Special Projects

The magazine for people who build electronic projects

By the Publishers of **Radio-Electronics**

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FALL 1983
#8
CANADA $2.75

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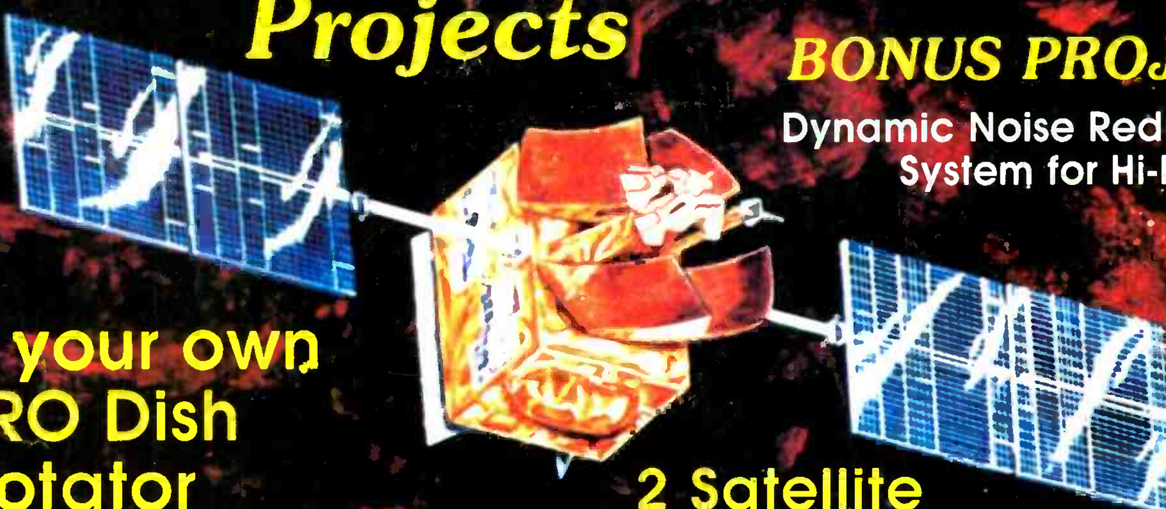

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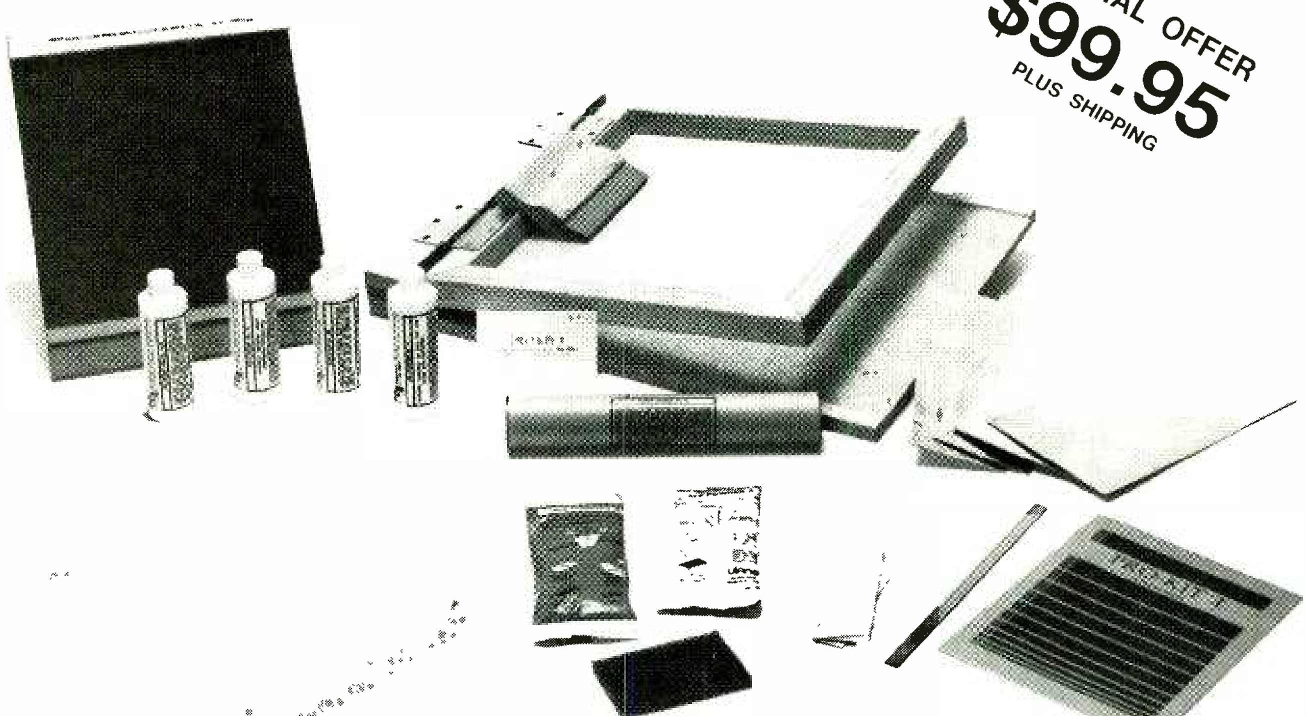

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Special Projects
The magazine for people who build electronic projects

#8
FALL 1983

The sky is the limit....

We accept the fact that NASA can position satellites in space with accuracy like that of a child pinning a decorative ball to a Christmas tree. And so, satellite-television relaying is an everyday occurrence we expect to take place without interruption, just as we'd expect McDonald's burgers to hit 100 million this decade. No wonder satellite antennas pop up all over our landscape like mushrooms in the rural areas, and proliferate in the big cities, too! So why is this editor surprised when a raft of satellite-television related projects show up in the mail?

Actually, we envisioned the technology related to satellites to be way beyond the knowledge and skills of the average home-electronics experimenter. How soon we forgot about Radio Amateurs and their numerous Oscars!

This issue of *Special Projects* has several home-brew projects that will improve the pleasure you derive from satellite-TV reception. One project illustrates the technique used by an author to rotate his big dish about its polar axis, thus pulling in all the available GEO satellites his equipment can receive. (Your editor liked the project so much that he modified it to open a skylight vent on breezy days. Now to discover a way to zap mosquitos that find their way into the house.) Also, two projects make it possible to receive quality stereo reception on those telecasts that provide for quality sound. One, which may seem new, was an old favorite in the late fifties that has been cut down in size by "chip" technology.

One project for Earth dwellers that can really space you out is our Speed-Switch Touch Control designed to work with an Atari videogame player. At the touch of a finger the game's cursor or other action device immediately responds, then stops when the finger is removed. Not only is action in the four cardinal directions possible, but combined up-left, down-right, etc., action is possible. If you own an Atari—build this control!

I'd like to thank our readers who have taken subscriptions to *Special Projects*. Many of you included complimentary notes and letters with your checks. We thank you for the financial endorsement, and the kind words you chose to send to us. For those who are seeing *Special Projects* for the first time. Should you wish to subscribe, seek out the special offer included in this issue. We promise that *Special Projects,* like good wine, will improve with age.

Julian S. Martin

Julian S. Martin, KA2GUN
Managing Editor

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Special Projects

Volume 1, No. 8 Fall 1983

The magazine for people who build electronic projects

24 DIGITAL SENSORS

Here is a designer-based article which will inspire the development of countless home-brew projects using sensors that detect changes in magnetism, light intensity, and temperature. Circuit details are complete!

26 DIGITAL DARKROOM TIMER

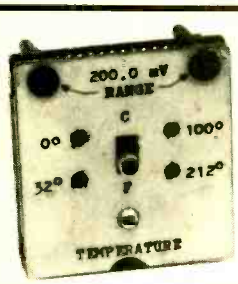
At last! A digital countdown timer designed for the photo buff's darkroom. Almost an identical counterpart for the mechanical clock, this timer offers 1- to 99-second periods.

42 M-1 MATRIX STEREO DECODER

Back in '58 audio buffs were talking about decoding L+R and L−R audio signals to get left- and right-channel hi-fi signals. Well, it's back again.

59 X10 PROBE

Set up the high-end voltage range with this 90-megohm probe. No—you don't have to modify the DMM. Just plug in the X10 you will increase the DMM's voltage range by a factor of 10.



73 TEMPERATURE PROBE

Plug this ultra-thin wafer-type gadget into the volts jacks of your DMM and you'll be measuring temperatures in either °F or °C with a passive circuit using a low thermal mass temp-probe.

90 DISPLAY CONTROLLER

This handy device can accurately measure frequencies +1 Hz from 1 to 999,999 Hz, can be built for under forty dollars, and can be used for a microcomputer-oriented counter/display system. Versatility makes it a winner!

4 LETTERS

We get letters from our readers and we share them with you.

89 NEW PRODUCTS

Take a peak at what's new in the marketplace for your shop.

CONTENTS/INDEX

LETTERS

SILICON VS. SELENIUM

I am planning to rebuild an old battery charger I found in the back of an old garage building. The selenium rectifiers are shot—it's easy to tell because someone rapped them with a hammer. So, I am going to replace them with some new silicon, high-current-capacity diodes. A friend cautioned me that I may be doing something very dangerous. Am I?
RALPH D.
Phoenix, AZ

Silicon rectifiers are inherently more efficient than selenium or other metallic-type oxide rectifiers. When a silicon rectifier is used to replace a selenium rectifier in a power supply, that supply will typically deliver higher DC output voltage than previously. The current capacity will increase some should the external load demand more current. I believe there will be no problem in the battery-charger circuit provided the original fusing values continued to be used. Also, you'll find that the circuit will consume less power for the rated output than previously delivered.

HE PICKED IT

Let's be honest—CP/M is the only way to go on any DOS so why is everyone coming up with his own system?
JAY Y.
APO New York, NY

It was Ben Franklin who took the same stand by saying that the carbon terminal of a wet cell battery was the positive terminal, and ever since we have had current going one way and electron flow going the other. Yes, CP/M is very good and has many basic programs written for it. But, there will come a day when someone will come up with CP/N followed by CP/O, CP/P, etc., that will surpass what we have presently. Also, the simpler computer systems manufactured by "toy" computer manufacturers make those computers possible and available because their retail price is so very low. Also, so many microcomputer systems are doing excellent work and performing well while not operating under CP/M, that the future is uncertain which way computer design will go. Who knows, a whole new microcomputer chip may be invented that will do away with CP/M entirely.

GOT ZAPPED AGAIN, AND AGAIN....

Man, I've got disk drive woes and the trouble seems to be the power line, because my woes multiply when the little woman runs her sewing machine. Please offer some suggestion and save my mind and our marriage. The sewing machine causes problem from any line in the house, so please do not tell me to move it.
B. MANN,
Olivenha, CA

First, give the Mrs. a hug hug. Now, about your problem—think of picking up a line isolator. Electronic Specialists, Inc., 171 Main Street, Box 389, Natick, MA 01760 has several units to select from. Drop them a note asking for spec sheets. Also, thumb through the advertisements in the back of ***Radio-Electronics***—*you may find other sources for line isolators. As for the sewing machine, it is causing problems because its brushes are arcing. Check out the motor. Replace the brushes and clean the commutator. You may want to install a commercial line filter on the AC power cord or add some filtering to the sewing machine internally.*

SOLDER TIPSTER

How come you don't warn your readers about the extreme care that should be used when soldering semiconductors into circuits? All the other magazines do?
DAN. R.
Liberty, NY

When we give the complete plans for a 30-chip circuit, we assume that an electronics experimenter has more than one or two successful projects under his belt. In fact, should he take on such a project, he should be writing articles for ***Special Projects.*** *When we run a story on a one- or two-transistor project, or a simple one- or two-IC device, you can be sure that we include some suitable warnings about the possibility of destroying a semiconductor. We are very much like other hobby-type books. For example, when an automative editor tells his readers to use a torque wrench on a certain nut, the reader who owns that wrench has had experience using it. He won't over-tighten engine head bolts. A degree of skill comes with the ability to undertake a specified project. But as the level of required skill diminishes, our instructions and warnings tend to increase.*

SO WATT'S A BJT?

Everyone knows what a FET is, but how many know what a BJT is? I use it all the time in my notes, but engineers who read them get confused.
ED B.
Ahoskie, NC

(Continued on page 6)

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2602-093

(Continued from page 4)

An FET is a field-effect transistor and an BJT is a bipolar junction transistor—the most common kind of transistor in use today. That's why no one knows what you are talking about. You would not specify a wood screw by using the term "righthand", however, you would specify a screw as "lefthand" when one is required, because it is the exception. So forget about that BJT designation and speak the language as everyone else does.

COST VARIATIONS

Why is it that common integrated-circuit chips in the very-common CMOS 4000 series vary so much in price from mail-order supplier to mail-order supplier?

N. SMITH,
Show Low, AZ

One supplier may have obtained his supply at a very low cost and is passing the saving on to the buyer, or he may be overstocked and want to dump his inventory by lowering prices. Of course, there is also the seller who wants to retire at an early age! The reasons are unimportant. What is important is that you pay less for your parts. Here is what you do. Make up an order of parts and price them out. Be sure to include shipping costs, taxes, etc. It would be logical to take the cheapest price, however, look into splitting the order provided you meet the seller's minimum order amount. By splitting your order you should be able to save a bit more cash. One other input should be considered and that is your previous experience with the mailer. Was he fast and accurate with no back orders? Were the parts in good condition and new? All those inputs are important when making your final decision. It's your bucks, so the buck stops with you!

METER MEASURING

What is a safe way to determine the DC resistance of an ammeter? I have a few salvaged units that do not indicate the meter sensitivity. All the formulas in the world won't help if you don't know the ammeter's internal resistance.

ALBETT R.
Irving, TX

Right you are? To begin, always assume you have a microammeter movement in your hands and proceed accordingly. If you are proved wrong, no damage to the meter will occur. Now, place a dry cell or low-voltage supply in series with the ammeter and a series rheostat rated at about 10,000-ohms and set at maximum resistance. Next, place a rheostat of about 10,000-ohms in parallel with the ammeter and leave one end disconnected. Slowly decrease the resistance of the series rheostat until the meter indicates a full-scale reading. If that occurs near the bottom of the series rheostat setting, a full-scale setting may be difficult to obtain, so replace the series rheostat with a unit rated at a bit more than the approximate setting in resistance previous attained. Try again! It will now be easier to obtain a full-scale indication on the meter with the series rheostat. Now connect the loose leg of the parallel rheostat and adjust it until a half-scale reading is obtained. Without upsetting the parallel rheostat setting, remove it from the circuit and measure its resistance—it will equal the resistance of the ammeter. You may have to play around with rheostat sizes, but you'll get the hang of it and make accurate meter internal-resistance measurements.

IN THE DARK

I'm working on automating my darkroom. What I'd like to do is control the tap water in my wash tank. After I wash the prints for a period of time, I'd like to warm the water a bit so my hands don't get so cold. I've licked the sensing, water-level, and timing-sequence problems, but can't get started on the servos for the water valves. Any ideas?

J. CAPLAN
Westboro, MA

Forget about servos—that's the hard way. Think of using water-control valves from a washing machine. For the first period, during the wash cycle, only cold water is admitted to the tank. Then, during the hand-dipping procedure, the hot-water valve opens to mix the desired temperature. Since all you want is the chill taken out of the water, temperature-

(Continued on page 100)

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DSP

TVRO Antenna Rotator

R. H. EATON

Special Projects
FALL 1983

Direct your satellite dish at any of the synchronous satellites now in geo orbit from inside your home!

A NEW OWNER OF A SATELLITE-TELEVISION RECEIVING SYStem may be content to use a stationary antenna mount and receive from one satellite source only. This feeling of contentment does not last long, however, when well meaning friends brag of their satellite-reception conquests. The capability to move from one satellite to another with ease requires an adjustable antenna mount and a remote, antenna rotator.

This article will discuss some design considerations for the antenna polar mount, a useful counterbalance weight, and an easily-built, antenna rotator.

A properly designed polar mount is quite satisfactory for supporting and aiming a TVRO antenna. The polar mount has the advantage that rotation about a single axis allows aiming the antenna toward any of the synchronous satellites now in use for U.S. television. An excellent discussion of the polar-mount geometry was published in the April, 1981 issue of *Coop's Satellite Digest by Ronald Waltner. (The illustrations were subsequently corrected in the June, 1981 issue).*

The polar mount can be fabricated from metal or wood,

FIG. 1—WITH THE POLAR AXIS pointed at the North Star, rotation about that axis will bring into the antenna's view all of the current TV satellites hovering over the U.S. To make the pivoting action of the antenna easier about the polar axis, a counterweight is added to balance the dead weight of the dish.

depending on the material and equipment available and the skill of the builder. A pair of ball bearings should be incorporated to minimize the forces required to rotate the antenna. A ¾-in. diameter shaft and a pair of ball-bearing pillow blocks, sold in most hardware stores for V-belt shafts, will work fine. It is important that the builder plan the polar-mount bracing to allow room under the shaft for a counterweight and antenna rotator.

Many TVRO enthusiasts have been deterred from installing remote-control rotators on their antennas because of the high cost of the currently available equipment. The cost can be kept down, however, by (1) balancing the antenna and thereby reducing the power requirements and (2) by taking advantage of available mass-produced, variable-speed reversible motors in the design of the antenna rotator.

Counterbalance Weight

Tracking antennas throughout the world have incorporated large counterbalance weights which reduce motor drive-power requirements. The TVRO antennas on the market today use powerful actuators to overcome the unbalanced forces that occur as the antenna is rotated each side of center. Why not hang a counterbalance weight on a arm under the polar axis and thereby reduce power requirements? It is feasible by proper selection of the weight and length of lever arm to correct all or part of the unbalanced condition. For example: a small weight on a long arm will be just as effective as a much larger weight on a short arm. It is easy to calculate the weight and lever arm appropriate for a particular antenna but why bother? Build as long a lever arm as your polar mount will accommodate and a box on the end of the arm, which can be filled with rock, gravel, or other weights until the degree of balance is achieved. It's as simple as that!

The author's antenna is mounted on the roof of his house due to lack of lawn space. (This cuts down the likelihood of theft and accidental damage.) The antenna weighs about 200 pounds and requires a little over one cubic-foot of gravel and stones on a vertical arm about 2½-feet long below the polar axis. (See Fig. 1.) The slope of the roof limited the length of the counterbalance arm in this installation. Most ground installations can accommodate a longer arm and thus require less weight. It is wise to construct the weight and the container that holds the weight so that no water from rain or snow is retained by the weight. Use fist-size rocks, course gravel and pebbles. Also, should you use a metal can to hold the weight, be sure to punch several holes in the bottom of the can to prevent the capture of moisture.

Selecting the Motor Drive

Variable-speed reversible motors and their controls are usually quite expensive, because they are made in small quantities. This antenna rotator is designed around the mass produced ⅜-in. variable-speed, reversible-drill motor available at most hardware and building supply stores for $25.00 to $35.00. The brand is not important; however, the following features make the conversion more successful:

The motor should be rated at about ⅓ horsepower or better. If the horsepower is not given, make sure the electrical rating of the motor is about three amperes or better. The variable-speed, trigger-type switch is usually built into the handle along with the reversing switch. Choose a drill which has the handle plug controls bolted to the rear of the motor. Thus, removal of the handle leaves the drill-motor assembly intact. If you are stuck with a drill motor which does not have a removable handle, the switch assembly can still be removed and a suitable switch mounting can then be fabricated. It is easier, however, to choose a drill motor with a removable handle which includes controls.

The four wires connecting the variable-speed and reversing controls to the motor should be marked so you can add in the proper length of heavy, four-conductor, rubber-covered wire to connect your drive motor at the antenna with the handle-mounted controls near your TV set.

Mounting the Motor Drive

The motor, minus the handle and control switches, is

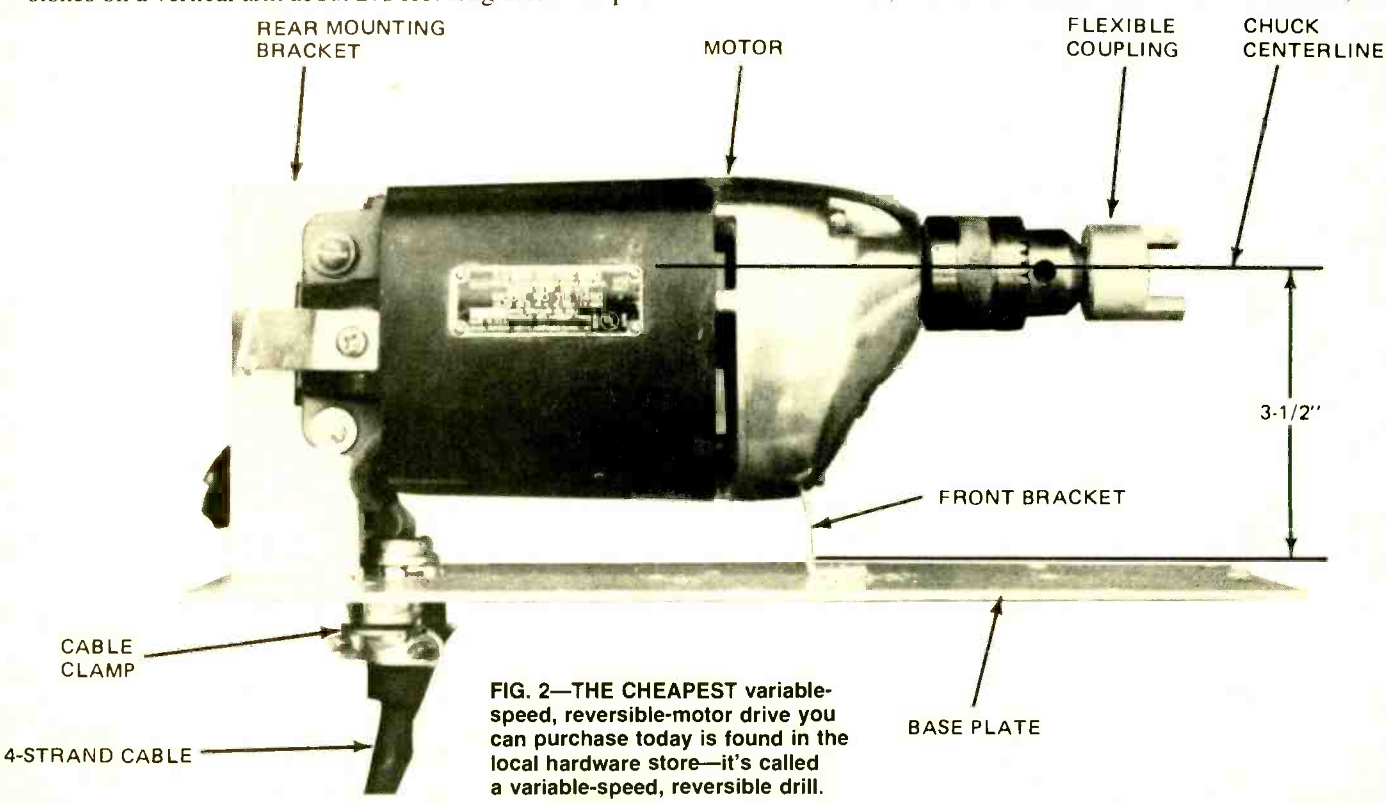


FIG. 2—THE CHEAPEST variable-speed, reversible-motor drive you can purchase today is found in the local hardware store—it's called a variable-speed, reversible drill.

mounted on a ⅛-in. steel baseplate 11½-in. long by 4½-in. wide. (See Fig. 2.) The rear mounting bracket can be fabricated similar to the attach points of the handle assembly. The front bracket can be a short piece of ⅛-in. steel strap fitted to one of the motor assembly bolts. The height of these two brackets should be trimmed to insure that the centerline of the chuck is parallel to the base plate and 3½-in. above the bottom of the base plate. The base plate should have a ½-in. by 2-in. notch cut out of one end to fit around the bearing mount.

A 1½-in. length of ⅜-in. bar stock with a ¾-in. long flat ground on one end is used to connect the drill chuck to the flexible coupling. The other half of the flexible coupling should have a ½-in. bore to fit directly on the rotator shaft. There is more than one way to make a flexible coupling. You could consider the possibility of a very stiff hose (rubber or nylon) to connect to the chuck and the lead screw. How you make it is best determined by you. Set the motor aside because the mounting holes will be drilled later, after the mounting brackets have been welded to the plate.

Rotator Assembly

The rotator assembly is shown in Fig. 3 and an assembly drawing in Fig. 4. The lead screw is made from ¾-in. stainless-steel, threaded bar stock (16 threads per inch) which can be purchased from mill suppliers or large industrial hardware stores. The only machining required is shown in Fig. 5 and described below.

Starting at the drive end turn the shaft to ½-in. diameter, 1½-in. long and then a ⅝-in. diameter shoulder for ⅛-in. Grind a flat for the flexible coupling set screw about ¾-in. long as shown in Fig. 5. The threaded portion is 22-in. long. Turn another ⅝-in. shoulder ⅛-in. long and finally a ½-in. shaft 5/16-in. long for the ball bearing.

