short beeps will signal the end of the sequence. There is no way to interrupt a sequence during

(Continued on page 106)

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TABLE 2—RUNABOUT OPERATION

Universal Remote Key	Runabout Action
Up Channel	Move Forward
Down Channel	Move Reverse
Up Volume	Turn Right
Down Volume	Turn Left
Key 1	Single LED On (Left)
Key 2	Single LED On (Middle)
Key 3	Single LED On (Right)
Key 4	"Erratic Driver" Mode
Key 5	Beep (Horn)
Key 6	Dual Tones
Key 7	Rising Tones
Key 8	Change Speed
Key 9	Falling Tones
Key 0	Shift Key (Selects Memory 1-6)
Enter Key	Enter/Exit "Program" Mode
Power Key	Run Selected Program
Mute Key	Pause (In Program Mode Only)

playback except to turn off Runabout or to remove the batteries.

To select a new memory location (one of six banks), press the "0" key on the remote. Two beeps signal that you can now press keys "1" through "6" (memory 1–6). Any other key will give an error signal. The Runabout always defaults to memory location 1 when power is first applied.

Runabout was designed for table-top use. The infrared receiver module will not function properly in direct sunlight, and you should therefore operate the device indoors only. The Runabout should work up to a distance of approximately 25 feet if the remote is aimed properly and contains fresh batteries.

Do not expect the Runabout to carry out long movement sequences with great precision. The gear assembly is not a precision mechanism, so there will be variations from one movement to another. Alkaline batteries have a sloping discharge curve.

As battery voltage declines, the overall speed of movement of the Runabout is reduced, and this reduction will effect positioning. Ni-Cd batteries have a more steady discharge rate, but their voltage is lower and the Runabout will move slower overall.

It's best to program short movement sequences if you want repeatability. Try to re-position the Runabout to its exact starting point. Also, a clean table top keeps small particles from getting trapped under the front skid and causing Runabout to turn slightly when it encounters them.

The Runabout might turn slightly due to other factors. The motors might not have identical torque and/or one gear assembly might not turn as smoothly as the other. You can solder in a low value resistor (typically 0.1 to 1 ohm or more) in series with the faster motor to try to slow it down. If desired, experiment with different resistor values in series with either motor wire. It might take several attempts to get the motors to turn at precisely equal speeds but patience will pay off and your robot will move in straight lines.

On some surfaces the front skid can resonate and cause a vibrating sound during movement. You can place a layer or two of masking tape directly on the bottom of the skid to solve this problem. The tape will dampen the contact between the table and the skid and reduce the noise.

Be careful when playing back pre-recorded sequences. You can easily lose track of where you started the sequence, and the Runabout can make an unexpected turn and fall off a table—and it *will* be damaged by a fall! Ω

PRODUCTS & BOOKS

(Continued from page 10)

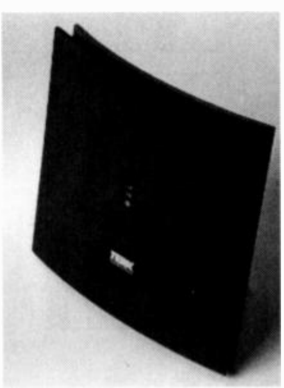
deck can also be positioned in the center to conserve space when not in use. Both the keyboard drawer and the mouse deck feature built-in wrist rests. The padded rest on the keyboard tray can be removed to accommodate larger, ergonomic keyboards that come with their own wrist rests. The mouse deck has a clear surface under which you can slide photos, notes, news clippings, or other memorabilia.

The Model 625M Underdesk Keyboard & Mouse Superstation has a list price of $74.95. For more information, contact Rubbermaid Office Products Inc., 1427 William Blount Drive, Maryville, TN 37801-8249; Tel: 615-977-5477; Fax: 615-977-6849.

CIRCLE 33 ON FREE INFORMATION CARD

INDOOR RADIO ANTENNA

Designed for use with mini-systems and basic stereo setups, *Terk Technologies' AM-FM+* is a stand-alone passive indoor radio antenna that offers high performance at a low price. Many people use the limited "low-tech" indoor antennas that come with their audio systems. Others connect an FM dipole antenna that gets lost in a jumble of wires. If they mount it to get better reception, they face the problems of high directionality—and unsightliness. The AM-FM+ is a solution for people who want good reception from a compact, easy-to-use, attractive antenna. It can stand on a shelf or be mounted on a wall.