The special cube nut which transmits the linear motion is made from a brass cube 1½-in. on a side. (See Fig. 4.) Drill and tap for a ⅜-in. threaded, brass rod all the way through the cube. Screw the brass rod into the cube leaving ½-in. protruding on each side. Drill and tap the cube for the ¾-in. diameter (16 threads per inch) lead screw at a right angle to the ⅜-in. rod. This will lock in the ⅜-in. brass studs. Lightly

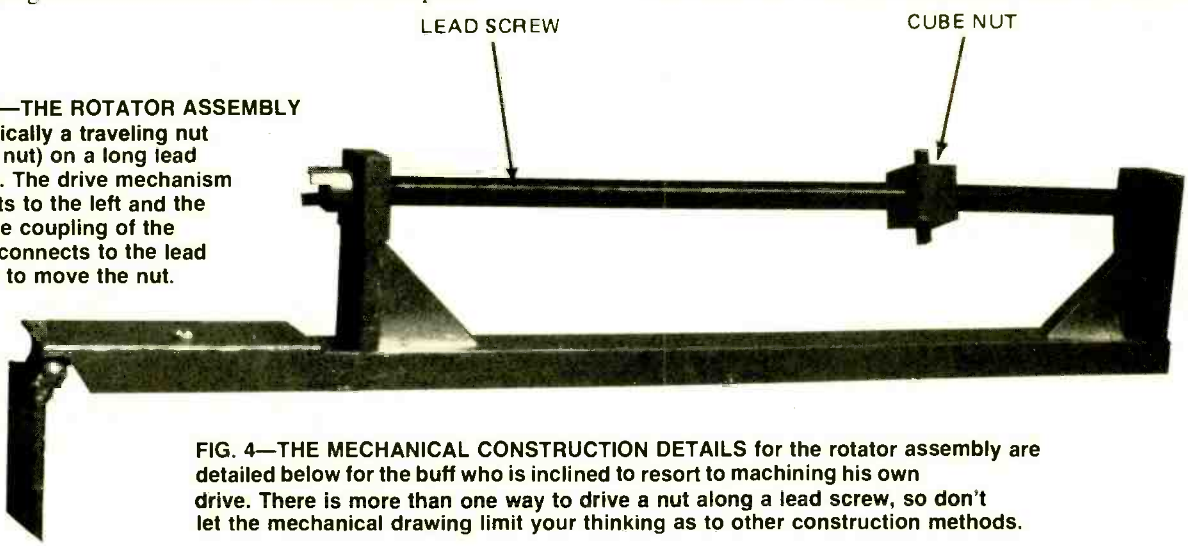
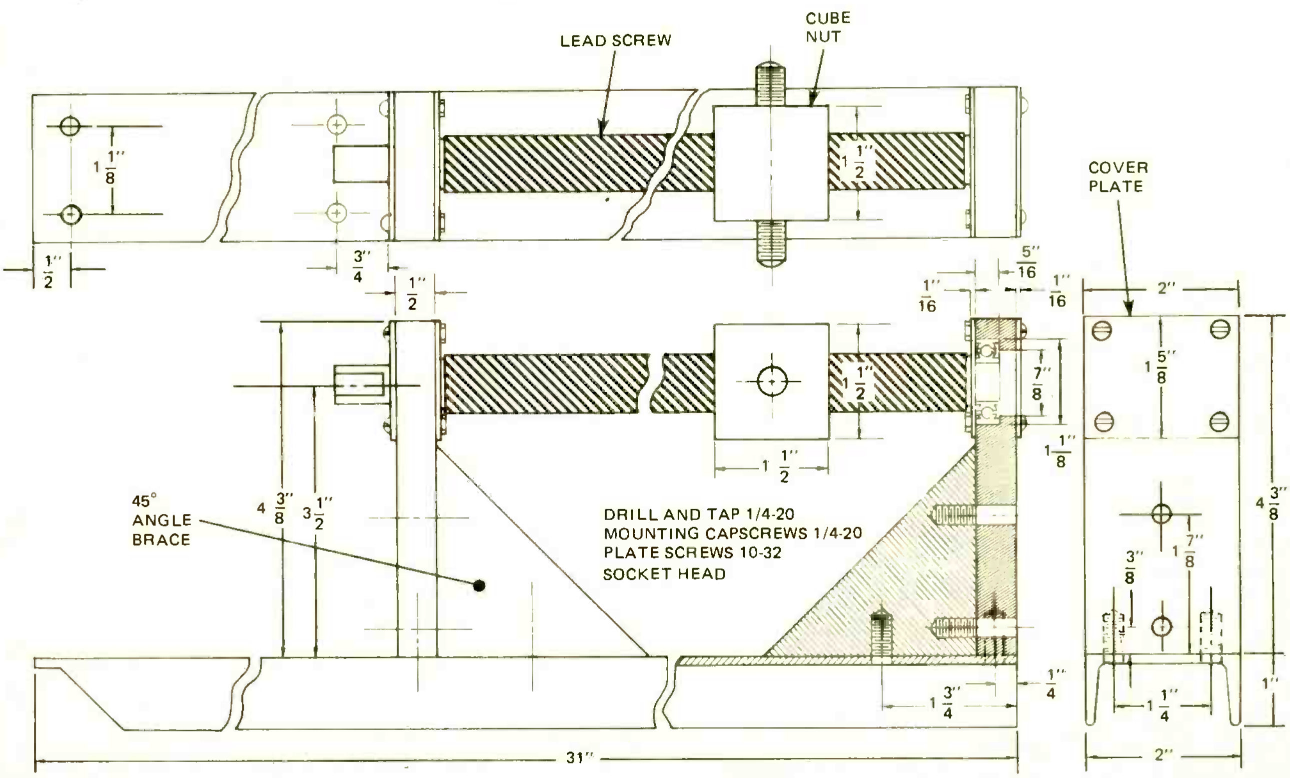


FIG. 3—THE ROTATOR ASSEMBLY is basically a traveling nut (cube nut) on a long lead screw. The drive mechanism mounts to the left and the flexible coupling of the drive connects to the lead screw to move the nut.

FIG. 4—THE MECHANICAL CONSTRUCTION DETAILS for the rotator assembly are detailed below for the buff who is inclined to resort to machining his own drive. There is more than one way to drive a nut along a lead screw, so don't let the mechanical drawing limit your thinking as to other construction methods.



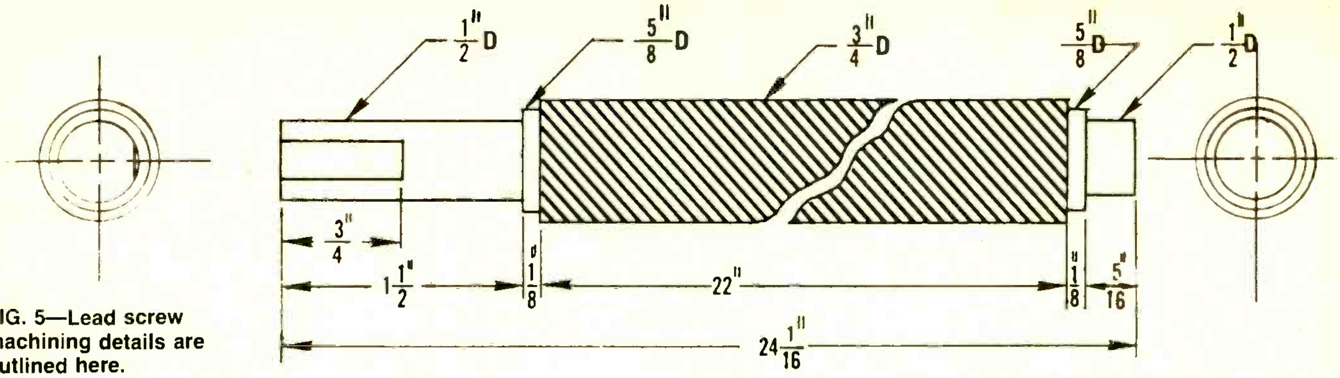


FIG. 5—Lead screw machining details are outlined here.

lubricate the inner threads of this nut with white grease similar to the Lubricate brand and install on the rotator shaft.

The two bearing mounts (see Fig. 4) and the two corner braces were fabricated from ½-in. aluminum plate because aluminum machines easily and does not rust. The bearing mounts require two pieces of aluminum plate 2-in. wide by 4⅜-in. long. The bearing cavity is formed by boring a ⅞-in. diameter hole through the mount 3½-in. up from the base end and a 1⅛-in. diameter bore to a depth of 5/16-in. The bearings are retained and sealed from the weather by four cover plates. These plates are cut from 1/16-in. sheet aluminum to a size of 1⅝-in. by 2-in. The two cover plates next to the lead screw require a ⅝-in. diameter hole ¾-in. up from the bottom edge. This hole will closely fit the ⅝-in. shoulder on the rotator shaft and thus help seal the bearing cavity. The end cover will remain blank since no shaft penetrates it. The cover at the drive end will have a ½-in. diameter hole to fit the drive shaft. All plates are drilled near the corners for the 10-32 screws which secure the cover plates on each side of the bearing mount.

The angle braces are 45-degree traingles 2¾-in. on a side. These should be fitted to the bearing mounting brackets as shown in Fig. 4 drilled and tapped for ¼-20 socket head screws and assembled.

The bearings chosen for the rotator shaft are the type R inch series with double shields. The number 77-R-8 bearings has a ½-in. bore, 1⅛-in. outside diameter, 5/16-in. width, is prelubricated and double shielded. It has been used for years and can be purchased at any bearing supply house.

Lightly lubricated the machined surfaces on the rotator (lead screw) shaft. Assemble the two cover plates on the ⅝-in. shoulders and press the two bearings on the shaft. Press the mounts on the bearings, fill the bearing cavities with grease to keep out water and bolt the cover plates in palce. Next set the assembly on top of the 2-in. channel and mark the location of the mounting screws. Bolt in place using ¼-20 socket head screws.

At this point the motor base plate should be clamped in place and the motor on its brackets checked for centerline height and alignment. Now the motor brackets can be bolted, brazed, or silver-soldered to the base plate. A hole should be bored through the base plate and an electrical cable clamp installed to fasten and seal the rubber-covered four-strand cable to the motor. Bolt the motor assembly to the channel and recheck motor alignment. (See Fig. 6.)

You now have completed fabrication and assembly of your antenna rotator, however, it must have a weather cover over the motor. A simple metal box 11½-in. by 4½-in. by 5-in. high with a 4¾-in. by 2-in. cut out int he end to fit over the bearing mount will be adequate. (See Fig. 7.) A narrow flange pointing inward around the bottom edge of the box allows it to be drilled and tapped for attachment to the motor base plate. In extreme weather conditions, gasket material or caulking compound can be used for weather sealing. The

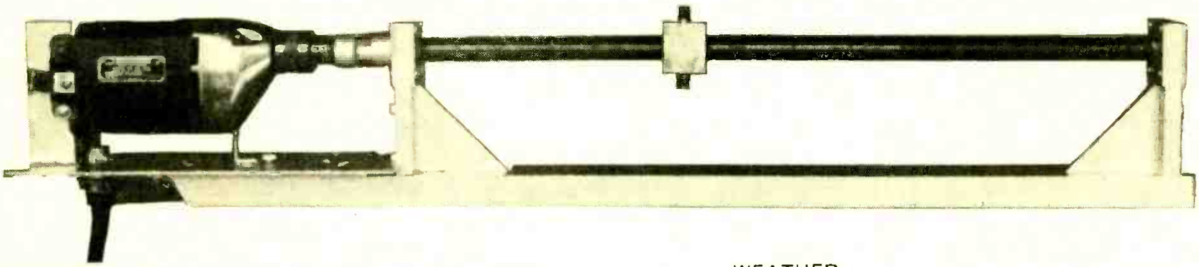


FIG. 6—THE MOTOR DRIVE is assembled on the rotator assembly and ready for checking. The drive shaft of the drill should coincide with that of the lead screw. Test this by driving the lead screw at maximum speed—the action should be smooth with no, or very little, mechanical noise or jamming.

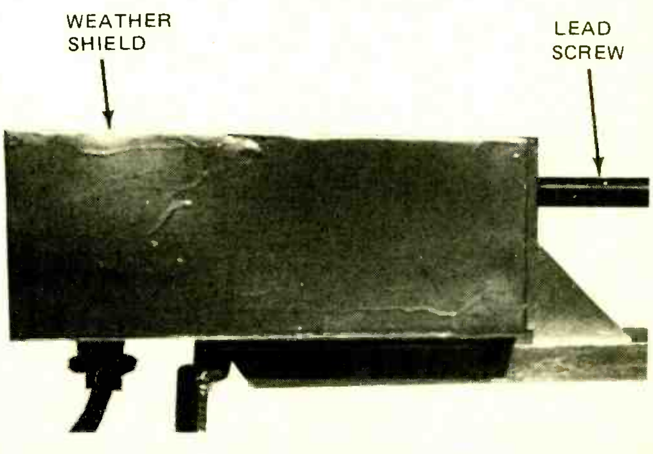


FIG. 7—THE MOTOR DRIVE is intended for indoor use; therefore, a suitable weather cover or shield should be placed over it to keep rain and snow from rusting the mechanism, or shorting the exposed electrical parts.

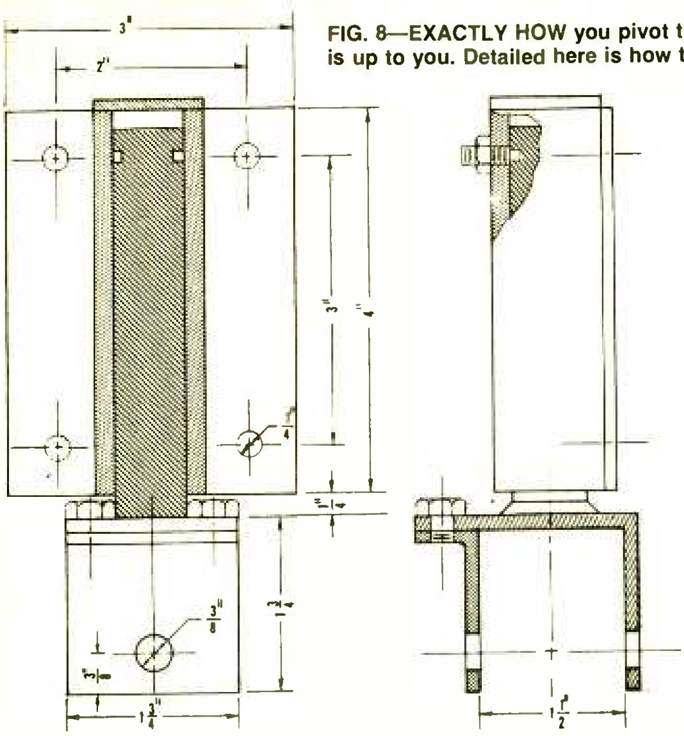


FIG. 8—EXACTLY HOW you pivot the end of the rotator assembly is up to you. Detailed here is how the author did it.

entire unit, except for the lead screw, should be degreased, primed, and painted.

Most of the fabrication of the actuator described above can be accomplished in a home workshop. The machine operations beyond the capability of the builder can be done by a local machine shop. The simplicity of these operations insures the lowest possible cost for these parts even though they are farmed out.

Mounting of the Rotator

Now that the rotator has been assembled, a look at the rotator mounts and linkage is in order. You will need a lever arm on your antenna that extends about 12-in. below and at a right angle to the polar axis shaft. (See Fig. 1.) Locate the positions of the arm when receiving from the two extreme satellites. Lock your antenna temporarily at the mid point between the two end positions. The rotator should be mounted so that the special brass nut (See Fig. 4) is at the mid point of the lead screw, and the lead screw is at right angles to the antenna arm.

The rotator should be attached to the polar mount by a hinged bracket. The lead screw nut is fastened by a swivel connector to the antenna lever arm. (Fig. 8) The swivel connection accommodates slight misalignments of the rotator assembly and prevents binding of the lead screw.

Visual Indicator

A foolproof indicator of satellite positions can be fabricated by cutting out a quadrant of a 24-in. circle from thin sheet metal, painting it white and mounting it under the polar axis where it can be seen. Fabricate a long pointer (about 10-inches long), paint it black and attach it to the rotating antenna base. See Fig. 9. Use your signal strength meter to indicate when you are centered on the satellite. A digital voltmeter across the posts of the signal strength meter increases the accuracy of this reading. Cut some strips of black electrical tape the same width as the pointer (about ¼-in.). After the satellite has been located, apply the tape to line up with the pointer. In operation the satellite position can be found by aligning the pointer with the tape and then fine tuning by watching for the optimum picture as you slightly move the antenna.

The antenna rotator described here has been installed on the roof of the author's home for about six months and has performed without trouble. It takes ten seconds to swing the antenna from SATCOM 1 to 135° longitude to SATCOM 4 at 83° longitude. Control is smooth and reversing easy. The only maintenance required is periodic lubrication of the lead screw with white grease to insure smooth operation and long life. **SP**

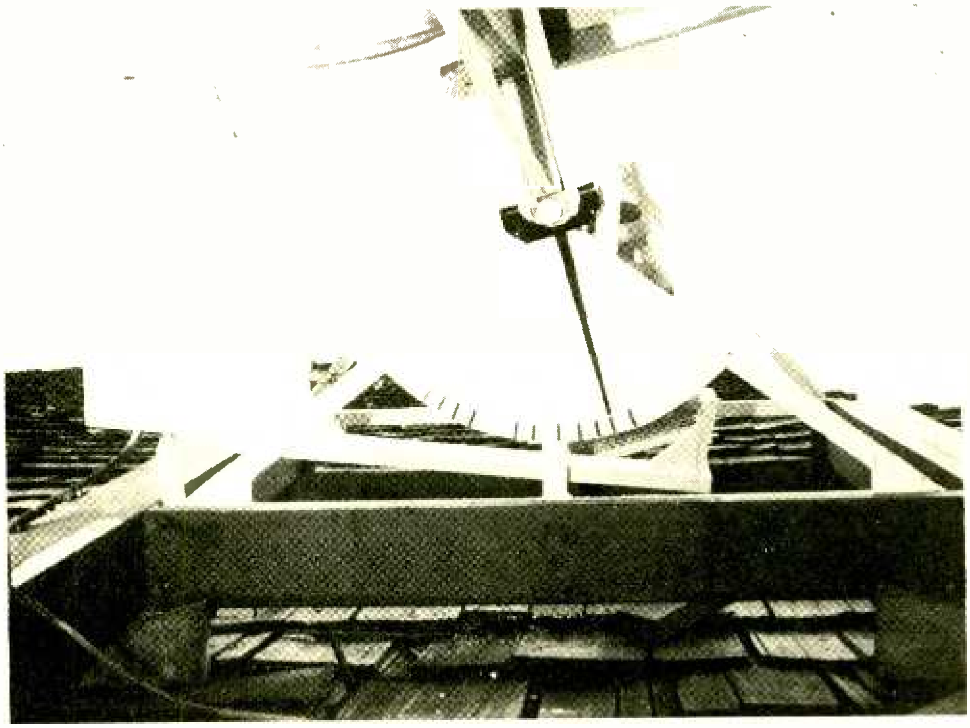
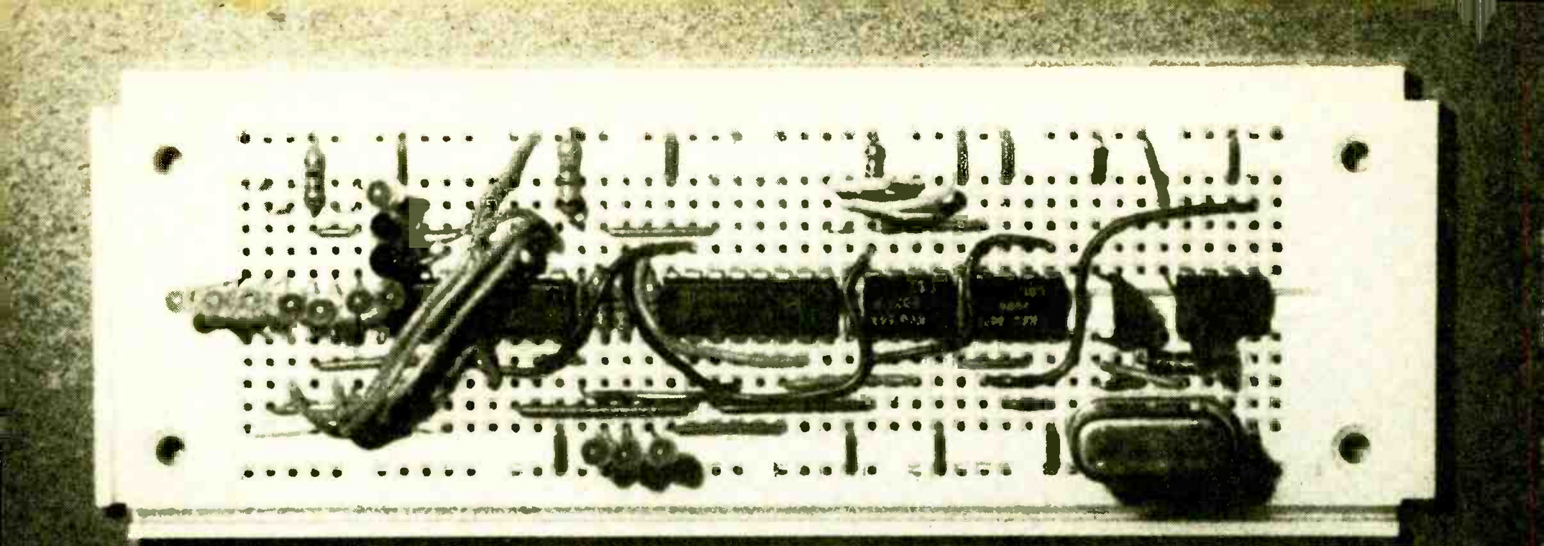


FIG. 9—DO YOU NEED an angle indicator? That is for you to decide. Should one be necessary, follow the author's design—his is simple to build. Rather than indicate angles by degrees, the author thought it wiser to mark angles where satellites will be found. Of course, you may want to install an indoor angle indicator, the plans for which we will leave entirely up to you!



ONE-BY-ONE SEQUENCER

You pick the period, and the timed outputs

EDWARD M. NOLL

☐A DIVIDE-BY-10 COUNTER INTEGRATED CIRCUIT CHIP, SUCH AS the CMOS 4017, can be operated as a sequencer that generates timed outputs or controls the turn-off events in a sequential manner. Operating sequences can be linked to real time using a clock generator chip and counter combination. Here are the details of a useful and practical circuit we call the One-By-One Sequencer.

The block diagram of the One-By-One Sequencer is given in Fig. 1. The 60-Hz output of the crystal-controlled clock generator is applied to a clock counter. The clock counter chip is a type that will produce an output corresponding to specific time intervals such as 1 second, 6 seconds, 1 minute, etc. The third chip is a counter that acts as a decade timer multiplier. This multiplier can be programmed for 10X, 100X, 1000X or 10,000. The final stage is the sequencer which will produce outputs in sequence that have a time duration corresponding to the time interval supplied from the multiplier. For example, there could be ten sequential outputs spaced by one minute. At the end of the ten-minute interval the entire process is repeated again and again.

Two small LSI Computer System, Inc. 8-pin, CMOS, integrated-circuit chips are used as the clock counter and addressable divider (decade multiplier). Five convenient chips are available for developing an output of a specific time segment, as shown in Fig. 2A. Each can be made to divide properly for either 60-Hz or 50-Hz power. When pin 7 is at logic 0 (grounded), the chip is programmed for dividing 60-Hz frequency; a logic 1 (high) connection to pin 7 sets up the proper division for 50-Hz power. In the circuit that follows the RED 300/360 chip is used and produces a 6-second output. Actually this is a period of 1/60th of a second × 360 or 6 seconds (.1 minute).

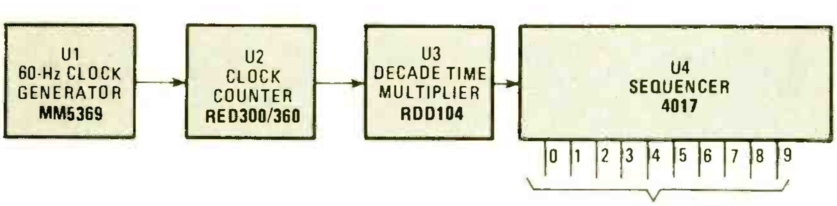
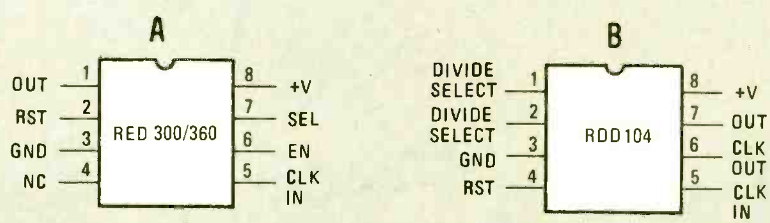


FIG. 1—BASIC BLOCK DIAGRAM for the One-By-One Sequencer. The basic timing element is a 3.58-MHz television crystal oscillator circuit.

FIG. 2—SPECIFICATIONS for the LSI Computer Systems, Inc. RED300/360 and RDD104 integrated-circuit chips. The RED300/360 divides down the 60-MHz input to a 6-second output. The RDD104 offers addition time division of 10 to 10,000 in increments of 10^1, 10^2, 10^3 and 10^4.



RED SERIES	DIVIDE BY
RED 5/6	5 OR 6
RED 50/60	50 OR 60
RED 100/120	100 OR 120
RED 300/360	300 OR 360
RED 3000/3600	3000 OR 3600

PIN 7: HIGH -50 Hz; LOW -60 Hz

PIN 2	PIN 2	OUTPUT DIVISION
0	0	÷10,000
0	1	÷1000
1	0	÷100
1	1	÷10

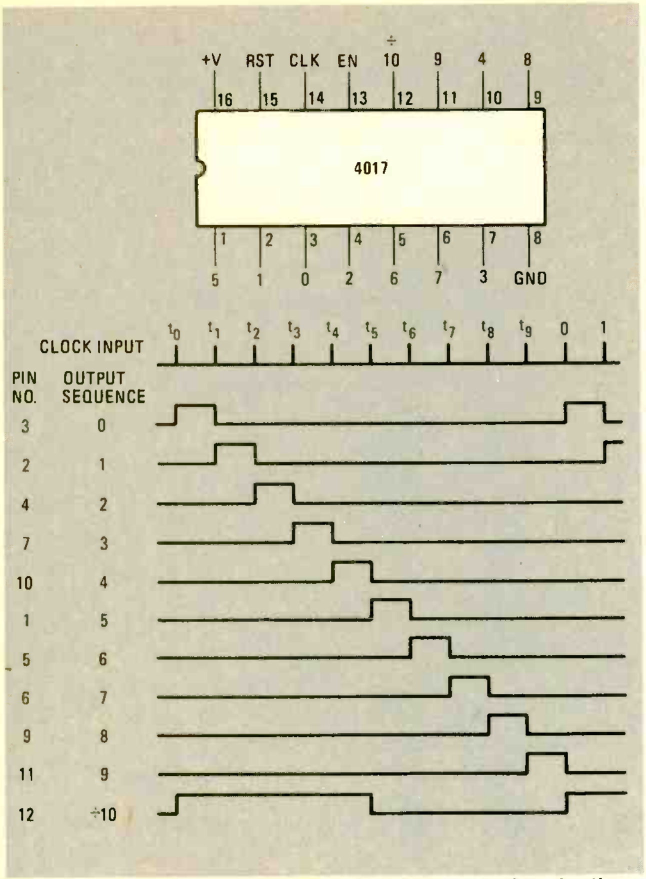


FIG. 3—THE 4017 SEQUENCER outputs compared to the time-input squarewave. Be sure not to confuse the "divide by" numbers with the pin numbers.

The second CMOS integrated-circuit chip that serves as the time multiplier is the RDD104 addressable (programmable if you wish) divider as shown in Fig. 2B. The division established depends upon the logic applied to pins 1 and 2 as shown in the table below the pinout diagram in Fig 2A. A logic 1 applied to both pins produces a time period multiplication of ten (10) up to a multiplication of ten thousand (10,000) when both pins are at logic 0.

In the first setup of the sequencer the addressable divider (RDD104) will be set for a division of 10. Since the output time of the RED300/360 chip is 6 seconds, the additional multiplication of 10 will produce an output at the RDD104 pin 7 of 60 seconds (6 × 10) or 1 minute. In effect, the period of the squarewave that will be applied to the sequencer integrated-circuit chip (4017) will be one minute.

Making Waves

The pinout diagram and the basic waveforms of the 4017 decade decoder are given in Fig. 3. This chip is synchronized by the leading-edge transition of the squarewave clock applied to pin 14 from the output of the decade time multiplier chip (see Fig. 1). As mentioned previously the period of this clock is one minute. Therefore, the time interval between the leading edges, as shown in the clock waveform, is one minute. At time t_0 there is a positive output of one-minute duration at output 0 (pin 3). Exactly one minute later, at time t_1, there is a one-minute positive pulse that starts at output 1 (pin 2). In this one-minute time sequence one-minute pulses appear at the remaining right decoder outputs of the 4017 ending with the output 9 one-minute duration pulse that completes the entire sequence. The output then returns to output 0 to repeat the sequence.

In addition, there is an output squarewave at pin 12 which is a 10-minute period. In effect, the 4017 has acted as a divide-by-ten counter insofar as this output is concerned. (Jump ahead to Fig. 4.) Note that its output at pin 12 will be logic 1 (LED1 illuminated) for five minutes and logic 0 (LED1 dark) for five minutes.

It is important to understand that for the outputs 0 through 9 there is only one output active at any interval of time. Outputs are of one-minute duration and sequence at one-minute intervals. Furthermore, the timing sequence is conrolled by the input clock. If the preceding count activities were to supply a clock with a one-second time interval, the decoder output will be 1-second pulses spaced in time by 1 second. Refer again to Fig. 3.

Sequencer Circuit

The One-By-One Sequencer schematic diagram is shown in Fig. 4. At the top left is the familiar MM5369 integrated-circuit chip, U1, that generates a precise 60-Hz output from a 3.58 MHz color-burst crystal. Capacitors C1 and C2 can be adjusted to obtain a very exact 60-Hz output squarewave. The succeeding RED300/360 clock counter chip, U2, is advanced by the negative transition of the 60-Hz clock applied to pin 5. The output period at pin 1 is 6 seconds and this squarewave is applied to pin 5 of the RDD104 addressable-divider chip, U3. Again, the negative transition advances the clock. In as much as pins 1 and 2 of U3 are connected to the supply voltage (logic 1) there will be a time interval multiplication of ten producing a 1-minute (60-seconds) squarewave at output pin 7.

Since the 4017 integrated circuit chip, U4, advances on positive transition rather than a negative, a 4049 CMOS hex-inverting buffer and TTL driver, U5,links the 1-minute output to the clock input of pin 14, U4. In so doing the system t_0 times are properly aligned.

At the lower right of Fig. 4 are three inverters, U5, and

PARTS LIST
FOR ONE-BY-ONE SEQUENCER

SEMICONDUCTORS
LED1-LED13—Light-emitting diode, 20-mA-type, any color
U1—MM5369 CMOS clock-generator integrated-circuit chip
U2—RED300/360 CMOS .1-minute output clock-generator integrated-circuit chip (LSI Computer Systems, Inc.)
U3—RDD104 CMOS addressable-divider, integrated-circuit chip (LSI Computer Systems, Inc.)
U4—4017 CMOS divide-by-10 counter with 1-of-10 outputs (synchronous) integrated-circuit chip
U5—4099 CMOS, hex, inverting-buffer and TTL-driver, integrated-circuit chip

ADDITIONAL PARTS AND MATERIALS
C1—3-30-pF trimmer capacitor
C2—30-pF disc capacitor
R1—22-Megohm, ¼-watt, 10% resistor
R2—10,000-ohm, ¼-watt, 10% resistor
R3-R6—330-ohm, ¼-watt, 10% resistor
S1, S2—SPST pushbutton switch, normally open
X1—3.58-MHz TV crystal
4-dry cells, solderless breadboard, wire, etc.

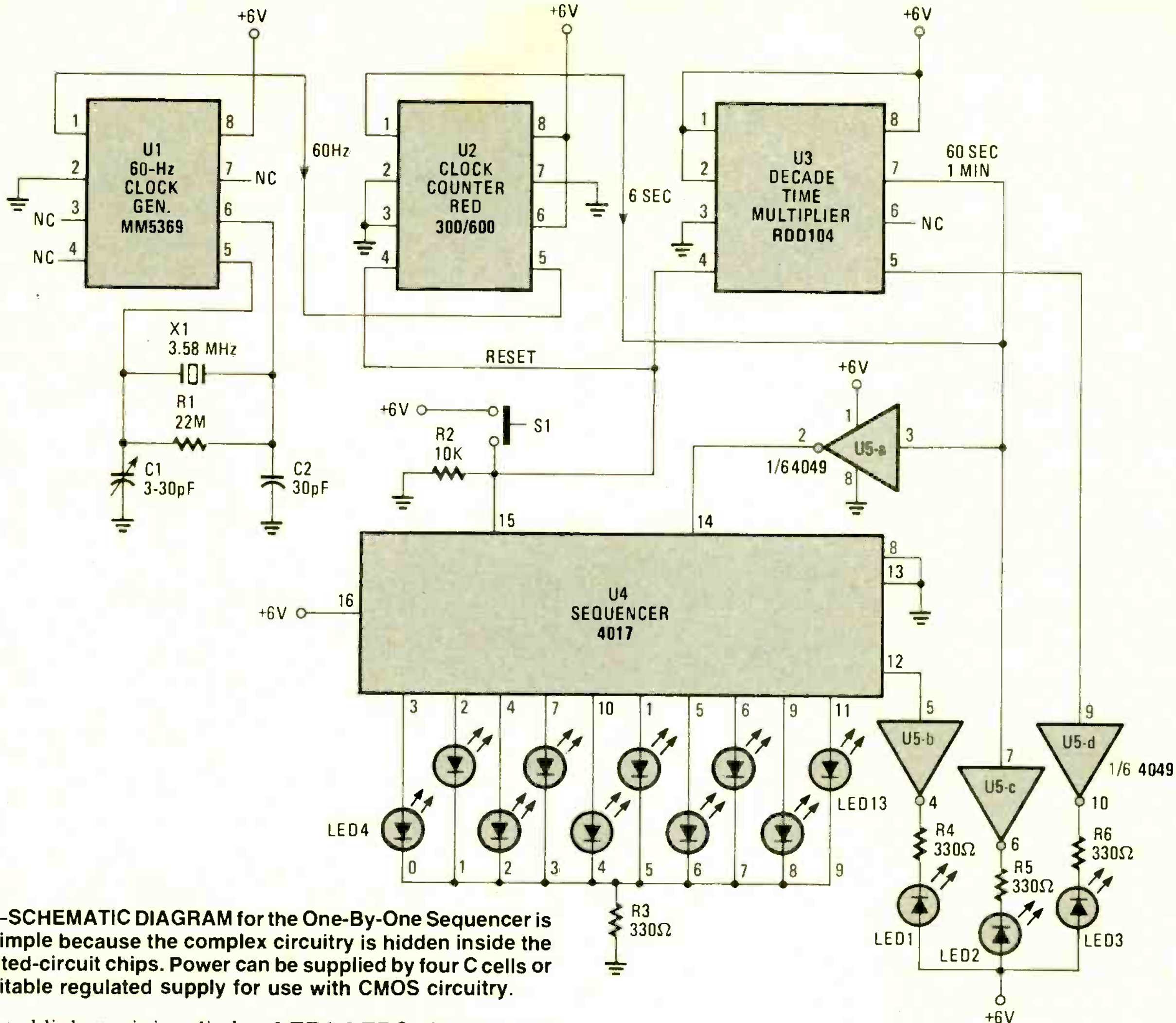


FIG. 4—SCHEMATIC DIAGRAM for the One-By-One Sequencer is quite simple because the complex circuitry is hidden inside the integrated-circuit chips. Power can be supplied by four C cells or any suitable regulated supply for use with CMOS circuitry.

associated light-emitting diodes, LED1-LED3, that monitor the 6-second and 60-second outputs as well as the divide-by-10 output of U4. The LED on/off activities will permit you to monitor and measure the appropriate time intervals.

A reset capability includes pushbutton switch S1 to apply a momentary logic 1 to each divider, U2 and U3, as well as the 4017, U4. Consequently, whenever S1 is depressed, the timing will be returned t_0. In conjunction with a analog or digital timepiece, the pushbutton can be depressed to match with any desired real time.

To demonstrate operation of the One-By-One Sequencer, individual light-emitting diodes (LED4-LED13) are connected to each of the ten decoder outputs of U4. Only a single 330-ohm, current-limiting resistor (R3 in Fig. 4) is needed because only one output is active at any one moment. If you arrange the LED's in a numerical order, you can observe the LED's illuminate in sequence between outputs 0 and 9.

Hook It Up

Wire the circuit illustrated in Fig. 4 and check its operation. Instead of the sequencing LED's, inverting (4049) and non-inverting (4050) buffer integrated-circuit chips can be connected in their place to the individual outputs of the 4017,

(Continued on page 99)

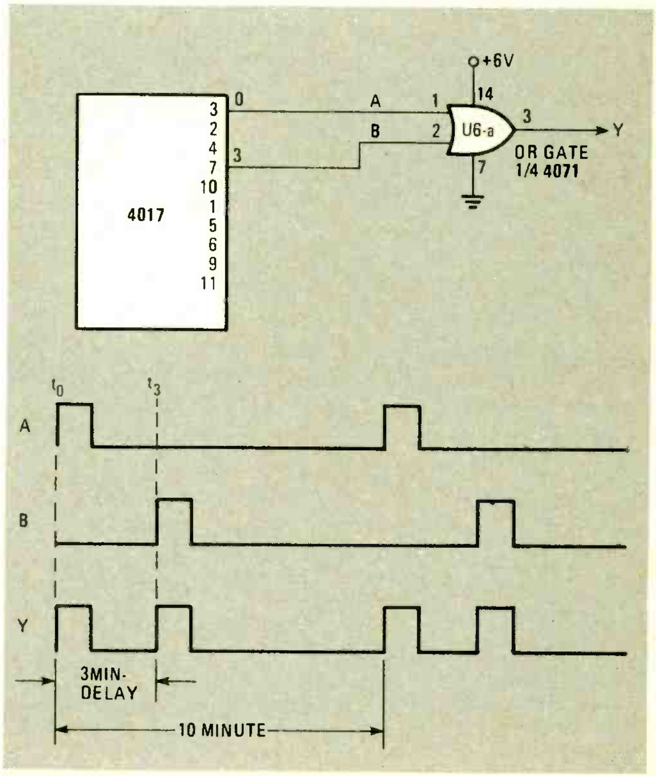


FIG 5.—ASYMETRICAL SQUAREWARE and unevenly-spaced squarewave outputs are possible with the One-By-One Converter with the addition of simple external circuitry. Here is a 3-minute pulse occurring after the initiation of a ten-minute pulse.

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HERB FRIEDMAN

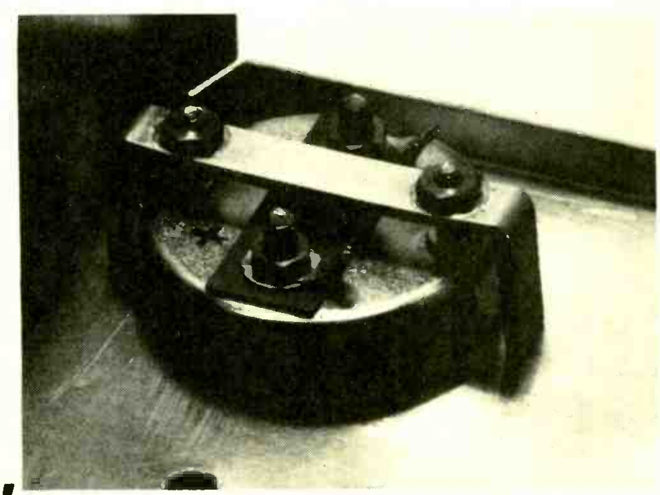
☐ONE OF THE HARDIEST GADGETS YOU CAN HAVE AROUND THE shop is a regulated, variable-voltage, DC power supply for the popular-experimenter voltage range of 5 to 15 volts DC—which covers everything from TTL logic to operational amplifiers and CMOS circuits. Unfortunately, if you have priced a modern, store-bought power supply you have gotten a good understanding of the meaning of the word "greed." It sounds like the old joke, but it often appears as if the numbers on the power-supply price stickers automatically increase in the dark of night.

However, if you're willing to spend a little time searching for surplus parts, and you use some old hardware you might have lying around the shop, you can put together a very convenient regulated variable-voltage power supply for a fraction of the cost of a commercial model. Should you be real lucky, the parts may sitting in your junkbox now, or in some project that has not been used for some time.

Just such a power supply is the Varyvolt shown in the photographs, which provides a metered-output voltage that's user-adjustable from 5 to more than 15-volts DC (maximum voltage depends on the particular parts you use). The output current is limited to 1-ampere DC by the maximum rating of the integrated-circuit regulator. The filtering is substantial, and the supply can be used to power a super high-gain audio amplifier without worry about introducing hum; what you hear is what you'll get if you later use batteries to power the amplifier.

How 5 Becomes 15

Though the IC regulator, U1, is rated for 5-volts DC output, we "rubber" the output voltage by applying a "compensating" voltage to pin 3 of U1. Normally, pin 3 is grounded, and the output at pin 2 is a regulated 5-volts DC. But by applying a voltage to pin 3—derived from the adjustable voltage divider consisting of resistor R1 and potentiometer R2—we can adjust the output voltage upwards from



MANY OF THE MOVING-VANE meters sold on the surplus market are secured by a U-bracket on the back of the meter. To avoid damage, don't try to run the bracket's nuts all the way down. Make them just tight enough to secure the bracket, and then make an additional half turn.

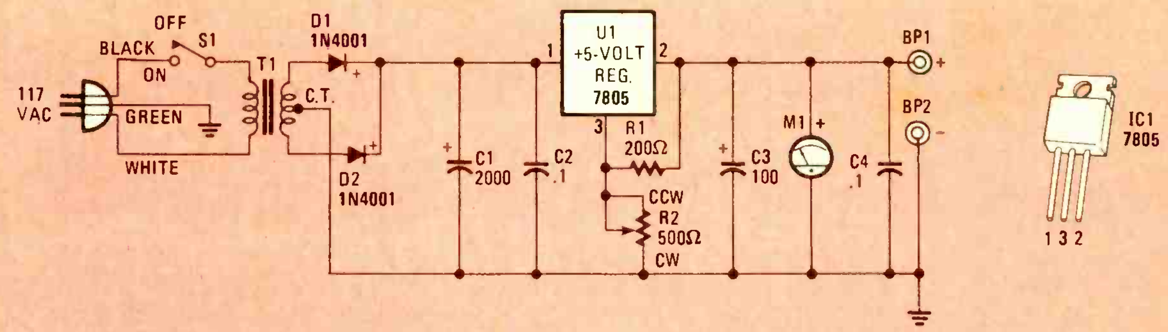


FIGURE. 1—THE SCHEMATIC DIAGRAM for Varyvolt is simple to follow and understand. There is considerable latitude in parts values that may be used, so refer to the text should you not have available the values specified in the Parts List.

the rated 5 volts to a usable 15-volts DC.

Consider for a moment that R2 is fully rotated anti-clockwise, thereby grounding pin 3; the regulator functions normally and the output voltage is 5 volts. Advancing R2 applies a small voltage to pin 3. The regulator attempts to maintain 5 volts between pins 2 and 3, so the output voltage at pin 2 is 5 volts plus whatever voltage is applied to pin 3. For example, if R2 is set so that 4 volts is applied to pin 3, the output voltage from pin 2 to ground is 5 volts + 4 volts, a total of 9 volts. It's a trick that fools U1 into becoming an "adjustable" voltage regulator.

Shopping for Bargains

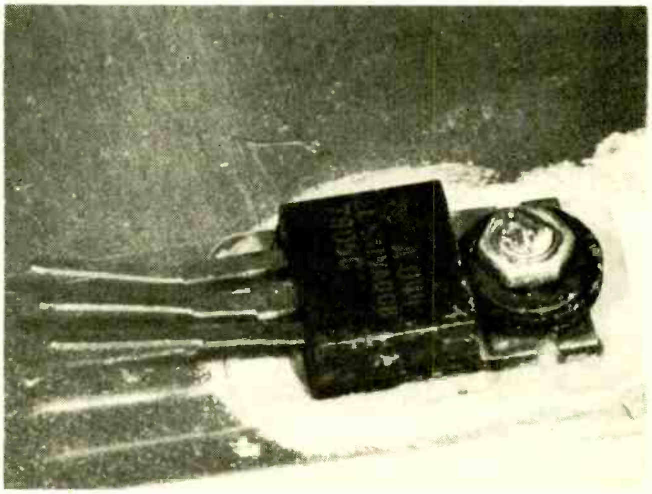
About the only thing "new" in the project is the cabinet. The 7805 5-volts/1-ampere regulator, integrated-circuit chip is available from Radio Shack should you not have a spare one in the junkbox.

Much of the expensive hardware is obtainable at bargain prices from the surplus dealers who advertise the **Radio-Electronics** magazine. For example, have you priced meters lately? Ten dollars is not unusual for a "new" meter. The meter used in the Varyvolt, however, is an old design picked up for less than five dollars when first used in another project. It has a 30-volt scale when Varyvolt's maximum output voltage is 16 volts, and it does have an old-fashion look; but the scale calibration is more than adequate, and appearance isn't worth five dollars or more for something that will be used on the workbench. Compromising now and then keeps costs down to rock bottom.

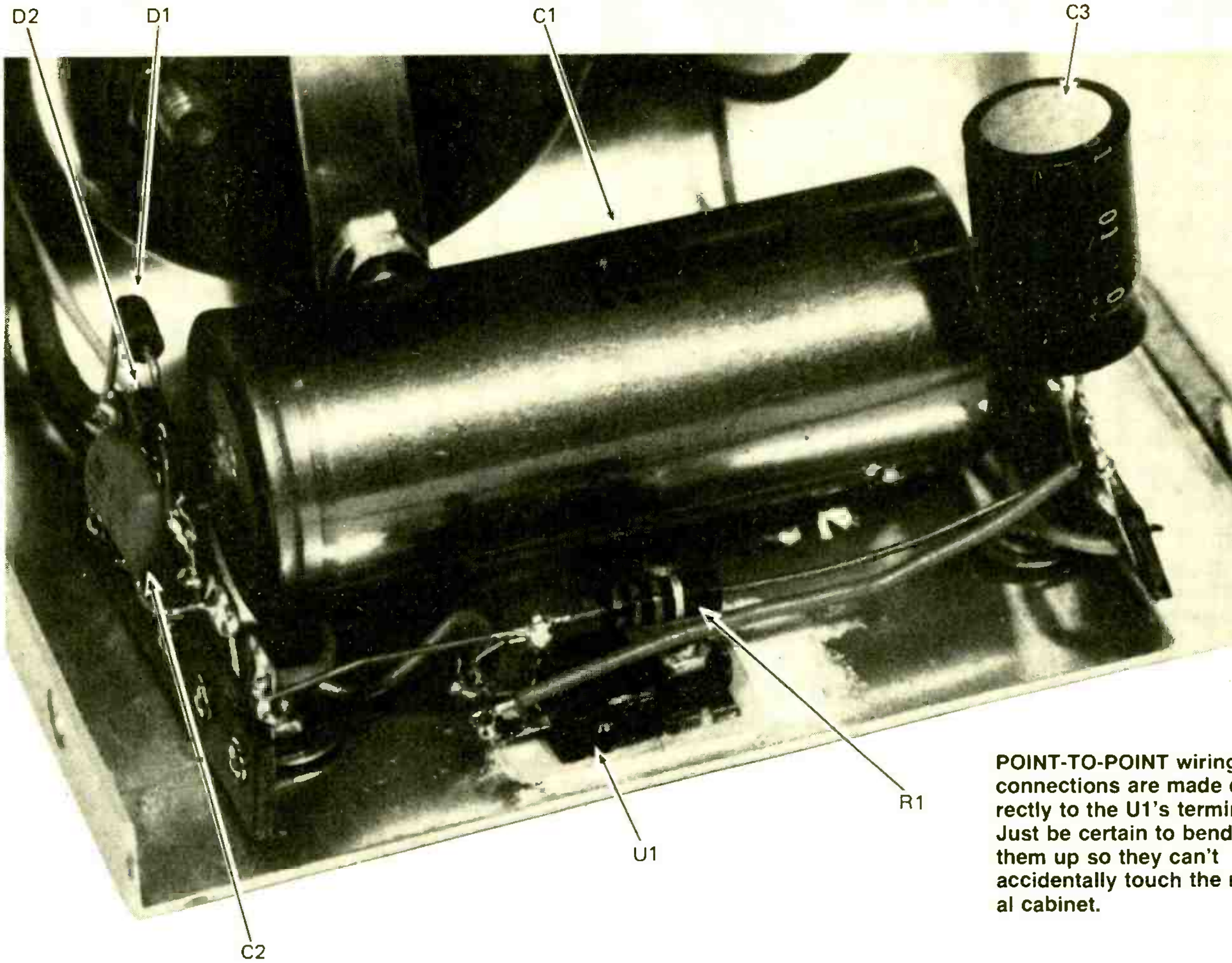
The power transformer, purchased two projects ago, was another bargain- $2.50 for 117-volts AC primary winding and a secondary winding rated at 40-volts AC center-tapped at 2 amperes. The center-tapped secondary permits the use of a full-wave rectifier using 10-cent silicon diode.

Once past the expensive hardware, nibble away at the prices of the less expensive components to save quarters and dimes, for they eventually add up to big bucks. For example, selective browsing in the local surplus house produced a 2000-μF filter capacitor (C1) for 69 cents, which is a heck of a buy when you consider that a 100-μF capacitor with the same voltage rating costs 79-cents at Radio Shack. The author paralleled a few electrolytic capacitors from the junkbox until the 69-cent buy popped up. Dimes and quarters you save on individual components add up quickly. With careful shopping you can end up with a regulated supply that cost you less than $20.

NEVER TRUST A FLUSH METAL CONTACT SURFACE to provide the necessary heat transfer to cool a power or high-current semiconductor. Heat sink compound, a silicone-based grease fills the voids between apparent flat metal surfaces and promotes the rapid transfer of heat. Be sure there is plenty of grease and no air bubbles.



YOU MIGHT RUN U1 at its maximum rating of 1-ampere, so make sure that you have an optimum heat sink by using heat-sink compound or silicon grease at the mounting location. It might look messy but this is the way the area around U1 should appear when you're finished. You can mop up the excess grease with a paper towel.



POINT-TO-POINT wiring connections are made directly to the U1's terminals. Just be certain to bend them up so they can't accidentally touch the metal cabinet.

Building the Varyvolt

Virtually nothing is critical in the selection or placement of parts. Use whatever you can scrounge from the junkbox or purchase at rock-bottom cost. Any DC voltmeter, of any design, that covers at least 15-volts DC can be used. Similarly, any power transformer between 30- and 48-volts center-tapped rated at least 1-ampere, can be used. If you can't get a center-tapped transformer you can use a single-ended model (no center-tap) and a bridge rectifier. Should your transformer have no center-tap, the secondary voltage should be 18- to 24-volts DC. Do not go over 48-volts DC center-tapped or 24-volts DC with no center tap on the secondary winding because C1's working voltage (WVDC) rating will then have to be higher than 35. That will require a more expensive and physically larger capacitor, which will probably necessitate a larger and more expensive cabinet. You've got to make trade-offs to keep the total cost down.