The AM-FM+ has a suggested retail price of $19.95. For more information, contact Terk Technologies, 63 Mall Drive, Commack, NY 11725; Tel: 516-543-1900; Fax: 516-543-8088.

CIRCLE 34 ON FREE INFORMATION CARD

TONAL VOLTMETER

(Continued from page 42)

case with the ink cartridge removed. The probe tip can be any sharpened length of metal wire, such as a wire-wrap IC socket pin or small nail. Make the connection between the probe and pin 9 of IC1 with a length of shielded cable.

Any 5-volt DC supply is suitable for this project, either batteries or an AC adapter. Use whatever power supply is most convenient and least expensive for you. Mount the finished circuit in an enclosure that will protect it and you are done.

To adjust the two potentiometers in the circuit, first ground the probe tip and adjust R2 for the lowest tone desired. Then connect the probe tip to +5 volts and adjust R1 for highest tone desired. Adjust R3 to increase or decrease the speaker volume if necessary. Ω

L/CMETER

(Continued from page 67)

60 components on a HP4275A L/C meter. Measuring these components on the L/C meter prototype found an average error of just 0.60% for inductors and 0.13% for capacitors. These values ranged from .1 mH to 6.8 mH for the inductors and 2.7pF to .068 μF for the capacitors.

The prototype was also used to measure the values of a series of 5% tolerance inductors up to 150 mH, and a series of 10% mylar capacitors up to 1.6 μF. All of these parts measured well within the specified tolerance of their marked values indicating the accuracy of the L/C meter extends at least up to 150 mH and 1.5 μF. These measurement were made on a single unit. The measured values could vary, from unit to unit, by 1% to 2% as a function of the exact value of C2, 1% tolerance polystyrene capacitor.

You can measure values as small as .01 mH and .1 pF with about 15% accuracy. However, you generally won't find components this small. A piece of wire less than one inch long has an inductance of 0.01 μH.

The resolution of the meter is, however, relative, and can be used for sorting a batch of similar components as it truly does indicate which are slightly larger of smaller than others.

For small values the frequency of operation (test frequency) is about 750 kHz decreasing to about 60 kHz at .1 μF or 10 mH and about 20 kHz at 1 μF or 100 mH. Ω

JAMMIX

(Continued from page 57)

balance can be set to place you essentially anywhere on the stage.

Positioning your guitar opposite the lead instrument often gives rise to stimulating exchanges with the recorded artist. The ability to position the instrument also allows you to master your own recordings. To do this requires two stereo tape recorders. A typical "home-studio mastering" might be done as the following scenario suggests:

Connect a tape recorder to the stereo OUT jack of JamMix. Set the BALANCE control of JamMix to midrange and record a rhythm track with, say, a guitar. Rewind and remove the tape from the tape recorder (do not disconnect the machine) and install it in a tape player connected to the JamMix stereo IN jack. Position the BALANCE control to the right side and perhaps turn up the GAIN for some distortion. Install a second tape in the tape recorder. Start the tape player with the rhythm track, as well as the tape recorder, and add your lead guitar solos via the INSTRUMENT jack. Rewind and swap the tapes, and move the balance control to the left. This readies you to mix in another instrument such as a bass guitar, keyboards, or perhaps vocals. Of course, it might be easier to simply mix yourself into a recording of Johnny B Goode, or perhaps your favorite blues number.

Your guitar's audio signal can be adjusted to the same position and levels of the lead artist, which is useful for memorizing note-for-note passages. Ω

SPECTRUM ANALYZER
(Continued from page 39)

bus with other 100,000-ohm resistors (R7, R10, R13, R16, R19, and R23). Because each stage is an inverter, there are two summing buses; with one for the "evens" and one for the "odds" of the seven stages. Those buses sum signal samples from each of the series-strung stages described above. Once a stage saturates, its output is limited, and it contributes no more to the summation. Thus, as the stages progressively saturate with increasing signal input, the summing buses appear to have less and less gain in front of them.

Each stage within the chain comes into saturation (limiting) very smoothly; there is no sudden "corner" in the individual stage transfer functions. This smoothness is due to the way the CMOS inverters behave. The overall effect is a smooth logarithmic amplifier performance.