The cabinet used for the model shown in the photos is a 3- × 4- × 5-in. aluminum chassis box. Be careful if you purchase a new cabinet because the price varies from about $2.75 to almost $6 for the very same cabinet; it depends on the individual store and whether the cabinet is "surplus" or "fresh" stock. The power supply itself is completely assembled on the main section of the cabinet.

Power transformer T1 is installed on the bottom of the cabinet so that its weight keeps the cabinet upright with the right amount of heftability. A small terminal strip at one mounting screw is used for the AC power line.

Make certain that there's room behind meter M1 for filter-capacitor C1. If you're using an extra-deep meter, and you doubt whether C1 will fit behind the meter, you'll probably have to use a larger cabinet.

The meter shown in the project is a "moving vane" type that mounts somewhat differently from the usual experimenter's meter. Instead of mounting screws passing through the panel, the meter is secured by a metal U-bracket on the back of the meter. When the U-bracket's mounting nuts are tightened they pull the U-bracket against the back of the cabinet, causing the meter to lock in position. If you're new to electronics construction, you probably haven't run across that kind of meter or mounting before; but a lot of those

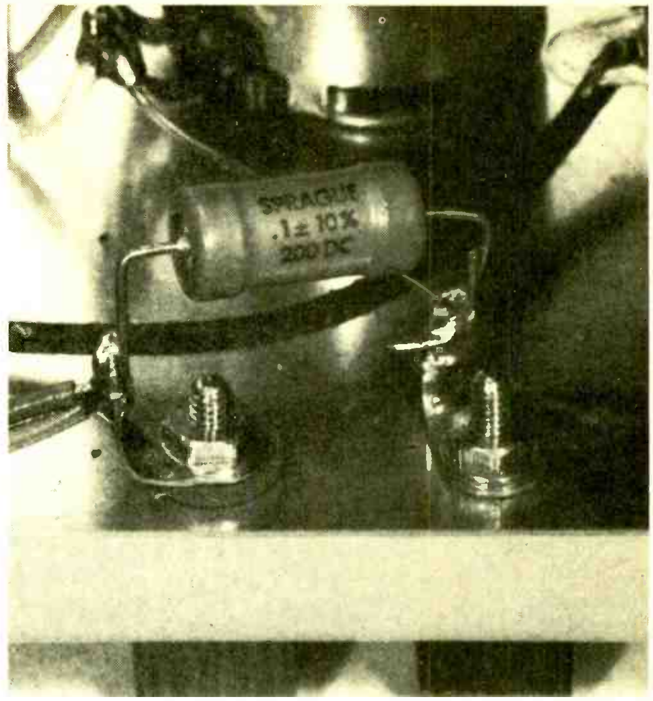
PARTS LIST FOR VARYVOLT

SEMICONDUCTORS
D1, D2—1N4001 rectifying diode, or equivalent
U1—7805 +5-volt regulator integrated-circuit chip

RESISTORS
R1—200-ohm, ½-watt
R2—500-ohm potentiometer, linear taper

CAPACITORS
C1—2000- to 3000-μF, 35-WVDC electrolytic
C2, C4—.1-μF, 100-WVDC Mylar or tubular
C3—100-μF, 35-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
BP1, BP2—Multi-way binding post, one red and one black
M1—DC meter, 0-15-volts DC or higher, see text
S1—SPST toggle switch
T1—Power transformer; 117-volt AC primary winding, for secondary winding—see text
TO-220 mounting hardware kit, Aluminum chassis box, terminal strip, decals, hardware, solder, wire, etc.



DO NOT ELIMINATE the .1-μF capacitors. A good location for C4 is directly across the Varyvolt's output terminals. The .1-μF capacitors can be Mylar, tubular, ceramic, or whatever you have, *except* Tantalum types.

meters are appearing in the surplus market at attractive prices, so you might as well get used to the "unusual" mounting and the savings.

U1, the integrated-circuit voltage regulator, uses the cabinet as a heat sink. Since its combination mounting tab and heat sink is connected to pin 3, U1 must be insulated from the metal cabinet. An inexpensive TO-220 mounting hardware kit, available from Radio Shack, provides all the needed mounting hardware: a mica insulator, an insulated shoulder washer, and a matching screw and nut. The mica insulator is placed between the body of U1 and the cabinet; both surfaces should be lightly coated with silicon grease to provide maximum heat transfer to the cabinet. Radio Shack also sells a small, inexpensive tube of silicon grease. The shoulder washer is supposed to fit into the hole in U1's tab; it probably won't. Whoever picked the hardware for the kit has never had any idea of what the correct size washer should be. You will probably have to drill or ream U1's hole slightly larger and file a flat on the washer so it clears U1's body. If you can locate the correct size shoulder washer at your local electronics parts house, by all means make the substitution.

Terminals strips are used to secure the remainder of the components. Just make certain that the capacitor you use for C1 fits in the available space; if not, either use a larger cabinet or get a physically smaller capacitor. Usually, the difference in size between a 35-volt DC electrolytic capacitor and a 50-volt unit is substantial, so try to use a 35-volt size.

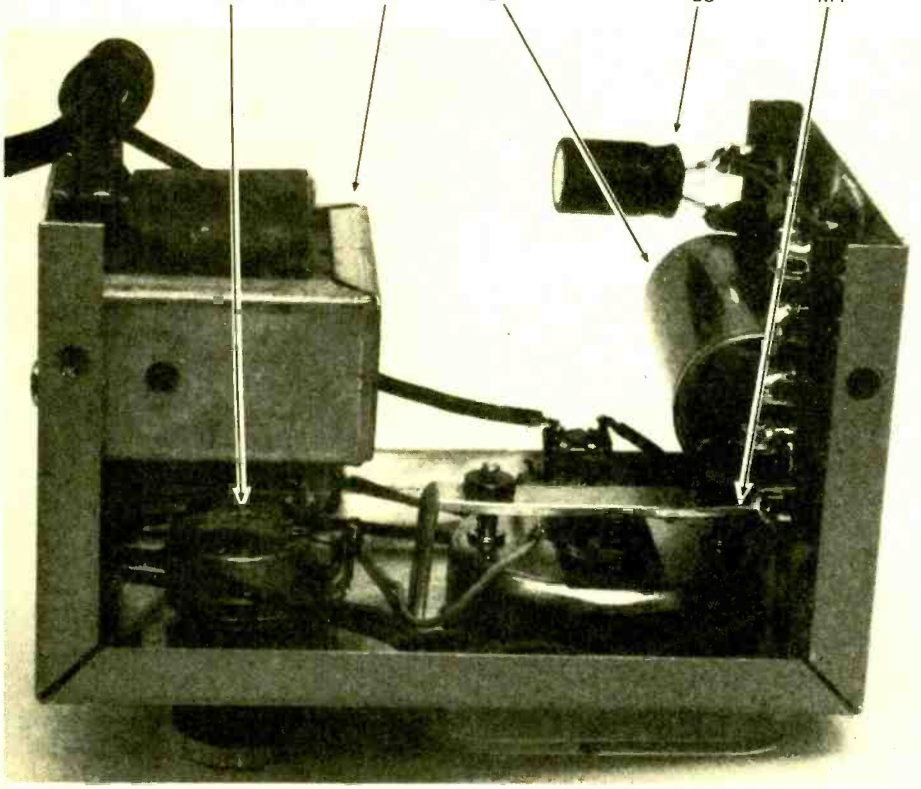
Do not eliminate the .1μF capacitors; they provide high-frequency stability and a ground path for any high frequencies on the power-supply rail.

To be certain that the output voltage tracks from low to high when R2 is advanced, orient R2 so that its terminals are up, and facing the back of the pot; make your connections to the center and left terminals.

Check out

Set R2 fully anti-clockwise and turn power switch S1 on. The meter should indicate 5 volts. If it indicates more than 10 volts, you have probably used the wrong terminals on R2. Advance R2; the voltage should rise, eventually reaching its maximum when R2 is fully clockwise.

If you get a reverse meter reading, check the polarity of the connections to meter M1. If you get no meter reading, check your wiring from the power transformer to U1. **SP**



THE COMPLETED VARYVOLT inside view is shown for general parts location. Exact location of parts is not critical; however, neatness always counts. Be sure to mount the heavy transformer, T1, at the bottom of the unit so that it will be difficult to tip over the cabinet when upright.

DIGITAL SENSORS

EDWARD M. NOLL

□THERE ARE VARIOUS TYPES OF DIGITAL SENSORS THAT SUPPLY a logic 0 or a logic 1 output in rèsponse to changing conditions that have reached a predetermined level. This article describes and demonstrates three such digital switches that respond to temperature, light, and magnetism.

Hot Stuff

The temperature-sensing switch made by Midwest Components, Inc. consists of a read relay and special linking ferrite material. At low, normal temperature, the coil and ferrite provide the necessary magnetic field for keeping the contacts closed as shown in example A of Fig. 1. Above a specific temperature (referred to as the Curie temperature) the ferrite material experiences an abrupt decrease in magnetic reluctance. In effect, the field breaks down for the reed relay and the contact opens as shown in example B.

Various forms of temperature-sensing relays can be supplied, such as single-pole, double-throw types as well as normally open versions. Midwest can supply them at 5-degree C intervals between 0 and + 125 degrees. In the demonstration circuit a TS-30B was selected. The 30 in the part number refers to a 30-degree change-over temperature. In Fahrenheit, that would be approximately 86 degrees. Therefore a change-over is possible when a hot soldering iron is held near the sensor.

The switch contact rating is quite high, being 10-watts at 12 volt-amperes. Recommended current-carrying maximum is 1 ampere. However, in digital applications it may only be necessary to provide a logic 0 or logic 1 data for a TTL or CMOS input. Two basic arrangements for CMOS inputting are shown in example C of Fig. 1. A logic output results when the switch opens above the Curie temperature for the first connection. If it is convenient to work with a logic 0 at the output when the temperature rises above the Curie value, the second circuit will do the job.

Light Switch

A second interesting sensor is the Sprague ULN-3330Y Opto-electronic swtich. That integrated-circuit swtich turns on when incident illumination falls below 5 lumens-per-square-foot. It will now remain on until the illumination rises approximtely 18%. It can be operated as a photo-detector in consumer or industrial applications. It is interesting that the ambient illumination at twilight is about 1 lumen-per-square-foot. Thus it can be used conveniently for switching activities when darkness falls.

Key blocks of the light switch, Fig. 2, are photo-detector, low-level amplifier, level detector and output driver. The use of a pull-up resistor makes digital operation possible. When the switch turns on at low light level, the output logic is zero. When the switch is off, the output logic is 1.

Good Gauss!

Sprague also has a Hall-effect digital switch. When a magnetic field of proper strength and direction is held near its

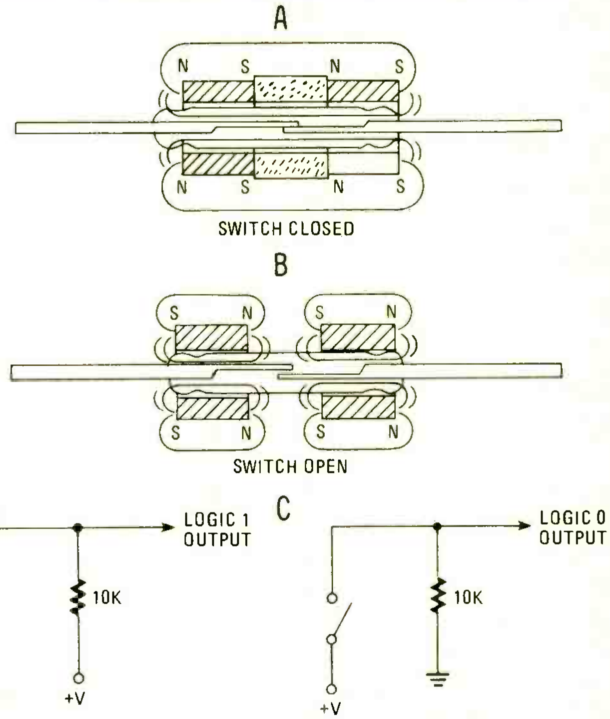


FIG. 1—TEMPERATURE-SENSING reed relay below switching temperature holds reeds close (A). Above switching temperature, the magnetic field weakens and the reeds open (B). Circuitry (C) offers either a logic high or low.

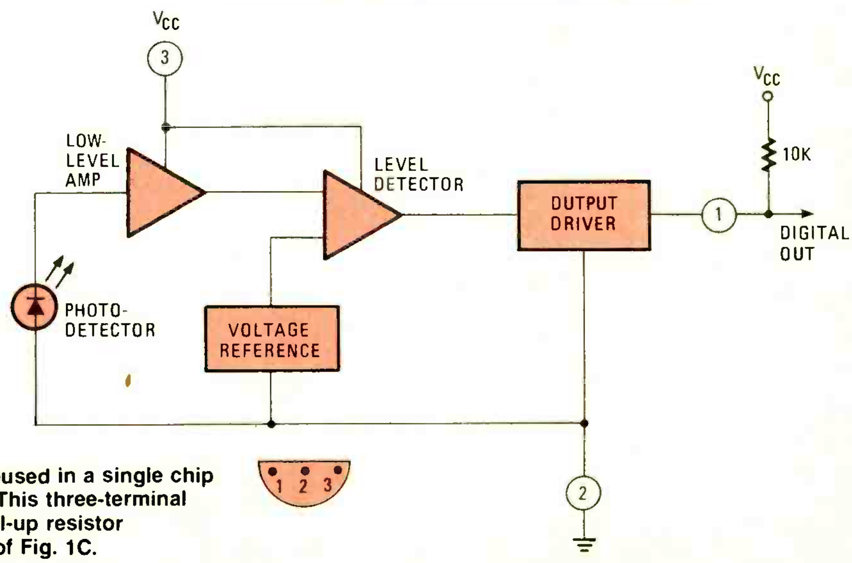


FIG. 2—OPTOELECTRIC SWITCH is housed in a single chip with a window for the photo-detector. This three-terminal device is externally connected to a pull-up resistor very much like that shown on the left of Fig. 1C.

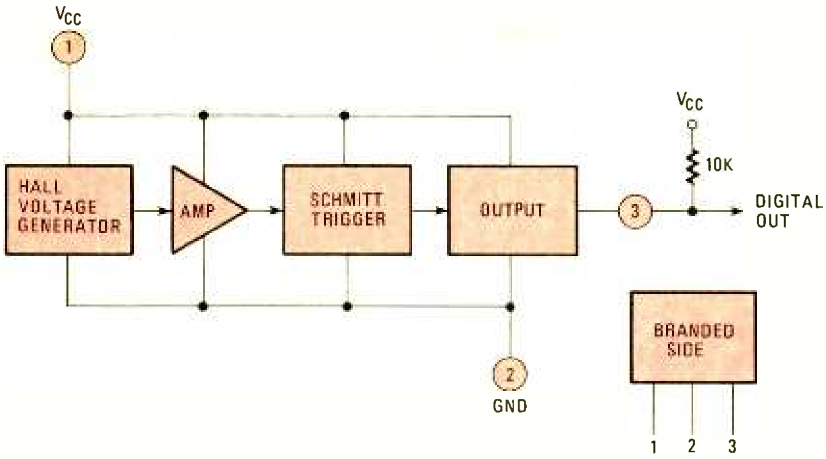


FIG. 3—WHAT WAS ONCE CONSIDERED hi-tech is now just another electronics experimenter's device available from local parts dealers. The device switches on as a magnetic field nears it.

sensitive side (branded side) it switches on and can supply a 15-milliampere sinking current. A lower strength magnetic field turns off the switch. A low-cost ½-in. diameter, button magnet (Radio Shack 64-1880) when held near to the device will switch it on.

The integrated-circuit device consists of a Hall voltage generator, amplifier, Schmitt trigger, and output stage as shown in Fig. 3. Again a simple pull-up resistor adapts it to digital operation. When turned on by an adequate magnetic field, the output logic is 0. When magnetic field strength is below the design level, the output logic is 1.

Demonstration Circuit

The three sensors discussed (Figs. 1, 2, and 3), along with a CMOS hex inverter and appropriate individual output LED's, can be mounted on a solderless circuit board. Note in Fig. 4 that the temperature-sensing switch has been wired to provide a logic 0 output above the 86° F critical temperature. The switch has been connected to + V and the free end of the resistor to ground; the output connects to input 5 of the 4049 inverter.

The Opto-electronic switch wiring and pull-up resistor are shown. In this circuit a logic 0 appears at the output when the light level falls below the 5-lumen level. Its output is applied to input 7 of the inverter. All inverters encased in the 4049 are identical and you can choose the three best suited to your wiring plan.

The final sensor is the Hall-effect device. Wiring is again very simple, using only the added pull-up resistor. A logic 0 results when the magnetic field is of adequate strength; its output is connected to pin 3 of the inverte.

In summary, the appropriate LED will come on when temperature is above the critical level, light below the critical level, and magnetic strength above the critical level. Under those conditions a logic 0 will be delivered to the individual inputs of the inverter, and the logic 1 at the output of the inverter will turn on the respective LED. Instead of the LED's the outputs could just as well be sensitive electromechanical relays, solid-state relays or some other digital or microprocessor input system.

A low-power soldering iron held near the temperature switch can produce the 86° F critical temperature. Holding your finger in front of the light-sensitive side of the opto-electronic switch will turn it on. Holding the button magnet near to the branded side of the Hall-effect switch will turn it on. If it does not come on, turn the button around to change the magnetic field direction. The device will also respond to the magnet when it is held near the blank side of the device, even though it is not quite as sensitive on the branded side.

Summary

We hope that you have been impressed with the way simple digital sensor devices can be used to generate appropriate digital data. It is up to you to choose some application that stirs your imagination. Don't just blue-sky your ideas; breadboard them. That's what solderless breadboards are for—experiment; and to add many happy, productive hours to your hobby. **SP**

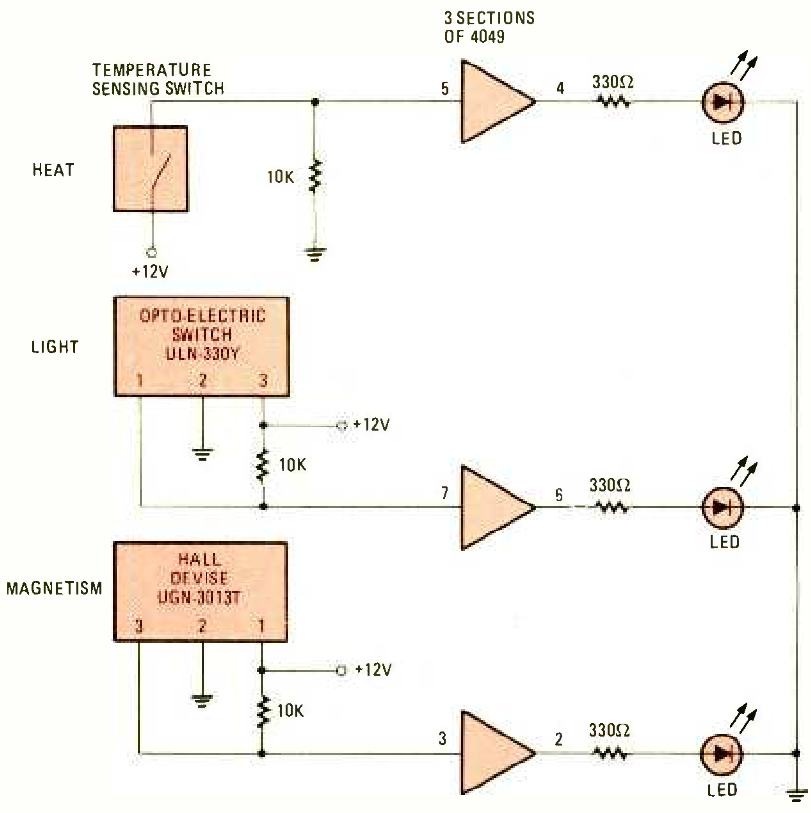


FIG. 4—HERE ARE THREE sensor circuits activated by heat, light, and magnetism that switch on their respective LED indicators.

INFORMATION CORNER

If you need more information, then write to the addresses given below asking for specification sheets on the sensors discussed in this article.

Midwest Components, 1981 Port City Boulevard, Box 787, Muskegen, MI 48443

Sprague Electric, Optoelectronics Section, 115 Northeast Curoff, Worcester, MA

Sprague Electric, Hall-Effect Section, Pembroke Road, Concord NH, 01606

DIGITAL DARKROOM TIMER

A darkroom timer designed for the photo technician only

ED SLINGLAND

☐THE EXPOSURE TIMING OF PHOTOGRAPHIC PRINTS IS A CRITIcal element in the photographic process. It is important to be able to accurately and consistently control the amount of time that an enlarger lamp is lit in order to ensure the quality of the final print. The Darkroom Timer allows just such accuracy and control. Two thumbwheel switches on its front panel allow any time from 1 to 99 seconds, in 1-second intervals, to be set into the device, and the START switch simultaneously sets this time into the timer and switches power to the enlarger. At the end of the designated time period, AC power is removed from the enlarger and the sequence may be repeated without resetting the thumbwheel switches. This allows the user to repeat the photographic printing process with the touch of a single button.

About the circuit

The Digital Darkroom Timer is divided into a few basic sections: a divide-by-60 counter, a countdown timer with control circuitry, a relay output to power an enlarger, a display decoder and display, and an unregulated power supply. The circuit is centered around a versatile CMOS integrated-circuit chip, the 14510 presettable BCD up/down counter. This integrated-circuit chip is frequently used as a divide-by-n counter in frequency synthesizers because of its ease of design application.

Divide-by-60 Counter

U1 and U2 form a divide-by-60 counter; and R1, C4, and U8-a square-up to 60-Hertz sinewave coming off transformer T1 to provide a clean clock signal for those integrated-circuit chips. The clock is presented to both chips simultaneously, but niether U1 or U2 will count unless its carry-in (C1) input (pin 5) is held low during a positive transition of the clock. The carry-in input of U1 is constantly held low, as are all of its preset inputs, to make U1 divide by 10. U2's carry-in signal (pin 5) is tied to U1's carry-out signal (pin 7) so that it only counts when U1 is at zero and has enabled its "carry-out." The carry-out signal of U2 is tied, through an inverter (U8-b), back to its preset-enable (PE) input at pin 1. This means that each time U2 enables its carry-out function (at zero) the chip's internal counters are set to a value determined by the BCD code set into is preset inputs (P1 to P4).

BCD stands for Binary Coded Decimal, and means that this number's value will be no more than 9. A four-digit binary number can have a value as high as 15. By tying presets 2 and 3 high (U2, pins 13 and 12), a binary 6 is set into U2's counters and its carry-out signal goes back high, allowing it to begin counting down from 6 the next time it receives a carry-out signal from U1 and a positive transition on its clock input (pin 15). The carry-out signal from U2 is used as a 1-Hertz clock (1 second) in the rest of the circuit.

Both of those integrated circuits, U1 and U2, are set into the countdown mode by a low on their up/down (U/D) inputs. They could have been put into the count-up mode and made to divide by 60, or any number up to 100, but the number set into the preset inputs would have to be subtracted from 9 instead of added to 0, as it was here. The 14510 chips (U1 and U2) enable their CO signals at zero when counting down, but at 9 when counting up. Thus, if U1 and U2 had been set into the up-count mode, preset signals 1 and 2 would have to be set high, instead of 3 and 4, to yield the proper result. That would have input a binary 3 into the BCD counters, and the chip would have counted up from there, enabling its carry-out signal upon reaching 9 and thus starting the sequence over again.

The Countdown Timer

The countdown timer works in a fashion similar to that of the divide-by-60 counter, except that its preset inputs (P1-P4) are controlled by the setting of BCD thumbwheel switches S4 and S5 instead of some fixed value. U7-a and U7-b made up A NAND RS latch circuit that controls the operation of the countdown timer. When momentary START switch, S2, is pushed, a low is felt on U7-a, pin 2 setting the

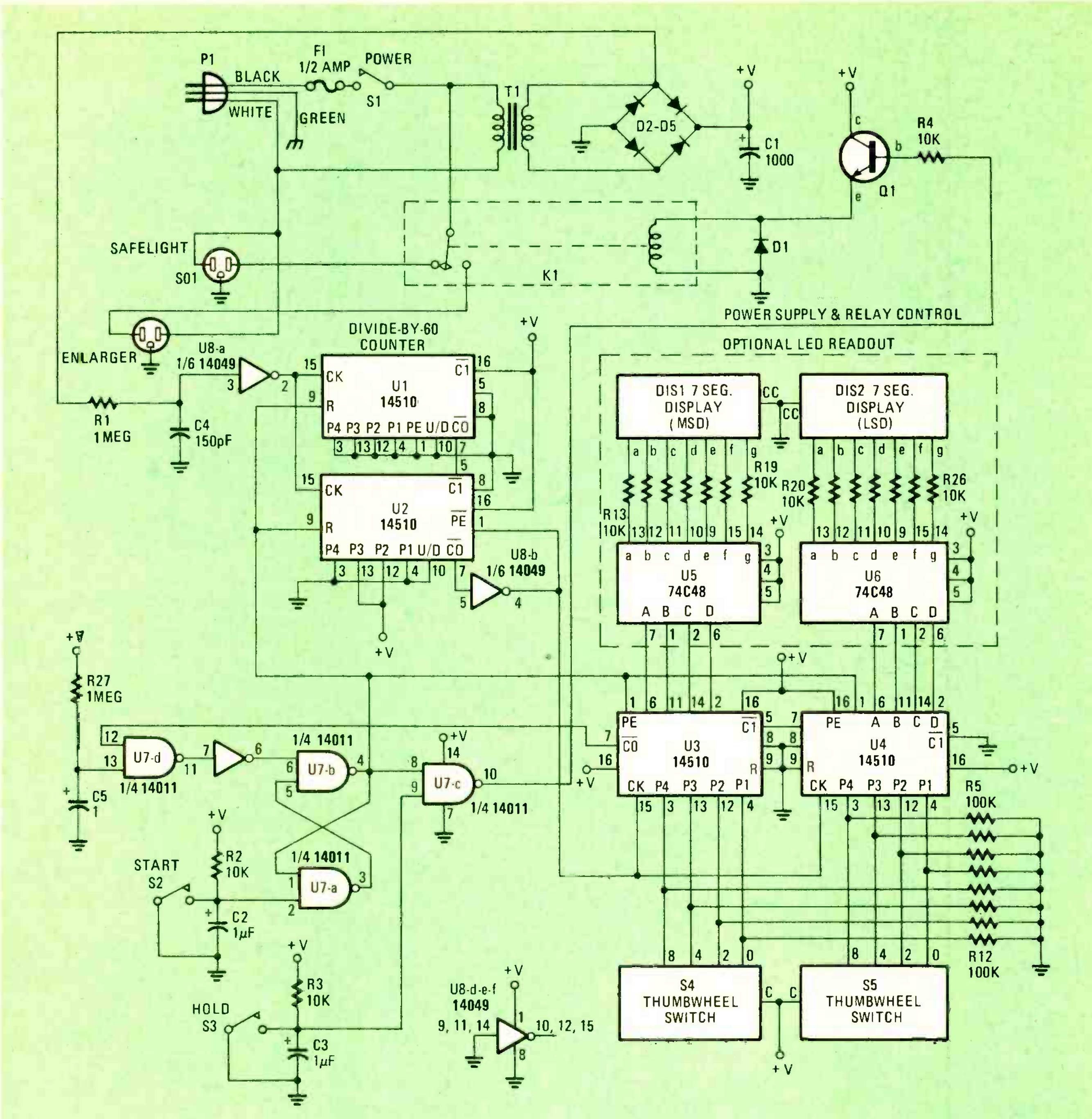


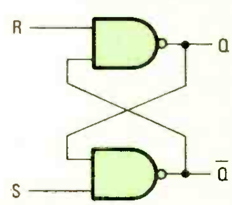
FIG.1—THE SCHEMATIC DIAGRAM for the Digital Darkroom Timer looks very impressive until you spend some time breaking down the circuit's sub-elements. Then, logic prevails and circuit operation becomes quite clear.

RS latch, and thus outputting a high from U7-c and a low from U7-b (see Truth Table in Fig. 2). The low from U7-b enables U1 and U2 by placing their reset inputs low, and turns on NPN transistor Q1, through U7-c by placing a high on the transistor's base. That allows current to flow through K1, energizing it, thus putting line voltage out to the enlarger.

At the end of the time period set into thumbwheel switches S4 and S5, U3's CO signal (pin 7) goes low. That resets the NAND RS latch (U7-a and U7-b), through U7-d and U8-c; which is turn, resets U1 and U2; de-energizes K1 through U7-c; and puts the preset (PE) inputs of U3 and U4 high, causing the setting of thumbwheel switches S4 and S5 to be shown in the displays. That allows easy setting of the switches in the darkroom.

The combination of R27, C5, U7-d and U8-c provides a power-up reset level to insure that the NAND RS latch does not enable the countdown timer during power-up.

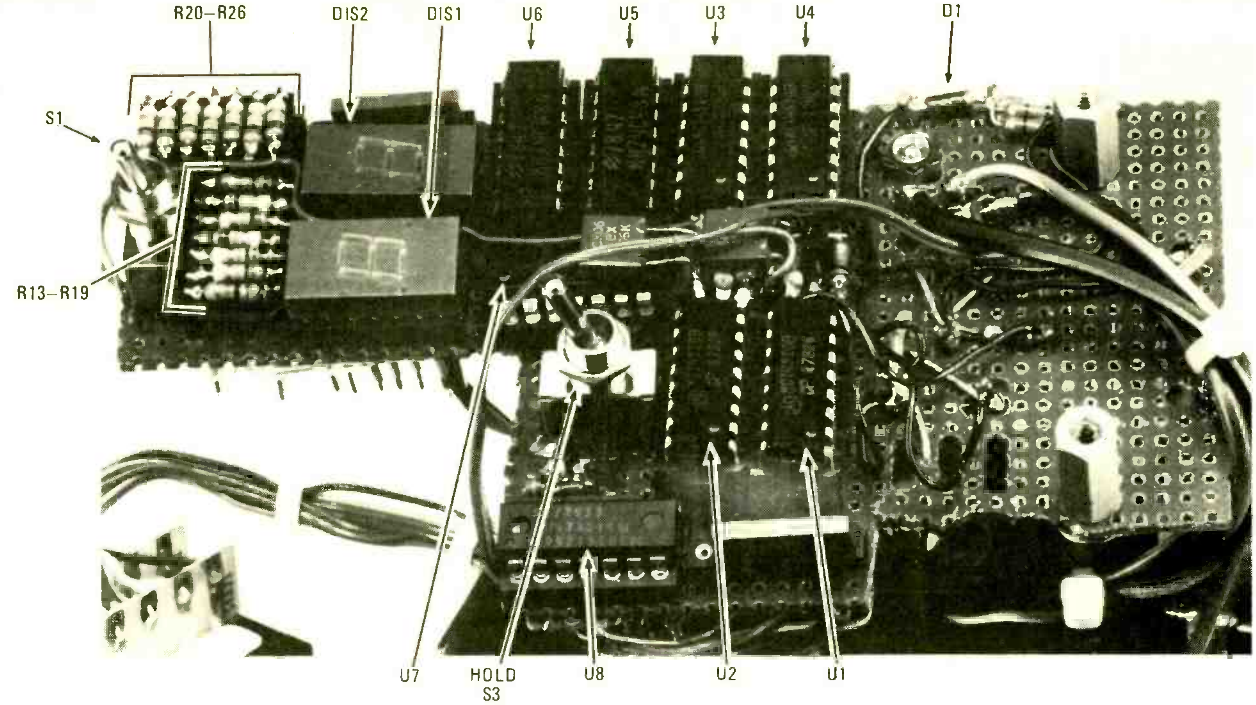
TRUTH TABLE FOR NAND RS LATCH



S	R	Q	Q̄
H	H	*	*
H	L	H	L
L	H	L	H
L	L	H	H

* = NO CHANGE

FIG. 2—TWO 2-INPUT NAND GATES, U7-a and U7-b, make up the NAND RS latch circuit that controls U1, U2 and Q1.



PERFBOARD is what the author used to assemble almost all the circuit parts. Notch makes room for thumbwheel switches.

Another feature of the Digital Darkroom Timer is HOLD switch S3. When actuated, S3 puts a low onto pin 13 of U7-c, which enables Q1, energizing K1 and turning on the enlarger, irrespective of whatever else the circuit might be doing. That allows the darkroom operator to set up and focus his enlarger for a given print without being restricted by a selected time period determined by the thumbwheel switched, or having to disconnect the enlarger from the Darkroom Timer and connect it directly to an available outlet.

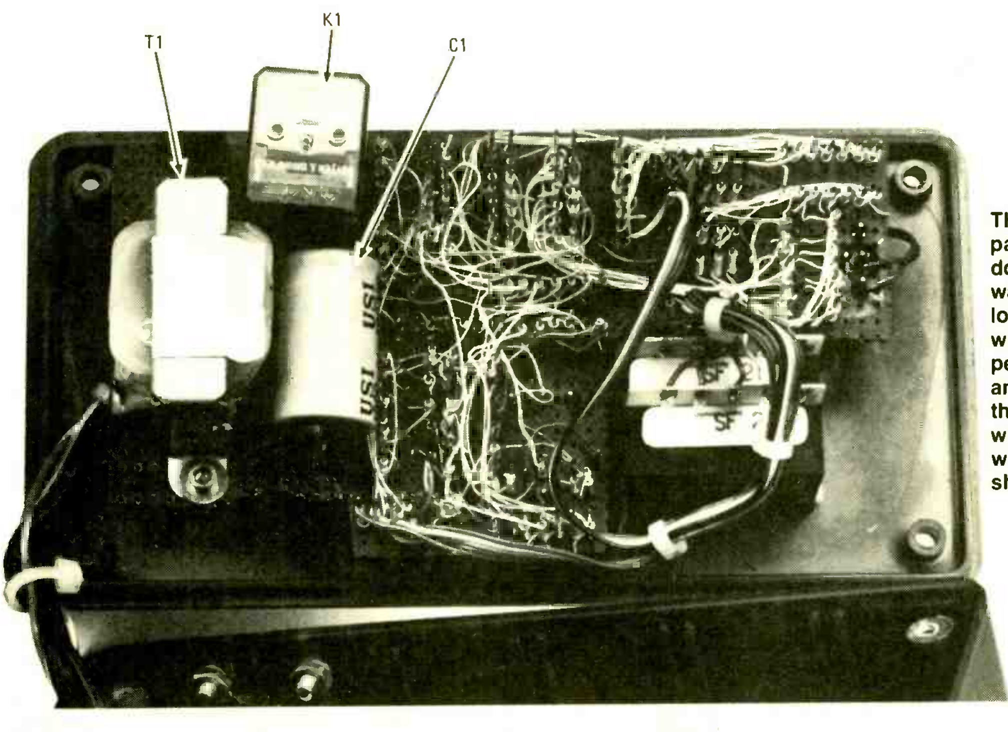
Power Supply

The unregulated power supply consists of a 110-volt AC to 12-volt AC transformer, T1, rated at 300 milliamperes, a full-wave bridge rectifier, D2-D5, made up of 1N4001 diodes and filter capacitor, C1. That is a cheap-and-easy-to-build supply, and is sufficient because of the inherent high-noise immunity of CMOS chips. Since the circuit uses the 60-Hertz line frequency to control the countdown timer, and not an internal oscillator, the circuit is immune to instability due to power-line voltage fluctuations, even though a regulator is not used. The circuit is as accurate as the line frequency coming out of the wall.

The Display Decoder and Driver

This portion of the circuit (Optional LED Readout in Fig. 1) is not necessary for circuit operation, but is for those who like to have a visual indication of what circuits are doing at all times. It may be left out, if so desired.

Integrated-circuit chips U5 and U6 decode the BCD outputs of U3 and U4 into outputs suitable for driving 7-segment



THE PERFBOARD shown at the top of this page is flipped over and mounted face down inside its plastic case. Provision was made so that the LED displays would locate at an opening alongside the thumbwheel switches. Also, be sure that the perfboard clears the front-panel switches and outlet sockets mounted on the side of the cabinet. Note that the author used wirewrap connections. Different colored wires would make troubleshooting easier should the unit fail when first fired up.

PARTS LIST FOR DIGITAL DARKROOM TIMER

SEMICONDUCTORS
D1-D2—1N4001 diode rectifiers
DIS1, DIS2—7-segment, common-cathode LED display
Q1—2N222 NPN transistor
U1-U4—14510 CMOS presettable BCD up/down counter integrated circuit chip
U5, U6—74C48 CMOS BCD to 7-segment decoder/driver integrated-circuit chip
U7—14011 CMOS quad, 2-input, NAND gate integrated-circuit chip
U8—14049 CMOS hex inverter integrated-circuit chip

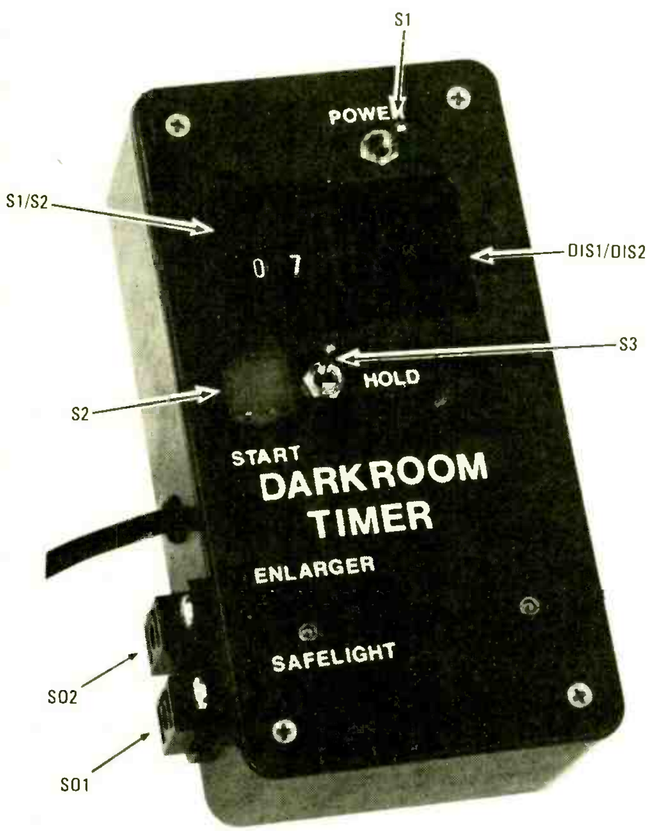
CAPACITORS
C1, C4—1000-μF, 25-WVDC electrolytic
C2, C3, C5—1μF, 50-WVDC electrolytic
C4—150pF, 50-WVDC disc

RESISTORS
(All resistors are ¼-watt, 10% fixed units)
R1, R27—1-Megohm
R2-R4—10,000-ohm
R5-R12—100,000-ohm
R13-R26—2.7,000-ohm

SWITCHES
S1, S3—SPST miniature toggle
S2—SPST, momentary-contact, miniature pushbutton
S4, S5—BCD thumbwheel with end plates

ADDITIONAL PARTS AND MATERIALS
F1—½-ampere 3AG fuse
K1—SPDT relay with 12-volt DC solenoid and 1-ampere contacts
P1—3-wire molded AC plug and power cord—length optional
SO1, SO2—3-wire AC outlet
T1—Power transformer: 117-volts AC pri.; 12-volts AC, 300-milliamperes sec.
Plastic chassis box with cover, red plexiglas bezel, 3AG fuse holder, perfboard, 7 16-pin wirewrap IC sockets, 7 14-pin wirewrap IC sockets, wriewrap wire, assorted hardware, front panel decals or press type, etc.

LED displays. Resistors R13-R26 limit the current through the display LED elements. The 74C48 integrated-circuit chips (U5 and U6) were selected to drive the LED displays because they were in the junkbox. Another integrated-circuit chip that would do the job is the flexible 14543. That integrated-circuit chip will drive either common-cathode or common-anode 7-segment LED displays, as well as liquid-crystal displays. If you think that you will be constructing future projects containing 7-segment displays, the 14543 is a good choice because of its versatility. You can choose any of a number of displays available (whichever is cheapest when you are building your project) without worrying about which 7-segment decoder you should use.



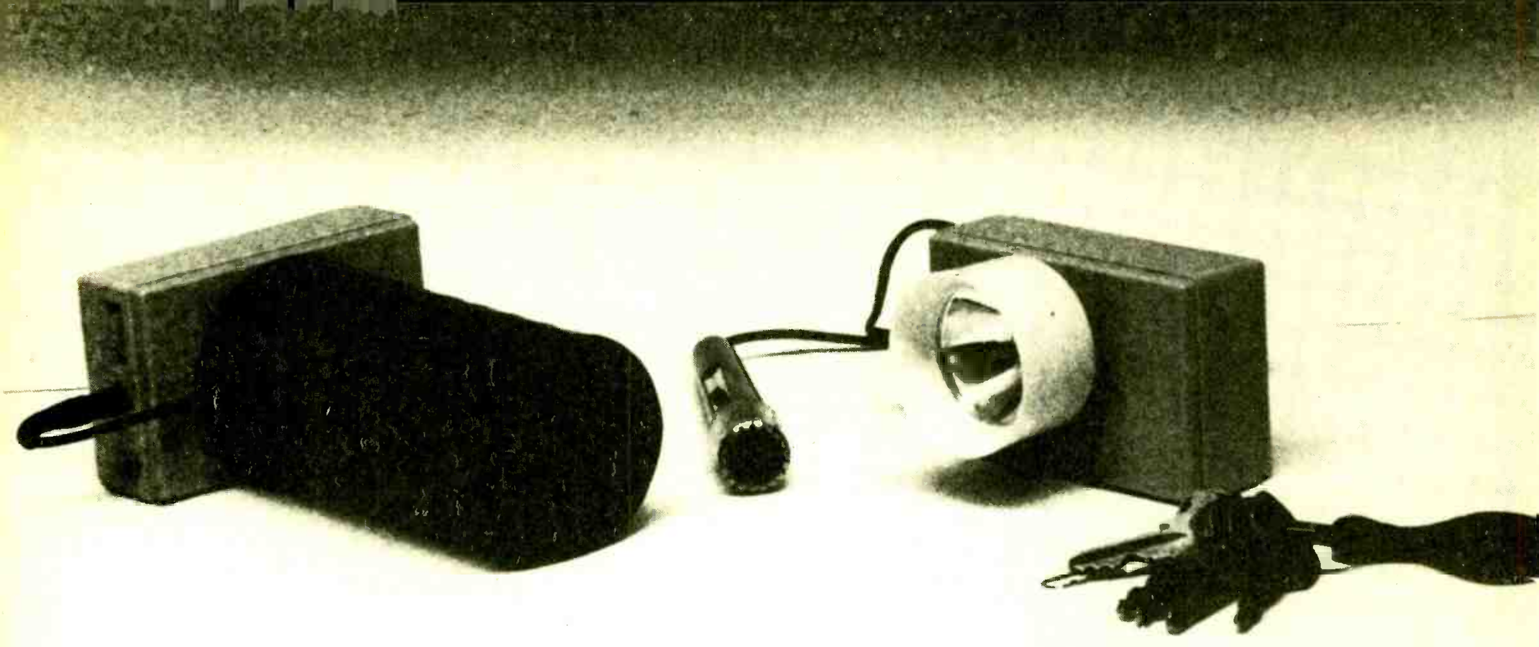
THE OPERATING CONTROLS for the Digital Darkroom Timer are identified here by front-panel decals and schematic diagram notation. SO1 and SO2 should be three-wire AC power outlets for safety's sake.

Construction

Standard construction techniques were used in building the Darkroom Timer. Its enclosure is a plastic project box available from either Radio Shack or Jameco. Cut one large hole in the box to accommodate both thumbwheel switches, S4 and S5, and the red-plexiglas bezel for the 7-segment displays, DIS1 and DIS2. Mount the electronic components onto one piece of perfboard. All of the integrated-circuit chips are mounted on wirewrap sockets. Resistors and capacitors were soldered to components carriers and put into chip sockets as well. Be careful to insulate all 110-volt AC sections of this circuit, since, as Murphy's Law might have said, "If you *can* stick your finger where it's dangerous to do so, you *will* stick your finger where it's dangerous to do so."

Wire two AC-power receptacles SO1 and SO2, across K1 to enable you to control a safelight as well as an enlarger. That way the safelight will turn off whenever the enlarger is on, and vice versa. Don't forget to put D1 across K1's coil. D1 is an anti-ringing diode; destruction of Q1 could result should D1 be omitted. Wiring of the chips is not critical, because of the low frequencies and currents present in the circuit; but neatly-dressed wiring is easier to troubleshoot than messy wiring, and it makes a much more favorable impression on the people who will see the internal workings of your project.

Standard precautions for CMOS circuitry should be taken. Avoid areas of high-static charge, such as carpets, when handling CMOS integrated-circuit chips and be sure to tie all unused inputs (shown on the schematic diagram, Fig. 1) to VDD (V+) or VSS (ground), because the CMOS integrated-circuit chips will tend to overheat if you fail to do so. **SP**



Modulated-Light Communications System

STAN GIBILISCO

MODULATED LIGHT—IT'S NOT REALLY A NEW OR ESOTERIC concept. Edison did it with light bulbs. Now they're doing it with sophisticated devices and hair-thin optical fibers. Hundreds or thousands of radio and television signals can be put on a single light beam. You can communicate by means of modulated light waves, using apparatus you can easily build yourself. This article describes the construction of a simple modulated-light transmitter and receiver for only about forty dollars.

While most modulated-light communications links make use of lasers, you do not need a laster to generate those signals. A flashlight bulb will do just fine, and a solar cell enables good reception of voice modulation, as well as frequencies beyond the audio range. Look about your shop. You may find many of the parts, as well as materials called for in this article.

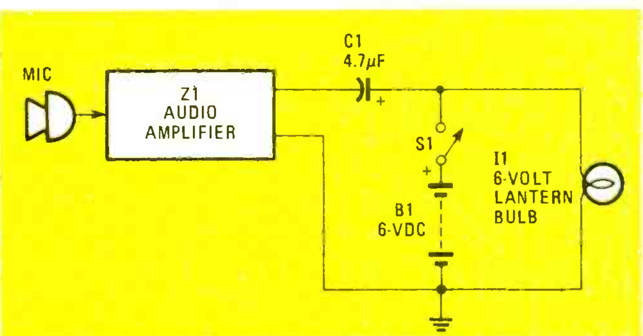


FIG. 1—SCHEMATIC DIAGRAM for the transmitting unit. The only external elements in the circuit that are not a part of the audio amplifier, Z1, are the microphone (MIC), 6-volt bulb (I1), Capacitor C1, and 6-volt battery (B1). Switch S1 and capacitor C1 are part of the original circuit in Z1.

The Transmitter

All the parts you need to build the modulated-light system are available at your local electronics parts dealer or Radio Shack store. The transmitter consists of a modified miniature amplifier/speaker unit, a flashlight reflector, and a microphone with an impedance of 200 to 5000 ohms. The modulation scheme is shown in the block diagram, Fig. 1.

The lantern bulb (I1) is illuminated to full brilliance by the 6-volt battery (B1). The 4.7-μF blocking capacitor (C1), which is built into the amplifier (Z1), allows the audio output of the amplifier to reach the bulb, but prevents the battery DC from directly shorting the output integrated-circuit chip. Switch S1, shown in Fig. 1 as separate from the amplifier unit, controls the DC to the bulb. In fact, switch S1 as well as the blocking capacitor are already built into the audio-amplifier unit, Z1.

You may wonder why DC is applied to the bulb at all. Wouldn't the audio signal alone, with sufficient power, illuminate the bulb and modulate it? Yes, it would, but only on modulation *peaks*. You see, the first volt or two will heat up the bulb's filament, but it would not be hot enough to cause the filament to emit any sort of visible light. The results would be severe distortion of the audio signal. Also, as you will see in a moment, the audio frequency will be doubled.

The DC through the bulb creates a visible-light "carrier," which is then modulated by the audio-frequency energy from the amplifier. The principle is exactly the same as in an ordinary AM broadcast transmitter, except that the "carrier" is white light in the teraHertz range instead of a discrete wavelength in the megaHertz range! Fig. 2 illustrates the situation with various levels of modulation. Never does the modulation level reach 100 percent, because the bulb does not respond to current changes fast enough. However, some fluctuation of brilliance *does* occur, and it is quite sufficient to allow the transmission of voice intelligence.

Building the Transmitter

To construct the modulated-light transmitter, you will have to perform some modifications to the miniature amplifier/speaker unit which is specified in the Parts List.

First, remove the back portion of the unit. The rear section is a piece of plastic with a ventilation grille. That grille must be cut out partially to accommodate the flashlight head. Fig. 3 shows the arrangement. There are nine plastic bars running crosswise to form the vent; remove the middle five using diagonal cutters. File down the remaining stubs.

Take the small plastic bulb-holder from the back of a flashlight head, and remove the bulb. (Put the bulb aside; it is a 3-volt bulb, and you'll burn it out with 6 volts!) The flashlight head should fit nicely into the rectangular hole you have made. Replacing the bulb holder temporarily from the inside of the case should affix the flashlight head without the need for glue or other adhesive preparations.

The bulb you will need is a Westinghouse PR-12, or any equivalent bulb that you can find with no difficulty in any hardware store. Get a bulb with a flashlight-style holder, not a screw-in base. The bulb you are seeking is designed for lantern batteries or flashlights that take four D cells. Fig. 3 gives some installation details. Solder a 5- to 6-inch piece of stranded No. 18 to 24 insulated wire to the bulb tip. Very carefully, solder another identical piece of wire to the little ball of solder on the side of the bulb base. Run both wires back through the rear section of the amplifier module, and then through the bulb holder. Put the bulb in the flashlight head and secure the head to the back of the amplifier module, using the bulb holder as previously described.

The miniature amplifier/speaker normally runs from 9-volts DC power source. However, that is too much for the 6-volt lantern bulb! The bulb, ironically, consumes too much current for a little "transistor" battery as well; such a battery would die rapidly under the load of the bulb, were it not for the fact that the bulb would quickly burn out because of the battery voltage. You will need a source of 6 volts at greater milliampere-hour capacity, which will still operate the amplifier but will not burn out the bulb.

Remove the speaker from its mounting, first unsoldering the lead wires from the speaker terminals. Break off the plastic tabs that hold the 9-volt transistor battery in place. Leave the speaker wires fastened to the circuit board for reference.