Because of the "even-odd" signal collection on the two buses, it is necessary to invert the signal on one so that both are in phase and ready to be totaled. This is done with IC2-d and emitter follower Q1. The signal at the emitter is now in phase with the signal on the other summing bus. The two bus contributions are finally summed in IC2-e and Q2, which form the final output stage of the log amplifier. The transfer function slope (mV/dB) constant is set with resistor R28.

The signal input to the log amplifier is a symmetrical heterodyne "bubble" of sinusoidal signal that consists of positive and negative swings around a baseline. Because spectrum analyzer displays are unipolar (one signal polarity), output stage IC2-e is bias-offset with resistors R26 and R27. This clips the negative going spectral line spikes and so only positive going ones are displayed on the oscilloscope. Finally, input gain trimmer R2 sets the smallest signal at which logging begins, so that logging does not occur on baseline noise but rather just above it.

This completes the theory discussion for the HSA and pretty much all the space we have for this month. Next time, we will get right to work on showing you how you can build your own under-$100 spectrum analyzer. Ω

DECISION MAKER
(Continued from page 42)

neath the LED cap, and about 3/16-inch from the bend to the end of the leads. Don't trim the LED leads until after you have soldered them in place.

First, mount all components except the LEDs. Use a socket for the microcontroller, but don't install that IC yet. Next drill the holes for the LEDs and the start switch in the enclosure's cover, using the template in Fig. 5 as a guide.

Now place the PCB in a pair of slots along the side of the enclosure and bend the leads of a single LED. Insert the LED into the board and tack-solder one lead. Temporarily place the cover on the enclosure to check lead length. If the cover fits properly, finish soldering the LED, then bend the remaining LEDs to fit, and solder them in. Otherwise, adjust the bend in the first LED and try again.

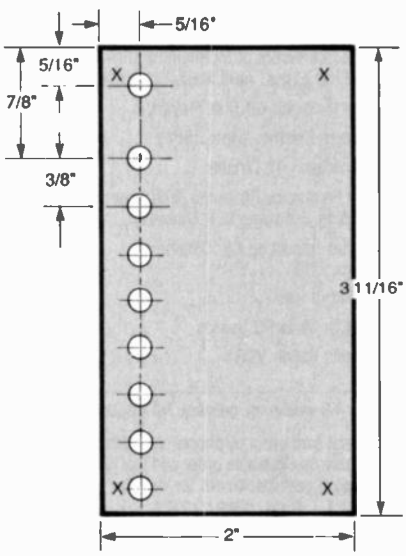


Fig. 5. Here's the hole template for the cover. Nine holes are required, eight for LEDs and one for the start switch. The power switch mounts on the upper end of the case.

To keep the front panel as clear as possible, we mounted power switch S2 in the side wall of the narrow end of the enclosure. We used a low-cost, low-profile slider for S2.

Test and final assembly. After completing construction, but before installing the microcontroller, let's do a few simple tests to ensure that everything is working properly.

Apply power to the circuit by closing S2. The battery voltage should now appear at the input of regulator IC2, and a constant 5-volts should appear at its output. The same voltage should appear at pin 13 of IC1's socket (remember, we have not installed that IC as of yet), at the anode of each LED, and at the buzzer.

Next, with power still applied, use a short jumper wire to short pin 3 of IC1 to ground (pin 14). That should cause the buzzer to sound. Also try grounding pins 5–12 of IC1. Each LED should light in turn. If LED4 does not light, put JU2 in the other position.

The last test verifies operation of S1. Connect your voltmeter between pin of IC1 and ground. When the switch is open, the meter should read +5-volts DC, but when closed it should read zero.

After verifying operation of all components, remove power and install the 68HC705K1 into its socket. Then reapply power. You should see and hear the initialization sequence, after which the unit is ready for use.

The label. The most difficult (and the most fun) part of this project is creating the front panel label. Self-stick labels work well in this application; you can also use heavy stock and rubber cement.

The author created a template file in Word for Windows that allows you to format labels precisely. One is shown in Fig. 1, and another in the lead photo for this article.