Take the printed-circuit board out of its case very carefully. Unsolder the two speaker wires and replace them with the leads from the 6-volt bulb. Remove the black and red wires from the 9-volt battery holder, and, in their place, solder the leads from the four-cell penlight holder. Be careful that the red and black wires are kept in the same places, and not reversed! The wrong polarity may damage the amplifier circuit.

There's one more little detail: As it is, the bulb will get audio when the amplifier is operated, but it will get no DC, and so there will be no "carrier." Fortunately, the modification necessary to achieve "carrier" insertion is very simple. On the bottom of the printed-circuit board, locate the tiny green alphanumeric sequence "GEM194HB." Turn the board so that those symbols appear right-side up. The volume control will then be to the top-right, and the two ⅛-inch jacks at center and lower right. Solder a stiff piece of insulated wire, about ½ inch long, between the terminal immediately above the "H" (that goes to the jumper on the component side) and the terminal above and to the left of the "G" (that goes to the rear terminal of the external speaker jack). Now the 6-volt bulb will get DC whenever the amplifier module is turned on, and it will also get audio energy through the 4.7-μF blocking capacitor, in proportion to the setting of the volume control.

Carefully replace the printed-circuit board. Place four AA-type penlight cells in the battery holder, being careful to observe the proper polarity. Test the unit by switching it on.

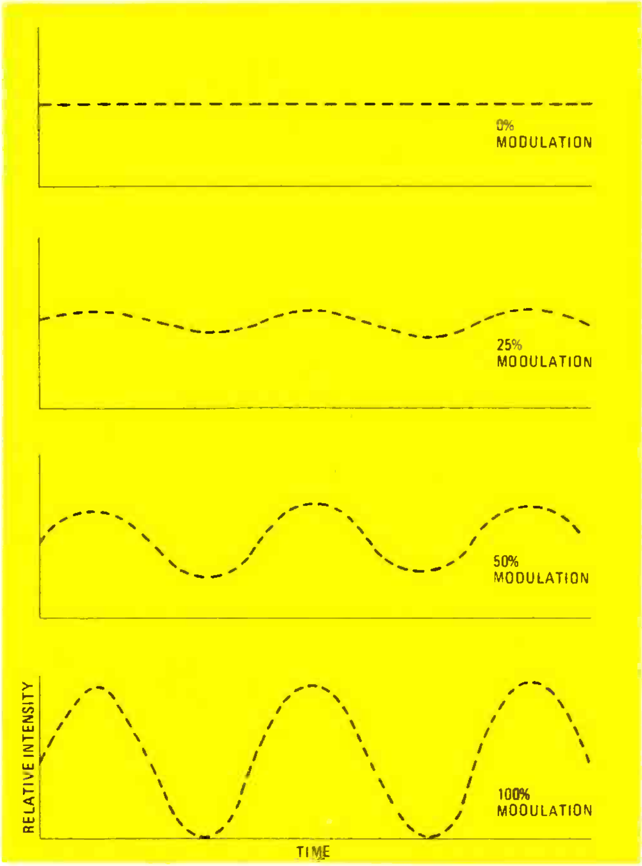


FIG. 2—MODULATION PERCENTAGES are illustrated while riding on a white-light carrier. Unlike RF waves, distortion increases as percent modulation increases because at low lighting intensities the bulb's characteristics require larger wattage swings to produce equal lighting changes as at higher levels.

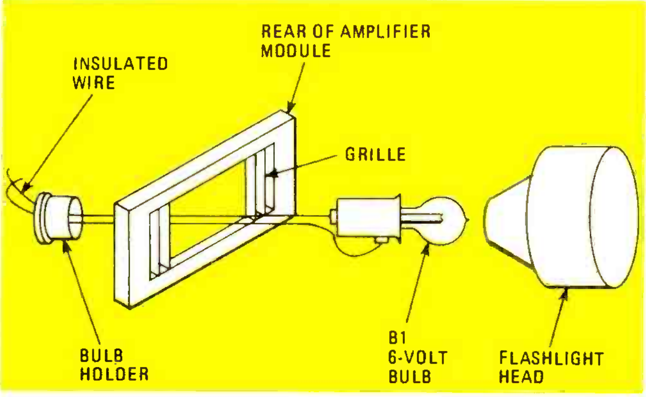


FIG. 3—FLASHLIGHT HEAD assembly to the rear of the amplifier case is diagrammed here. Of course, position is not important here and you do what is best for your needs. You may opt for a bracket attachment or pistol-pointing device.

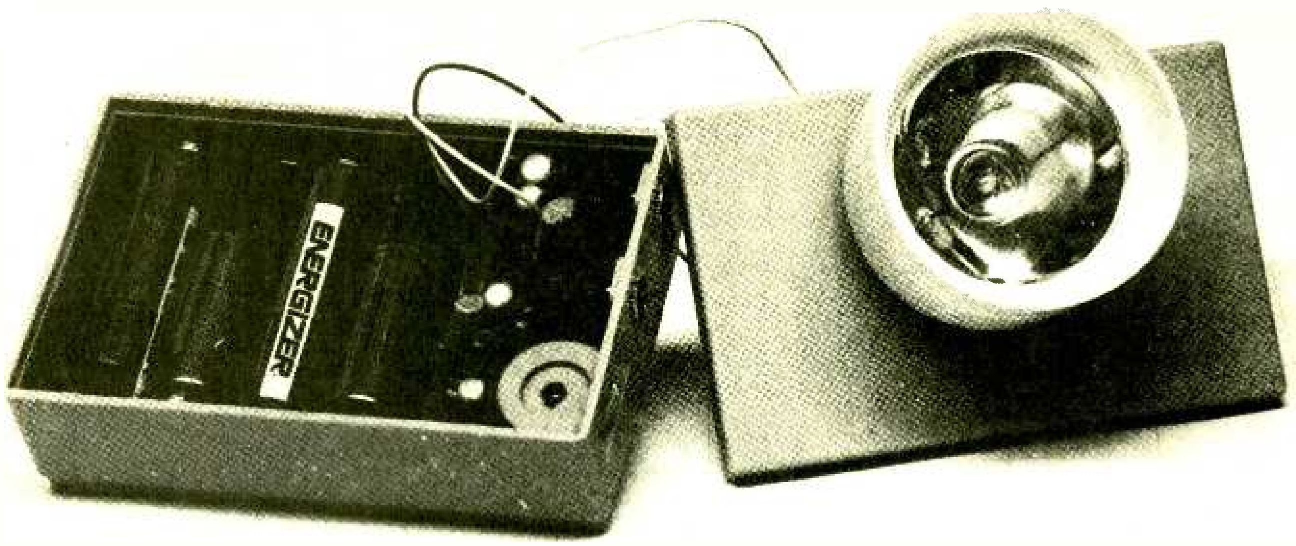


FIG. 4—THE TRANSMITTER UNIT assembled and ready for use. Batteries fit in case where speakers were originally located. Should you decide for larger-capacity batteries, such as D's or lantern type, outboard them with an interconnecting jack-plug combination that will not mate with the microphone connector.

The bulb should light fully. The bulb should go off when the unit is switched off. If that doesn't happen, you might have bad dry cells; you could have a burned-out bulb; or you could have made a wiring error.

When the foregoing test yields the desired results, tuck the battery pack carefully into the front section of the unit (see Fig. 4). Replace the back cover. Do not pinch any wires.

PARTS LIST FOR MODULATED-LIGHT TRANSMITTER AND RECEIVER

NOTE: Parts suggested are by no means rigid in specifications. Substitutions within the scope of application in the devices should be made where savings can be achieved.

2—Amplifier module (Z1 and Z2), 200-milliwatts, Archer type 277-1008A available at Radio Shack
1—Flashlight head (focusing reflective lens and lamp holder)
1—Microphone, high-impedance, Radio Shack 33-1034A or equivalent
1—Battery holder for 4 AA cells
4—1.5-volt AA dry cells (B1)
1—9-volt battery, transistor radio type
1—6-volt lantern bulb (I1), type PR-12 or equivalent, flashlight mount (not screw type)
1—Solar cell, 2-sq. in., wafer-type, Radio Shack 276-124 or equivalent
1—Earphone with 1-8-in. phone plug
1—Cord with ⅛-in. phone plug, Radio Shack 42-2444 or equivalent

PREAMPLIFIER

B2—1-volt transistor battery
C3 C5—4.7-5-μF electrolytic capacitor
J1-J2—RCA phono jack, see text
Q1—NPN audio transistor, general purpose type
R1—100,000-ohms, ½-watt, 10% resistor
R2—10,000-ohm, ½-watt, 10% resistor
R3—4700-ohm, ½-watt resistor
R4—680-ohm, ½-watt resistor, 10% resistor

The transmitter cannot be fully tested, of course, until the receiver is built. Connect a microphone of 200- to 5000-ohms impedance to the input jack. You might see a barely perceptible flicker of the bulb when the volume control is fully advanced and you talk loudly into the microphone. Do not expect to see a large change in the brilliance of the bulb with modulation. Although there are significant instantaneous fluctuations, in terms of milliseconds, your eyes should not see any change in the average brilliance of the bulb. Excessive brightening or dimming with modulation indicates distortion.

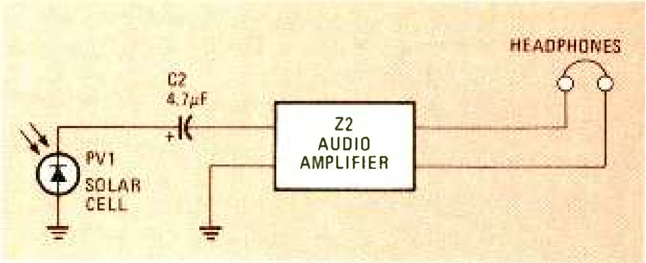


FIG. 5—SCHEMATIC DIAGRAM for the receiving unit is shown here. Capacitor C2 is an integral part of audio amplifier Z2. Solar cell PV1 mounts physically on the amplifier case.

The Receiver

Another miniature amplifier/speaker is used, along with a solar cell, as a modulated-light receiver. The receiver requires no internal modifications.

The heart of the receiver is a solar-cell wafer, PV1, measuring 1 by 2 inches. A smaller solar-cell wafer may be used, but do not opt for a larger one, which would probably have too much internal capacitance. Those cells generate direct current in the presence of light energy. The more light the cell gets, the more current it will produce, up to a certain maximum. In direct sunlight, the wafer-type cell reaches its saturation level, and any further increase in the illumination level will result in no change in the power output of the cell.

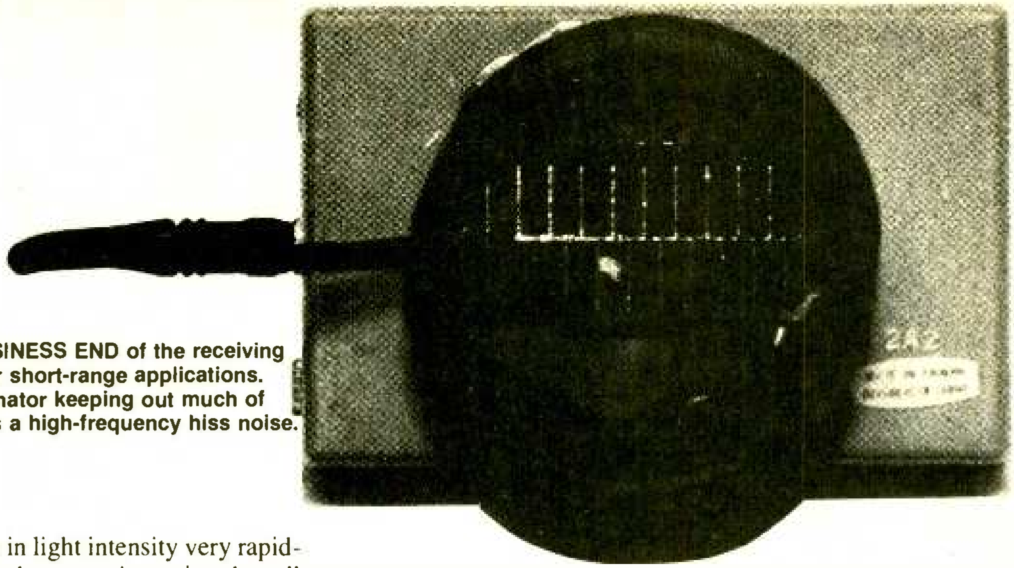


FIG. 6—LOOKING INTO THE BUSINESS END of the receiving unit. This version is designed for short-range applications. The black tube serves as a collimator keeping out much of the ambient light that is heard as a high-frequency hiss noise.

The cell can respond to changes in light intensity very rapidly, as long as it is not operated at the saturation point; the cell can, in fact, reproduce changes at frequencies well above the audible sound range. The amplifier/speaker boosts those current fluctuations so they can be heard. Fig. 5 shows the basic design of the receiver.

A blocking capacitor, C2, is used at the input of the amplifier to prevent the solar cell from improperly biasing the transistor. That capacitor also keeps the amplifier DC supply from getting to the solar cell. Either of those might ruin the effectiveness of the amplifier at audio frequencies. Fortunately, blocking capacitor C2 is already built into the module. Just plug the solar cell into the input jack!

Building the Receiver

The only difficulty you might encounter while putting the receiver together is damage to the solar cell, PV1. It is fragile! If you drop it on a hard surface, or try to bend it, or set anything heavy on top of it, it has had it! So be careful.

Cut the shielded audio cord (the one with the ⅛-inch phone plug) to the desired length. You may want to attach the solar cell physically to the back of the amplifier module; in that case you'll need only about six inches of cord. if you want to mount the cell independently from the amplifier module, you may use any reasonable length of cord. If you add an extension, though, make sure it's shielded.

Remove ½ inch of the outer insulation from the cut end of the cord. Pull the braid to one side and twist it. Strip off ⅛ inch of the center-conductor insulation. Then tin both leads and solder them to the solar cell using extreme care. The polarity is not important. It is best, from a mechanical standpoint, to solder the braid of the cable to the foil side of the solar cell and the center conductor to the front of the cell.

When that connection is complete, plug the cord into the amplifier input and turn the unit up to full volume. Hold the cell (carefully!) near an incandescent, 117-volt AC, illuminated light bulb. You should hear a loud 120-hertz AC hum. Perhaps you didn't realize that even an ordinary house bulb emits modualted light! It's a 120-Hz hum, caused by the fluctuation of current through the bulb filament—two pulses per cycle.

The solar cell must be mounted on some supporting object. The back of the amplifier module will serve very well for that purpose. Simply cut a piece of cardboard to the size of the cell and epoxy-glue the foil side of the cell to the cardboard. Then glue the cardboard to the back of the module.

To protect the solar cell against accidental knocks and blows, and to keep stray light sources from saturating the cell or causing the unwanted modulation, a light shield should be attached as shown as in the photo. The shield must be large enough to fit completely around the cell. A used-up container of Morton "Lite Salt," with the top and bottom removed, is perfect! (The Editor is a "Quaker Oats" man!) The light shield may be wrapped with electrical tape for visual appeal. Attach the light shield centered on the solar cell using contact cement or epoxy glue.

Testing the System

Connect the earphone to the receiver output jack. The useful range of the system is greater when using the earphone, simply because you can hear fainter signals.

Have someone turn the transmitter up to full output volume and speak slowly and clearly into the microphone. Stand a few yards away and point the solar cell directly at the transmitter. Have the other person shine the light so that it falls on the solar cell. (Fig. 6 shows the "photon's-eye" view of the receiver input.) At that point, you should be able to hear the other person's voice. The tone will probably sound somewhat "bassy" (void of the highs), and there may be some distortion on modulation peaks. Those effects are to be expected. Severe distortion, however, that renders the voice unintelligible, might indicate a problem such as excessive modulation or perhaps a defective microphone or amplifier module.

Wait until it gets dark. The system works best when there is very little ambient light; the solar cell is the most responsive to changes in illumination intensity at its threshold. You should be able to achieve a range of 150 to 200 feet. There are several things you can do to increase the range.

Shooting for Distance

The first, and perhaps the least obvious, way to increase the system range is to improve the electrical sensitivity of the receiving amplifier. A one-transistor preamplifier, such as the circuit of Fig. 7, will work quite well. You should put that preamplifier in a separate enclosure, outboard from the main amplifier, because you may otherwise have trouble with feedback and oscillation. Even when the best precautions are taken, such as a shielded enclosure and separate power source for the preamplifier, there is some possibility that the system will break into oscillation. If it does, try reducing the gain of the amplifier/speaker module. You might also remove the 4.7-μF capacitor (C5) across the 680-ohm emitter resistor in the preamplifier.

A more immediately apparent way to increase the receiver sensitivity is to get a larger capture area for the solar cell. The larger lens in front of the cell will gather much more light than the cell alone, and focus it all onto the cell. The cell itself is just 1 by 2 inches. Using a 4-inch circular lens, the capture area increases almost sevenfold increasing the sytem's overall range.

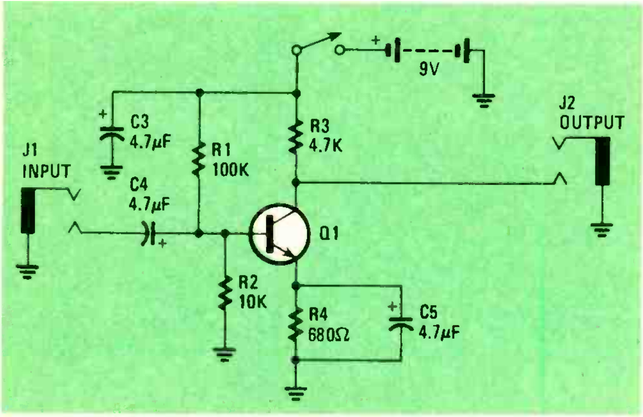


FIG. 7—OPTIONAL PREAMPLIFIER schematic diagram is presented here for those who would like to consider increased range. Parts are junkbox variety. Battery B2 is transistor-radio type permitting remote and portable operation.

A large parabolic mirror, or a flat Fresnel lens, offers a still better way to increase the capture of the solar cell. The main problem with those devices is finding one! Fresnel lenses are appearing on back windows of van-type vehicles, so look in an automotive accessories store for that lens. Some Fresnel lenses are as big as 24 by 24 inches. They offer a 17-fold increase in useful range—perhaps from 50 yards to one-half mile.

The receiver is not the only place where range improvements are possible. A larger collimating device for the bulb will concentrate its beam, and provide a range increase in direct proportion to the diameter and focal length of the reflector. For example, that little flashlight head might be replaced with a lantern reflector having triple the diameter and triple the focal length. That will triple the useful range. Larger parabolic reflectors are harder to find, but if you can locate one, the result will be worth the effort. Communication may be carried out over distances of several miles, in theory, by using parabolic mirrors or Fresnel lenses at both ends of the circuit.

There is one more way to increase the range of the system, and that is the use of high-power lamps with better modulation response. Lamps such as the mercury-vapor type are available, but they operate off normal house current. They are not only much brighter than incandescent bulbs of the same wattage, but they respond much more rapidly to modulating current changes.

Experiments

It is not difficult to multiplex several signals on a single light beam. The simplest way to do that, using the light transmitter and receiver you assembled, is to inject two or three Morse-code signals into the transmitter at different audio frequencies, and separate them at the receiving end by means of a tunable audio filter. For example, you might send Morse-code signals simultanously at 400 Hz, 700 Hz, and 1500 Hz. Select audio frequencies that are not harmonics of each other.

You can change the frequency of the light beam itself. Without using sources of monochromatic, coherent light (that is, lasers), and resonant pickup devices, you can still experiment using red and green, or red and blue, color filters. Placing a red filter at the transmitter output and a green or blue one at the receiver, you can see just how great the "adjacent-channel rejection" is. Color filters are not particularly selective; a red filter is just about the same as an orange one, and a blue one is almost the same as a green one.

There is still another variable you can make use of: polarization. There are essentially two modes of polarization. Sometimes they are simply vertical and horizontal; but they may be at any relative orientation as long as they are different by 90 degrees. To perform polarization experiments, all you need is a pair of polarized sunglasses. Take out the lenses (carefully!) and place one over the solar cell at the receiver, the other in front of the bulb at the transmitter. When the polarization is the same or nearly the same at both ends of the circuit, the system will allow communication. But when the filters are perpendicular, there will be a large amount of attenuation.

The most fascinating possibilities for modulated-light experimentation involve high-power transmitters, perhaps using mercury-vapor bulbs of 200 watts or greater, along with "brute force" audio amplifiers. Just as with an AM signal, one-third of the power must be supplied as audio; the rest may be DC or perhaps high-frequency AC. (Thus with a 200-watt bulb, about 130 watts could be supplied by rectified house current, and 70 watts as audio.) With such a transmitter, and a receiver having a sensitive front-end preamplifier and a parabolic reflector. Long-distance communication would be practical. Also, it may not be necessary to have a direct line of sight between the transmitter and receiver if they are elaborate enough; the scatter from objects in the vicinity, such as tall buildings, snow-covered hills, or even clouds (Fig. 8), might be picked up.

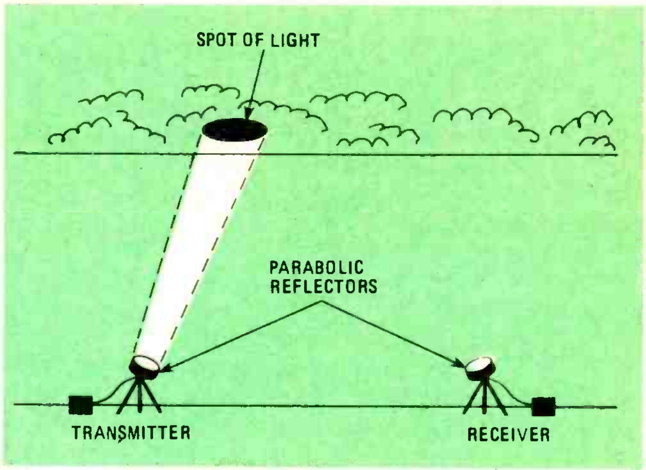


FIG. 8—THIS IDEA may seem way out at this time, but it is a distinct possibility. The text covers extended-range ideas that are practical. In rural communities, where sky glow is low, you can expect success on nights when the moon is low and so is the cloud bank above. Very often clouds drop to one— or two—thousand feet. Keep distance between transmit and receive units a hundred feet apart. Check spill-over effect on a clear night to be sure that the scatter effect of free air does not deceive you in your installation setup.

A few experiments have been suggested here, but there is room for almost unlimited research in this area. Your imagination is the only constraint. **SP**

UP-1 RF CONVERTER

☐WITH THE EVER GROWING POPULARITY OF HOME SATELLITE receivers, more people are joining the ranks of private, home TVRO (television-receive-only) system owners everyday. Many of these people are true videophiles who demand the exceptionally high-quality audio and video signals available only via direct satellite reception. Others are hobbyist-pioneers who have taken up the challenge of this new electronic frontier. However, whether you've built your satellite receiver from scratch, or purchased it from one of the numerous manufacturers now marketing consumer systems, this easy-to-build accessory UP-1 RF Converter, will enhance the versatility and performance of your TVRO receiver.

Whether your TVRO receiver is store-bought or home-brewed, the audio section is probably designed using IC technology borrowed from standard, television-set design. These circuit designs are adequate for a regular television-set audio system because a moderate amount of hum, noise, and distortion are tolerable when reproduced via the small speakers used on most TV sets. Even if you are using a high-quality television to reproduce the audio from your satellite receiver, the TVRO receiver is demodulating the satellite audio-RF subcarrier to audio, then remodulating it with a TV-RF modulator to the standard 4.5-MHz audio carrier required by the telvision set, and then finally demodulating it again in the television itself. All of this signal manipulation adds hum, noise and distortion to the reproduced audio.

Direct satellite broadcasting offers low-noise, low-distortion, high-fidelity audio. And, many transponders have numerous subcarriers for radio, slow scan TV, and data transmissions, as well as regular TV audio. But how can the home TVRO enthusiast take advantage of this without spending a fortune?

It's quite simple if you already own a quality FM tuner or receiver. The UP-1 RF Converter enables you to use an FM tuner as a satellite audio demodulator by making satellite audio subcarriers look like regular FM radio stations. Thus the stereo system you already use for FM, records, and tapes becomes a high-quality audio demodulator for your satellite receiver as well. The UP-1 adds true subcarrier frequency agility and superior audio performance to your TVRO system. And, if the FM tuner you use with the UP-1 is a multiplex-stereo tuner, you'll be able to receive the multiplex-stereo broadcasts now being transmitted by many satellite services.

The UP-1 may also be used with two FM tuners (or one FM tuner and a frequency-agile satellite receiver) to receive direct stereo transmissions used by most radio services relayed via satellite. With the addition of a simple matrix decoder, you'll also be able to decode the matrix-stereo transmissions used by the cable-television movie suppliers. More about matrix-stereo later.

The UP-1 RF Converter is an active RF-mixer circuit which combines the output of a 100-MHz, crystal-controlled oscillator with the baseband RF output of a satellite reciever. It is connected between the baseband output of the satellite receiver and the antenna terminals of any FM tuner. No modifications are required to the FM tuner and usually little or no modifications are needed at the satellite receiver. In operation, a 6.8-MHz satellite audio subcarrier may be tuned in on your FM tuner at 106.8 MHz. The entire satellite audio

TOD T. TEMPLIN

Give up using that standard audio section of your TVRO receiver and switch to high-fidelity stereo sound that is broadcast every day from communication satellites fixed in GEO orbits!