Customization is the key to transforming this project from simple blinking lights into a memorable gift. When creating the label, it's best to focus on either the personality quirks of the recipient or on the general humor of the situation. Ask yourself questions like: What things does this person like and dislike? When is he or she the least decisive? Are there any stereotypes concerning the new situation he will soon be in? As soon as you start letting the creative juices flow, you can have a lot of fun. Ω

LEDS FOR AUDIO

(Continued from page 24)

audio electronics equipment to match the response to the volume heard by the human ear.

Set the illuminating response level of the bargraph LED indicator following the same procedure as previously described for the other LED circuits. Connect the output of Fig. 2 of the averager circuit to the input of the bargraph level indicator in Fig. 5. Apply a maximum level signal to the input shown in the averager circuit of Fig. 5, and reduce the input level to allow for headroom. Then adjust R2 in Fig. 2 until the most significant LED (LED12 in Fig. 5) just turns on.

Picking the LED level indicator

The selection of the most appropriate LED level indicator depends on the existing arrangement of controls. If the front panel is already cluttered with knobs and switches, there might only be room for a single LED. However, if the front panel has room to spare, a ten LED bargraph might fit on it. Its installation could give the audio equipment a professional appearance. (Remember, you need two bargraphs for a stereo system.) The LEDs that make up the bargraph can be positioned vertically, horizontally, or even in an arc to convey the impression of a moving needle of a meter. Also, the LEDs can have different colors. Use red for the high levels, green for the low, and yellow for those in-between.

If only one LED will fit on the crowded panel, chose between a single-color LED or a tri-color LED. The tri-color LED has more resolution because it has four color states. However, if all you need is an overload detector, the single-color LED is a better choice because it clearly conveys a message of *too high*.

Finally, keep in mind that the addition of a solid-state level indicator might excite audiophiles who will admire and want to try out your project. Ω

SCOPE CALIBRATOR

(Continued from page 29)

ohm input impedance, or if you have applied the signal through a 50-ohm feedthrough termination, set the scope to 50-mV/division. You should see 6 divisions of amplitude as shown in Fig. 8 (Fig. 8 and 9 are scope photos from a 500 MHz Tektronix 7904 oscilloscope with a 7A19 vertical amplifier). Using only the flat parts of the waveform, ignore any leading or falling edge aberrations when measuring amplitude.

To test sweep accuracy, set the horizontal sweep speed of the scope to 1 µs/division. You should see 8 divisions as shown in the photo of Fig. 8. The best possible accuracy is obtained by centering the signal on the screen and measuring from the center point of the waveform.

To measure the approximate bandwidth, set the sweep speed to the fastest rate and adjust the triggering so the complete rising edge of the waveform is visible as shown in Fig. 9. If that is not possible, it is likely that the scope under test does not have a vertical-amplifier delay line, which should be considered a serious deficiency. Ignore the amplitude of any ringing or overshoot, and measure the rise time by noting the time to go from 10% to 90% of the waveform amplitude. Some scopes have that precalibrated on the screen using either 5 or 6 divisions for 100%. If your scope has a 6 division scale for 100%, just use the variable vertical scaling commonly available to adjust the waveform to 5 divisions. Otherwise, just measure from 0.6 divisions to 5.4 divisions. That gives the rise time of the scope and the pulser combined. If the observed rise time is small (<1.5 ns), then use Fig. 4 or the formula to correct for actual rise time (use a nominal 0.5 ns for the pulse output rise time). Remember that the bandwidth is found from:

$$BW = 0.35/t_r$$

The total ringing or overshoot should be less than approximately 15% of the signal's final value. Ringing beyond that value might indicate problems with the vertical amplifier such as a peaked response, miscalibration, or faulty components. Ω

POPtronix Spring 1997 Ad Index

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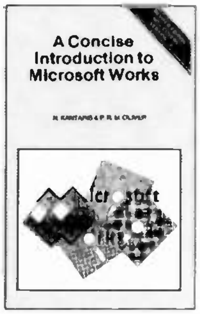

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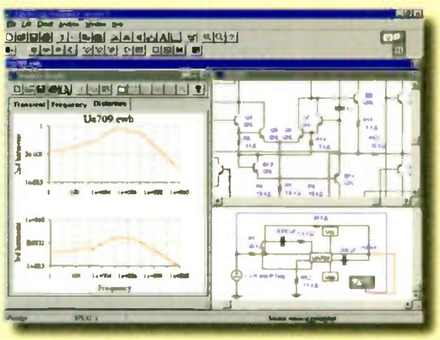

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