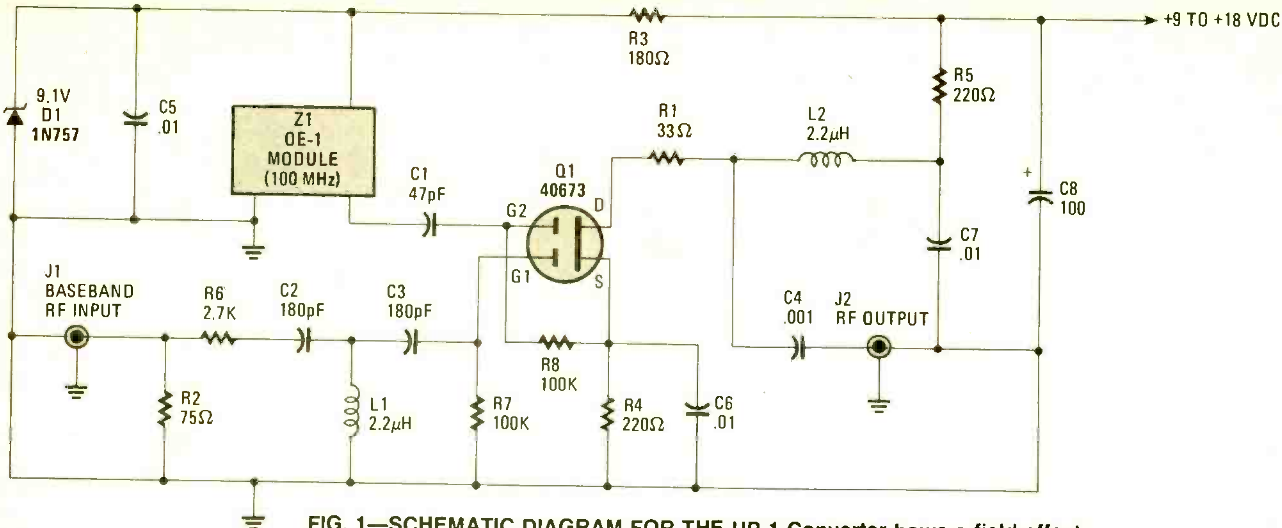


FIG. 1—SCHEMATIC DIAGRAM FOR THE UP-1 Converter hows a field-effect transistor mixing circuit and 100-MHz, local-oscillator module. The module is available from International Crystal and its use greatly reduces the overall circuit components to just a few which mount snugly on a printed-circuit board. The output of Q1 is the sum and difference of the two audio channels on an FM-band carrier.

subcarrier band is presented on the FM tuner between 105 and 108 MHz.

Theory

The baseband RF input from the satellite receiver is applied via J1 to L1, C2, and C3; a T-section, high-pass filter which has a corner frequency of approximately 5.5 MHz. See Fig. 1. This effectively removes most of the video information from the baseband signal, while passing the audio subcarrier. The subcarriers are then hetrodyned with the 100-MHz local oscillator in Q1, a dual-gate, N-channel MOSFET configured as a mixer. This produces both the sum and the difference of the two signals. Although both the sum and the difference frequencies may be tuned on the FM tuner, it is convenient to use the upper set. The output of Q1 is then capacitively coupled to the FM tuner antenna terminals. The value of R6 affects the conversion gain of the UP-1. If your FM tuner requires more signal level, lower the value of R6.

Construction

The UP-1 is designed around a pre-assembled, crystal-oscillator module, Z1. This makes construction fast and simple. There is absolutely nothing to adjust or align. The module is available from International Crystal Manufacturing Company. See the Parts List for ordering information. The remainder of the parts are available from most electronic stores or mail-order firms. The UP-1 is a high-frequency RF device, so although the circuit is simple, it is recommended that it be built on a printed-circuit board. A drilled and plated circuit board is also available (see Parts List), or may be fabricated from the circuit pattern shown in Fig. 2.

Before you mount any parts on the circuit board, you must determine if your satellite receiver has a 75-ohm, baseband, RF-output accessory jack. If you have a commercial receiv-

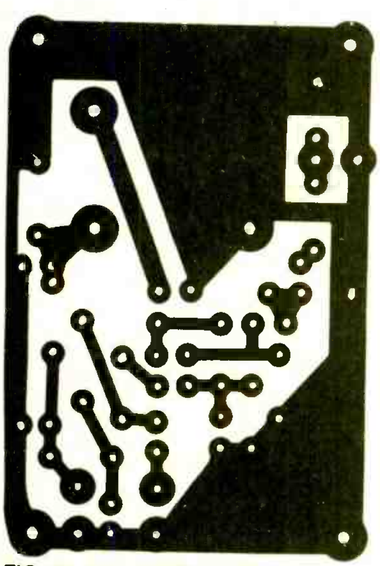
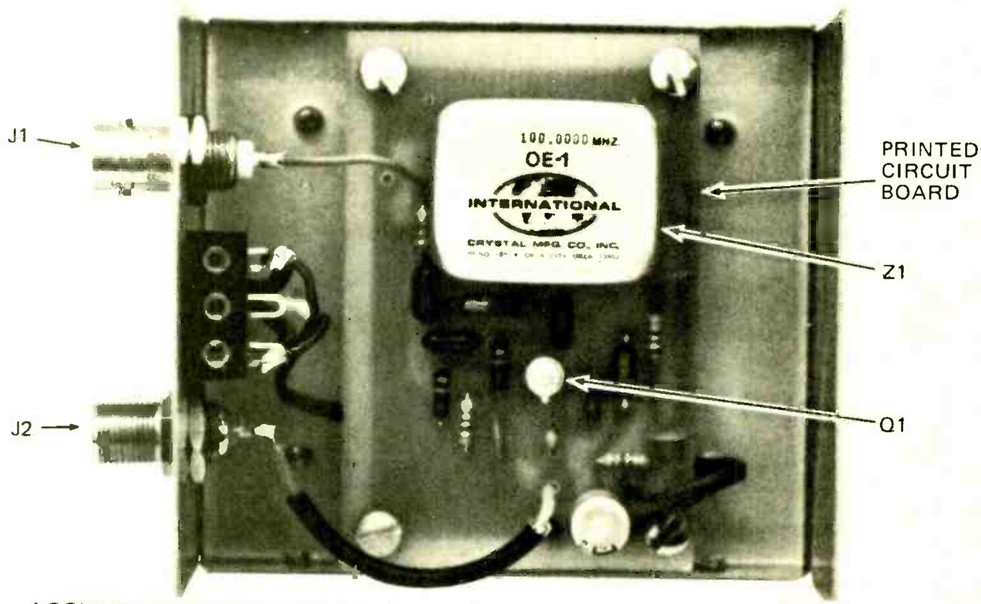


FIG. 2—FOIL-SIDE-UP VIEW of the printed-circuit board used wire-up the UP-1 RF Converter. Pattern is shown same size.



LOOKING STRAIGHT DOWN at the innards of the UP-1 RF Converter reveals how simple the actual layout of the project is! A palm-size, aluminum chassis-box from a local retail electronics parts store is used. Spacers, not shown in the photo, mount between the printed-circuit board and the metal chassis-box bottom. Selection of BNC and type-F connectors for the input and output jacks was based on the system cables used.

PARTS LIST
FOR UP-1 RF CONVERTER

SEMICONDUCTORS
D1—1N757 or 1N4739 9.1-volt Zener diode
Q1—40673 dual-gate MOS field-effect transistor

RESISTORS
(Note: all resistors are ¼-watt, 10%)
R1—33-ohm
R2—75-ohm (see text)
R3—180-ohm
R4, R5—220-ohm
R6—2,700-ohm
R7, R8—100,000-ohms

CAPACITORS
(Note: all units are 50-WVDC)
C1—47-pF, dipped, mica
C2, C3—180-pF, dipped mica
C4—.001-μF, disc
C5–C7—.01-μF, disc
C8—100-μF, upright-mount, electrolytic

COILS
L1, L2 2.2-μH (Miller 9310-20 or equivalent)

ADDITIONAL PARTS AND MATERIALS
J1—BNC female jack
J2—F-type female jack
Z1—Crystal oscillator module, type OE-1 (available from International Crystal MFG. Company, Inc., 10 North Lee Street, Oklahoma City, OK 73102. Order Catalog No. 035214 and specify 100.0000-MHz. Price—$19.79 postpaid.)

Aluminum inclosure, metal standoffs, 9-VDC power supply (if required), coaxial cables (see text), printed circuit board, wire, hardware, solder, etc.

A drilled and plated glass circuit board is available from: S. A. Electronics, P.O. Box 277T, South Milwaukee, Wisconsin 53172. Order No. UP-1. Price $4.95 postpaid.

er, consult the specifications sheet. If it is designed for a 75-ohm load, install the 75-ohm, terminating resistor, R2, on the UP-1 circuit board. (See Fig. 3).

If your receiver doesn't have a baseband output jack, then it will be necessary to add one. Don't attempt this unless you are absolutely sure of what you are doing. If necessary, consult a technician where you purchased your system.

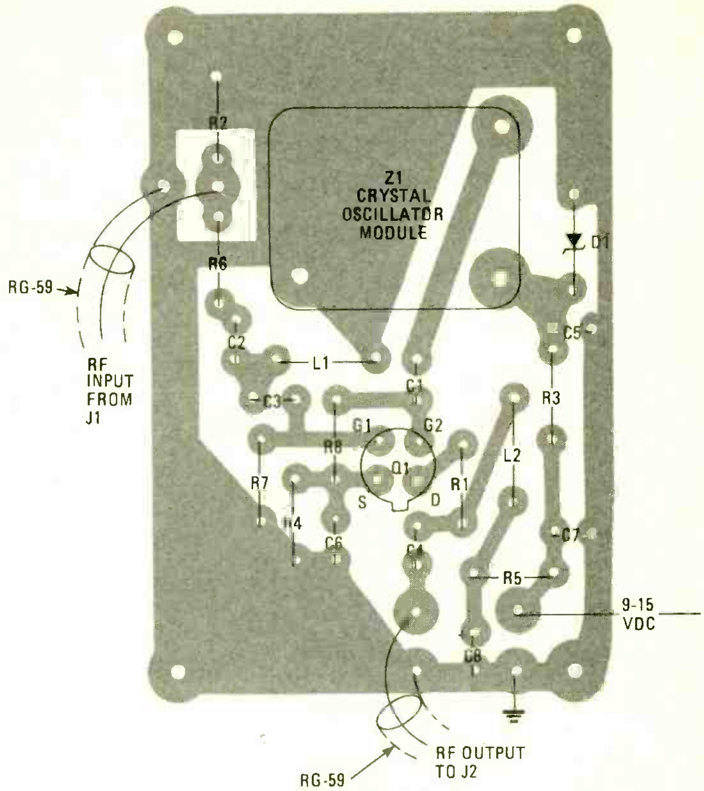
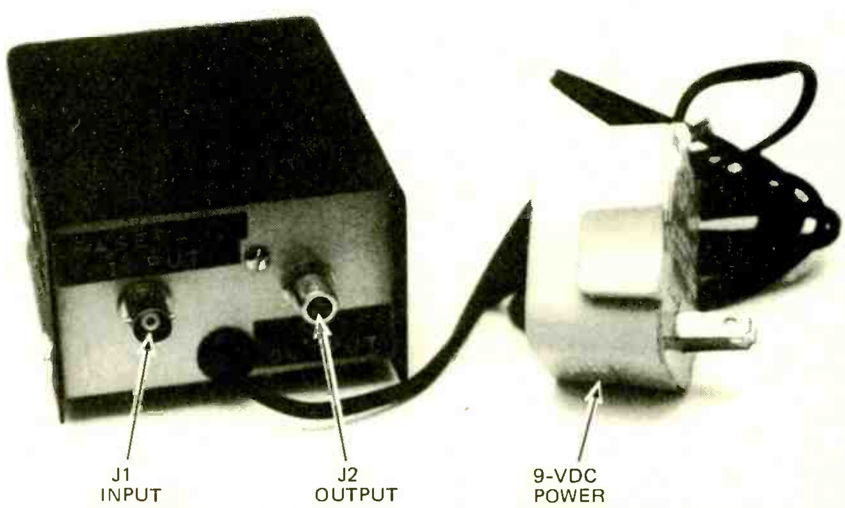


FIG. 3—PARTS LOCATION DIAGRAM pinpoints component placement on the single-sided, printed-circuit board. The direct-current power supply is a common wall-plug module rated at 9-volts DC at a low current drain.

The UP-1 must be connected to a point in the satellite receiver where the full pre-de-emphased RF signal is present. Use a schematic diagram of the receiver to determine where the regular audio demodulators RF tap-off point is located. The RF input of the UP-1 should be bridged across the same point. This will probably be at the emitter of the first transistor after the video demodulator. See Fig. 4. Use a short piece of shielded cable, like RG-174, to bring the signal up to a BNC jack mounted on the rear of the satellite receiver. In this case, leave the space on the UP-1 circuit board for the 75-ohm, terminating resistor empty.

Mount the remainder of the parts according to the parts placement diagram in Fig. 3. Good RF wiring practice should be observed. Keep component leads short, and use



AFTER AN EVENING'S WORK this is what you'll end up with—the UP-1 RF Converter neatly packaged in an aluminum chassis-box. The method of labeling the project is up to you.

shielded cable, like RG-174, between the circuit board and the input and output jacks, J1 and J2. To ensure that the UP-1 doesn't interfere with the normal operation of the satellite receiver, it must be installed in a metal enclosure with four metal, standoff spacers, one in each corner.

The UP-1 requires 9- to 15-VDC for operation. This may be tapped out of the satellite receiver or be supplied by a 9-volt, wall-transformer, DC power supply capable of at least 25 mA.

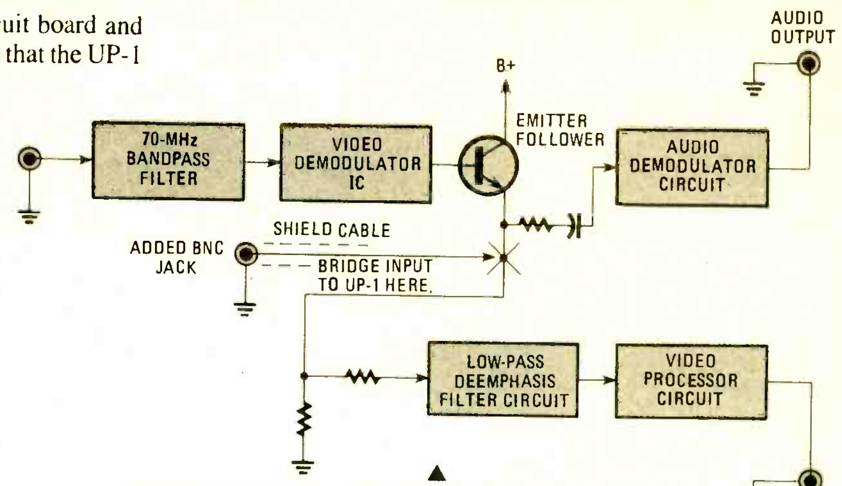


FIG. 4—FUNCTIONAL BLOCK DIAGRAM of a typical satellite receiver. If your satellite receiver does not have a baseband RF output, the UP-1 can be bridged across the input of the audio demodulator.

Operation

Connect the output of the UP-1 to the antenna terminals fo your FM receiver with an appropriate length of RG-59 (or 75-ohms unbalanced, If your FM receiver has a 300-balanced input, use a matching transformer. For convenience, a twoway, RF antenna switch may be used to select between the UP-1 and the regular FM antenna. See Fig. 5. Also use a piece of RG-59 to connect the baseband RF output of the satellite receiver to the input of the UP-1. Keep this cable as short as possible. Apply operating power. Select a transponder on the satellite receiver for which the audio subcarrier frequency is known. Tune the FM receiver to this frequency plus 100 MHz.

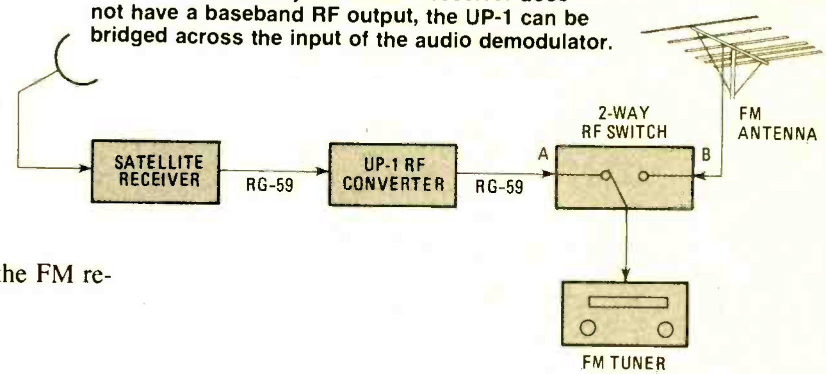


FIG. 5—INSTALLATION BLOCK DIAGRAM of the UP-1 RF Converter shows how the project interconnects with the other components of the TVRO system. Should you have a spare FM tuner of high-fidelity quality, you could eliminate the 2-way switch in the antenna circuit and use the FM antenna for your hi-fi system's FM tuner.

Stereo

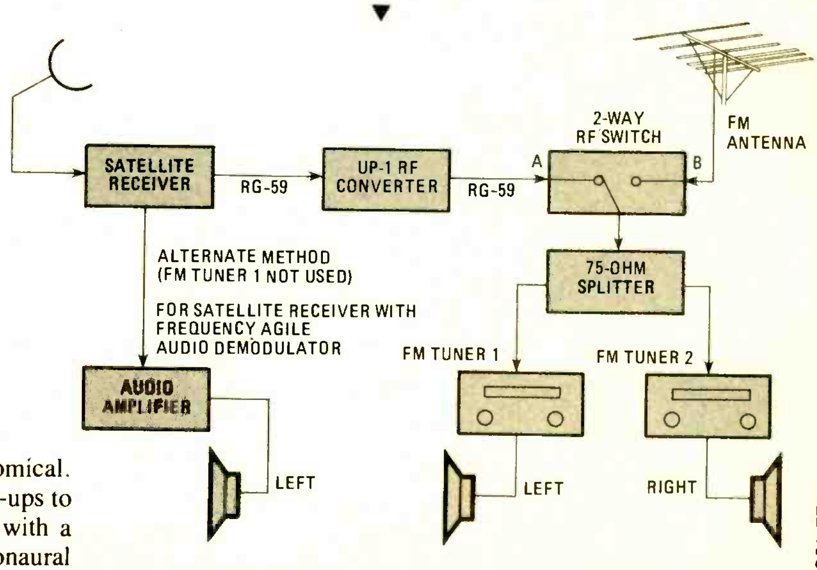
There are currently three types of stereo transmissions being relayed by satellite. They are the multiplex system, the direct system, and the matrix system. Check the Subcarrier Frequency Information Chart to see who uses what system.

The multiplex system requires only one subcarrier and is essentially the same as the multiplex system used by commercial FM radio stations. To receive this type of transmission, just connect the UP-1 between your satellite receiver and a stereo FM tuner.

The direct and the matrix system both require the use of two separate subcarriers. The direct system uses one subcarrier for the left channel and a second for the right channel. To receive this system, you need two audio demodulators; one tuned to each channel. If you have a second FM tuner, or the audio section of your satellite receiver is tunable, it can be used along with the first FM tuner and the UP-1 to receive direct stereo transmissions. See Fig. 6. If you use two FM tuners, connect a two-way, 75-ohm, antenna splitter to the output of the UP-1. Feed one output to each FM tuner. Connect the output of tuner 1 to the left-channel input of a stereo amplifier and the output of tuner 2 to the right-channel input. Tune each tuner to the appropriate subcarrier. Refer to the subcarrier Frequency Information Chart.

The matrix stereo system transmits the left-plus-rifht (L + R) monaural signal on one subcarrier and the left-minus right (L − R) difference signal on the second. This system is used for television audio because it is most economical. Cable companies not yet ready to supply stereo hook-ups to subscribers are still able to offer monaural service with a minimum investment in head-end equipment. The monaural

FIG. 6—INSTALLATION BLOCK DIAGRAM for receiving direct stereo. The FM tuners are tuned to different frequencies to receive each audio channel (left and right) and amplify them either in their internal amplifier or an external stereo power amplifier.



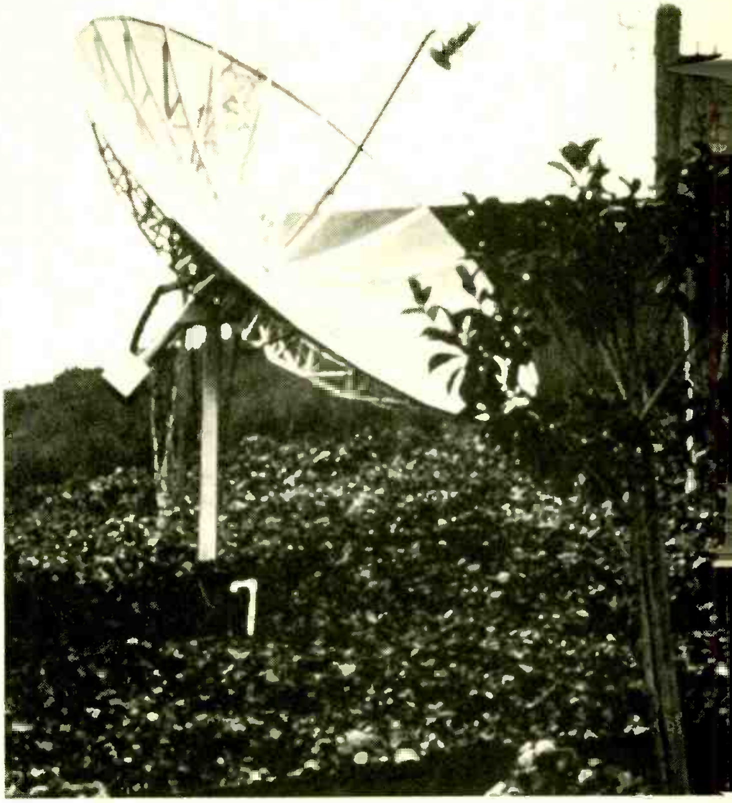
SUB-CARRIER FREQUENCY INFORMATION CHART FOR (SATCOM F3 R)

Service, Transponder	Frequency
PTL Satellite Radio Network, 2	6.2 MHz mono
WFMT radio Chicago, 3	6.3 MHz 6.48 MHz direct stereo
Bonneville Broadcasting, 3	7.38 MHz 7.56 MHz direct stereo
Seeburg Music, 3	7.695 MHz mono
Satellite Music Network, 3	5.58 MHz 5.76 MHz direct stereo
Satellite Music Network, 3	5.94 MHz 6.12 MHz direct stereo
Moody Broadcasting Network, 3	5.4 MHz 7.92 MHz direct stereo
Stardust, 3	8.055 MHz 8.145 MHz direct stereo
The Movie Channel, 5	6.8 MHz (L + R) 5.8 MHz (L − R) matrix stereo
North American Newstime, 6	6.2 MHz slow scan color TV New music programs added
Music TV, 11	6.62 MHz (L + R) 5.8 MHz (L − R) matrix stereo
CNN Radio Network, 14	6.3 MHz mono
Home Theater Network Plus, 16	6.8 MHz multiplex.

sound channel is compatible with all single subcarrier satellite receivers.

To receive matrix stereo transmissions requires all of the equipment used for direct stereo plus a matrix decoder. The matrix decoder is connected between the outputs of the two audio demodulators and the input of a stereo amplifier. Of course, should you need a matrix decoder, all that was previously said would be unusable unless plans for one are provided. The editors of **Special Projects** have provided for this eventuality in the following article. **SP**

THE UP-1 CABINET STYLE was selected to match that of the Matrix Decoder—see right, top.

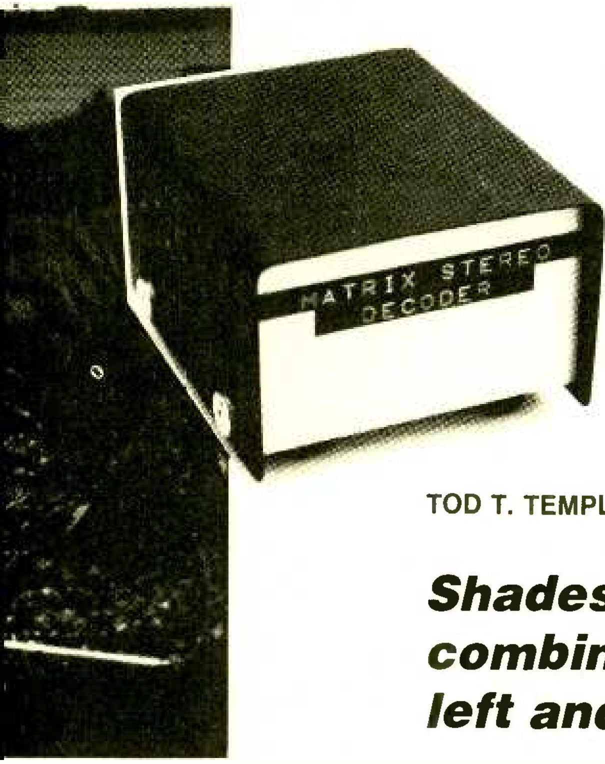


☐THE FEDERAL COMMUNICATIONS COMMISSION AND COMmercial television broadcastors are currently evaluating the feasibility of adding true stereo sound to television broadcasting. As of yet, technical standards for a commercial TV stereo sound system have yet to be established. The FCC and the National Association of Broadcastors are currently involved in an in-depth study of the technical aspects of several proposed stereo systems. The system chosen must be compatible with current TV standards, so that television sets already in use will still receive a monaural rendition of a stereo broadcast. And, once a system is finally chosen, commercial television broadcastors will need to modify or replace much of their audio and transmitting equipment; a huge expenditure many broadcaster will be reluctant to make. It is unlikely that there will be an over-the-air stereo television system in the near future.

However, since January 1, 1982, several suppliers of cable TV programming have been transmitting stereo movies and musical programs via satellite. This is possible because a satellite transponder may use multiple subcarriers to relay two or more audio channels.

Cable TV system operators receive and decode the satellite stereo transmissions and then retransmit via cable the stereo audio to the customer's home in the form of a stereo multiplex FM radio signal. The signal is included in the FM radio band along with regular FM services. The cable viewer receives the stereo audio portion of the program on his FM stereo tuner or receiver while the video portion is displayed on his regular television.

In the preceding article in this issue of **Special Projects** we discussed the merits and uses of the three types of stereo transmissions currently being relayed by satellite; the multiplex system, the direct system and the matrix system. Now we'll look at the matrix system in depth.



M-1 MATRIX STEREO DECODER

TOD T. TEMPLIN

Shades of 1958—the audiophile has to combine L + R and L − R signals to obtain left and right channel hi-fi outputs!

The Magic of Matrix

The matrix system is used by most cable television program suppliers. Matrix stereo transmissions have the left-plus-right (L + R) monaural signal on one subcarrier and the left-minus-right (L − R) difference signal on the other. These two signals must be electronically added or matrixed together to recover the left-only and right-only audio signals. The matrix system was chosen for satellite television because it is compatible with existing cable equipment. Even in a stereo cable system, monaural sound is required for the standard format TV service. And, because the monaural (L + R) signal may be recovered with only one audio demodulator, cable companies which don't have the financial resources to add stereo equipment to their systems, are still able to carry the originating stereo programs, but with monaural sound.

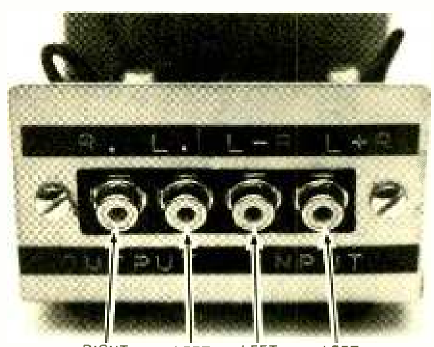
In the preceding article we discussed how to use the UP-1 RF Convertor and your TVRO unit to recover the L + R and the L − R audio signals from two FM tuners, or one FM tuner and a frequency-agile satellite receiver. However, if your TVRO system has two audio demodulators which may be tuned to the appropriate subcarriers, you can use the M-1 Matrix Stereo Decoder.

Theory of operation

The M-1 Matrix Stereo Decoder couldn't be simpler as you will soon agree! A dual, low-power, op amp configured for single-ended supply operation provides the means to electronically add and subtract two signals. See Fig. 1. Resistors are used to split the input signals from both demodulators into two pairs of equal-level signals.

Signal subtraction is performed by op amp U1-a. Half of the L + R signal is fed to the inverting input of op amp U1-a and half of the L − R signal is fed to the non-inverting input of op amp U1-a. Because an op amp amplifies only the difference between its inputs, the left (L) U1-a portions of each signal, which are identical, cancel, making the output of U1-a the right-channel-only (R) signal. It is interesting to note that since the original signals were reduced in half, the sum of the two 1/2R signals is R.

Signal addition is performed with op amp U1-b. Op amp U1-b is also fed half of the L + R and half of the L − R signals, but this time both signals are fed to the inverting input. No signal is applied to the non-inverting input of op



THE M-1 MATRIX stereo decoder has just two input jacks and two output jacks as you would expect for a stereo device. Since there is a one-time-only adjustment for each stereo channel, the gain potentiometers are mounted inside the case—there are no adjustments whatsoever to be made once the unit is assembled and the cabinet is closed tight. Not shown in this view is the power cable leaving the rear of the unit. The unit requries a 12-18-volt DC regulated supply that can be tapped from the TVRO unit or from an external power supply, the likes of which can be found in this issue.

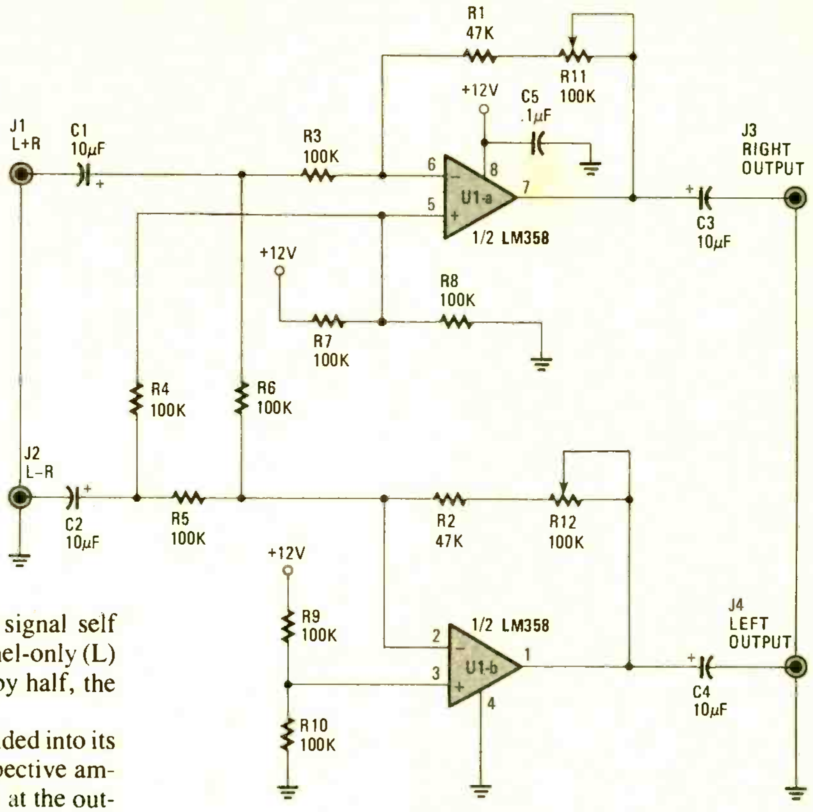


FIG 1—THE SCHEMATIC DIAGRAM for the M-1 Matrix Stereo Decoder uses both sections of a low-power, dual operational amplifier, LM358, in a simple circuit that adds and subtracts signals at unity gain. The upper amplifier in the diagram, U1-a, adds −1/2(L+R) and 1/2(L−R) to develop the R signal. Below, U1-b sums one-half of each input signal, 1/2(L+R) and 1/2(L−R) to obtain the L signal.

amp U1-b. The +R and −R portions of each signal self cancel in the input resistors, leaving the left-channel-only (L) signal. As before, since the signal was reduced by half, the sum of 1/2L plus 1/2L is L.

Thus, the signal that left the studio has been divided into its component left and right channels, and their respective amplitudes are unchanged and faithfully reproduced at the output terminals of the M-1 Matrix Stereo Decoder. The op amp U1-b acts only as a buffer amplifier for the summed signal.

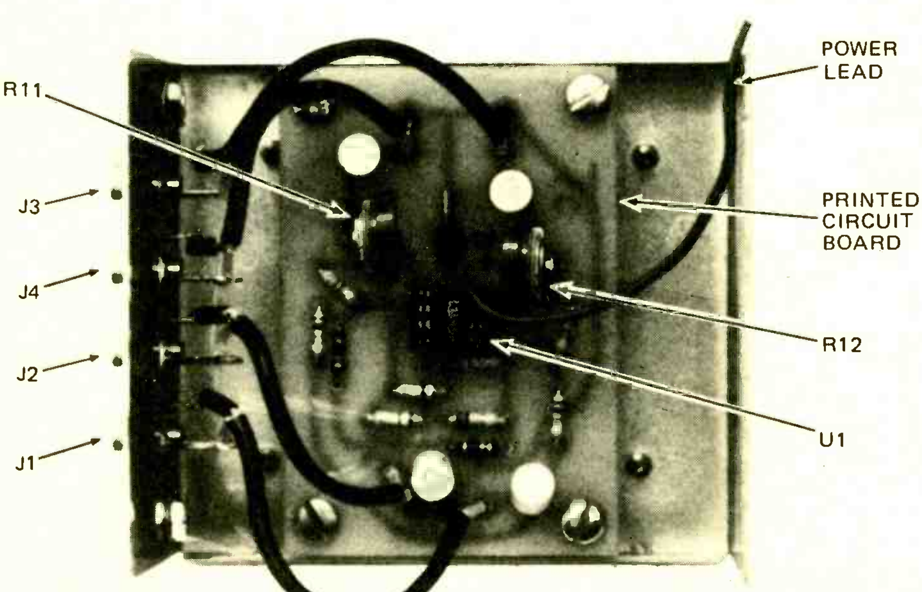
Putting It Together

The M-1 Matrix Stereo Decoder circuit may be hand wired on a small piece of vector board. If you are inclined to making your own printed-circuit boards, a full-size foil pattern is provided. See Fig. 2. Mount the parts on the circuit board as indciated on the parts placement diagram. Use shielded cable for all audio wiring. The M-1 Matrix Stereo Decoder requires from 12 to 18-volts DC for operation. This may be tapped from the satellite receiver, or provided by a wall-transformer, DC power supply. When finished, the decoder may be mounted inside your receiver or in a small enclosure.

Operation

Connect the output of demodulator 1 to the L+R input jack J1 and the output of demodulator 2 to the L−R input Jack J2 of the decoder. The right and left outputs of the decoder (jacks J3 and J4, respectively) are connected to the proper inputs of your stereo amplifier. Two gain-adjustment potentiometers, R11 and R12, are provided to match audio levels in your system, and also to help adjust for maximum channel separation. When the potentiometers are set to the center of their range, the decoder is set for unity gain. You could use a signal generator to supply alternately the left and right signals and adjust the potentiometers for unity gain at the outputs.

After you've wired everything up, you're ready to test it out. Use the Subcarrier Frequency Chart given in the preceding article to find a cable broadcast service which uses the matrix system. Not all transmissions will be in stereo, and since there is no



TOP VIEW of the M-1 Matrix Stereo Decoder with the lid removed from the chassis box. Simple printed-circuit board makes for neat assembly with minimum external wiring. Easy access to trimmer potentiometers makes adjustment procedure easy.

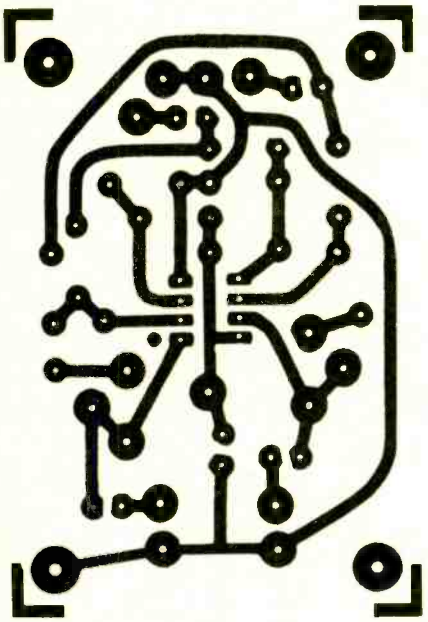


FIG. 2—FOIL-SIDE VIEW of the printed-circuit board layout used to mount the components for the M-1 Matrix Stereo Decoder. Layout is simple enough to use perfboard material, however, the printed-circuit board is much neater.

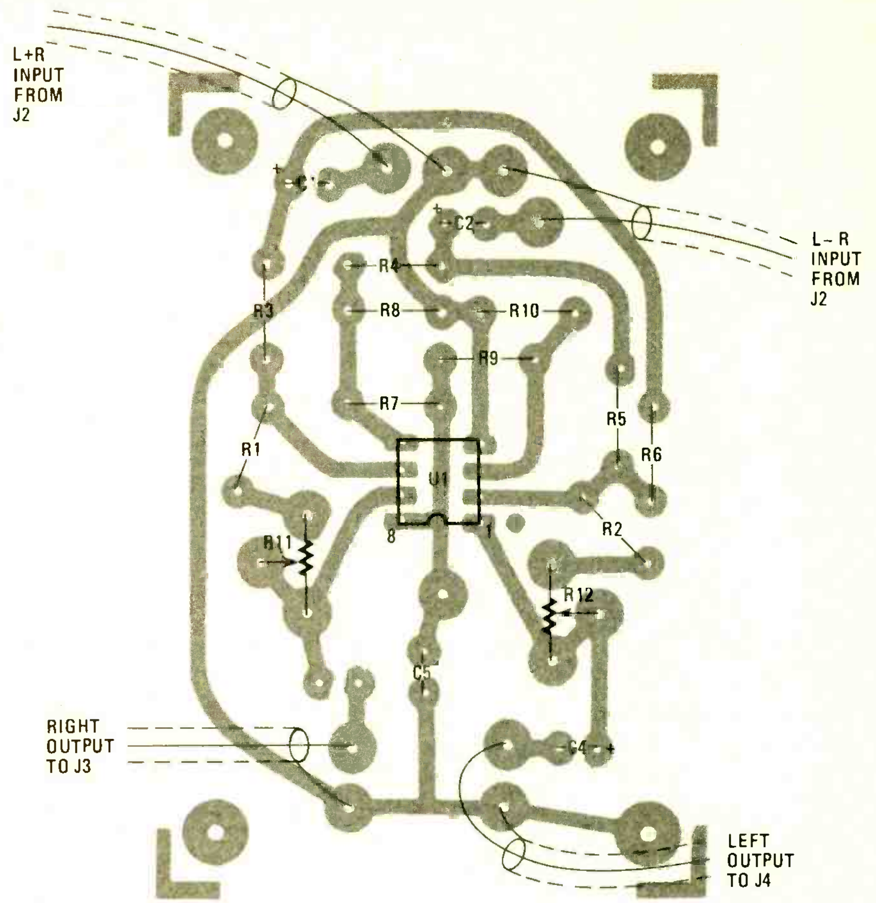


FIG. 3—PARTS LOCATION DIAGRAM shows the printed circuit board with foil-side down. Shielded cables interconnect the printed-circuit board with the RCA phono jacks, J1-J4, on the chassis-box apron, power cable exit other side.

pilot signal to detect, you can't be sure when a transmission is in stereo. Fortunately, transponder 11 on a satellite F3R is almost always in stereo. Tune demodulator 1 to the L+L signal and demodulator 2 to the L−R signal.

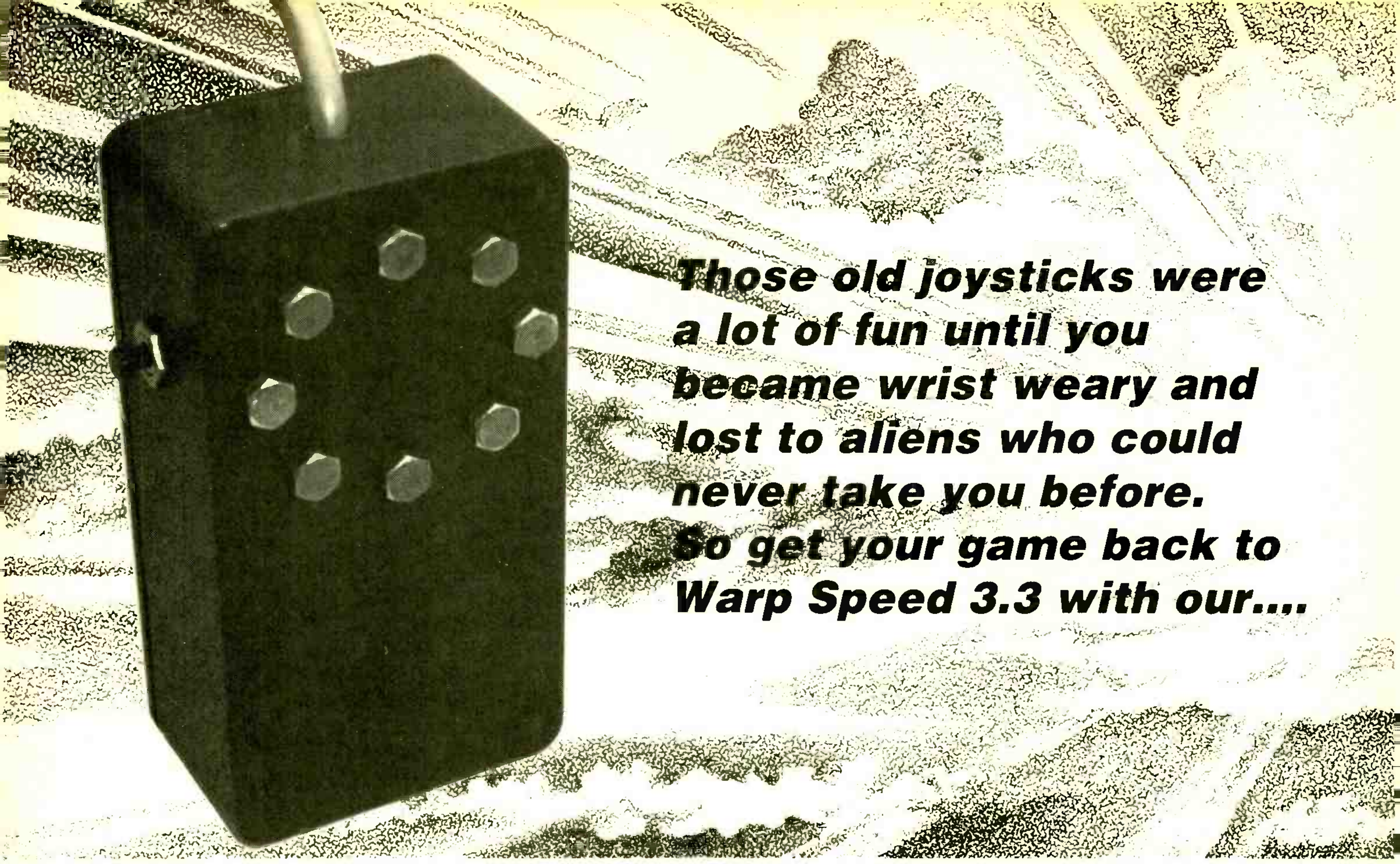
If you are unsure of which is which, the L+R signal can be distinguished from the L−R signal by the fact that it is much louder and does not have a muffled sound. Although the L−R signal is lower in level, because of the mathematical signal manipulation discussed earlier, the stereo output levels will be correct. If you have a stereo headset, you can make fine adjustments to gain potentiometers R11 and R12 while listening for maximum separation. If the outputs of both of your demodulators are equal for a given amount of signal deviation, both gain potentiometers (R11 and R12) should end up at approximately the same setting.

When stereo movies are made, the audio channels are mixed so that the voice of a person on screen appears to be coming from the center of the screen. This is done by mixing an equal amount of the actors' voice into each channel. When a stereo film is shown at a movie theater, besides feeding the left and right channels to the speakers on the corresponding sides of the theater, a portion of the left and right signals are mixed together and fed to a speaker directly behind the center of the screen. This provides a phantom third channel of sound to fill the hole in the stereo sound image and to focus the action on the screen for a more realistic effect. This may not be necessary in your home where the stereo speakers are only six-feet apart and not 30 feet as in the movies.

For stereo viewing at home which is most like a theater presentation, arrange your viewing area so that the television receiver is located directly between the left and right speakers. Provide a feed of the output of the L+R audio demodulator to the television audio system, just as you would if you were only equipped for monaural viewing. Adjust the television volume so that it is not quite as loud as the sound coming from the stereo speakers. You are now prepared to enjoy a new dimension in television viewing. **SP**

PARTS LIST FOR M-1 MATRIX STEREO DECODER

C1–C4—10-μF, 25-WVDC, PC-board-mount electrolytic capacitor
C5–C6—.1-μF disc capacitor
J1–J4—RCA phono jack, 4 units on one strip
(Note: all fixed resistors are ¼-watt, 5% units)
R1, R2—47,000-ohm
R3–R6—100,000-ohm
R7–R10—100,000-ohm
R11, R12—100,000-ohm upright, trimmer potentiometer
U1—LM358 or MC1458 operational-amplifier, integrated circuit
Printed-circuit board material, 8-pin DIP socket, shielded, audio cable, 4- × 3- × 4-inch chassis box, hardware, solder, etc.



Those old joysticks were a lot of fun until you became wrist weary and lost to aliens who could never take you before. So get your game back to Warp Speed 3.3 with our....

☐THE JOYSTICK USED ON ONE POPULAR VIDEO-COMPUTER GAME system is no more than a mechanical switch box. The reaction time is fairly adequate for some games, but in others, switching time is critical, and the joystick is slow in that respect. By using the Speed-Switch Touch Control, you can improve your response time (and possibly save the Earth from pesky invaders). The Speed-Switch Touch Control provides positive, solid-state switching and can replace the joystick entirely. Or, for any game not requiring the Speed-Switch Touch Control, the joystick can be plugged back into the system.

Joystick operation

Inside the joystick box commonly used in Atari products, there are five pushbutton, normally-open, switches mounted on a printed-circuit board (see Fig. 1). Four of the switches will close as determined by the joystick's position, and one is the red-button switch, which will close whenever the red button is pushed. Each switch has a common ground connection and a connection to an individually colored wire. There are colored wires (one for each switch) and one black wire (the system ground) connected to the printed-circuit board. Those six-wires run from the box, via a cable, to a plug which attaches to the computer console. When the cable is plugged into the system, each of the five colored wires is connected to a computer input, and the black wire is connected to the system ground. With the computer on, each of the five inputs will be held high at a +5 volts unless its wire-connected switch is closed, which will ground that input.

Figure 2 shows the eight possible switching combinations of the joystick. If the joystick is positioned to the left, only the left switch will close, which will ground the green wire input. If the joystick is positioned diagonally between left and up, both the left switch and the up switch will close, which will ground the green-wire input and the white-wire input. In a similar manner, moving the joystick to the other positions will close their respective switches. Thus, either a grounded input, or the combination of the two inputs is used to interface the joystick's position to the computer.

At most, only two of the four positioning switches can be closed at a time. Note that it is impossible (and unnecessary) to have both the left switch and the right switch closed at the same time. Neither can the up and down switches be closed simultaneously. Those two switching combinations are as unacceptable to the computer as they are to the joystick, which is mechanically capable of closing only one or two adjacent switches at any one time. With all that in mind, the Speed-Switch Touch Control must be able to:

1. Accept positioning data entered by a finger touch,
2. Prevent accidental, unacceptable combinations (such as left-right and up-down combinations), and
3. Interface the positioning data to the computer by grounding the correct computer input(s).

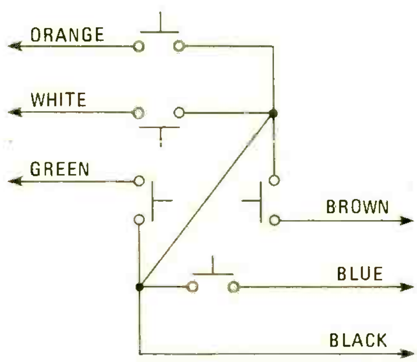


FIG. 1—TEAR OPEN AN ATARI JOYSTICK and you'll be able to trace out this simple diagram of its switching action.

Speed-Switch Touch Control Operation

Figure 3 is a schematic diagram of the Speed-Switch Touch Control. The circuitry is similar for all inputs, so let's

Speed-Switch Touch Control

R. VERNON

look at what happenes when the LEFT plate is touched. The operation of the touch switch depends on the ambient, 60-Hz, electromagnetic field which permeates throughout the average home. The input of inverter U1-a is at ground through R1, and the output is at 9 volts (high). When a finger touches the left plate, the 60-Hz field is picked up by the high-impedance input of inverter U1-a. Inverter U1-a amplifies the AC signal, and a 60-Hz, 9-volt, peak-to-peak squarewave is produced at its output. The squarewave is then rectified by diode D1. Point A, which was initially at 9 volts through R9, now drops to .9 volt because of filter capacitor C1 discharging through D1 on every low half-cycle of the squarewave. The R9-C1 time constant is long enough to allow point A to remain at .9 volt until the finger is removed, at which time the output of U1-a returns to a constant 9 volts. Now D1 is reverse-biased, and C1 recharges through R9 back to 9 volts. The operation of the UP, RIGHT, and DOWN touch plates is identical to the LEFT touch plate just described.

Now assume that the LEFT-UP plate is touched. See Fig. 3. U1-b reacts as U1-a did, but the squarewave is rectified by both D2 and D3. Point A once again drops to .9 volt, but so does point B. When the finger is removed, both points A and B return to 9 volts. The operation of the other diagonal touch plates is identical.

You can see that points A, B, C, and D in the schematic diagram roughly correspond to the left, up, right, and down positions of the joystick. A high level (9 volts) at those points represents an open switch, and a low level (.9 volt) corresponds to a closed switch. But, by touching both the left plate and the right plate, which could happen accidentally, both points A and C will drop from high level to low level. This low level, left-right combination is unacceptable to the computer, as is the low level, up-down combination, represented by points B and D. A way to specifically select either left *or* right and either up *or* down must be added if the circuit is to protect the computer from illogical inputs.

To see how the left-right combination and the up-down combination are prevented, first look at the truth table for the CMOS 4013 flip-flop chip in Fig. 4. No matter what condition is present at the reset and set inputs, the paired (Q1)-Q1 and (Q2)-Q2 outputs can never be low at the same time. Either a single low input or the first of two low inputs will determine the condition of the outputs. That is characteristic of the 4013 chip. If both inputs were to be low, the outputs would remain in their previous condition, depending upon which input went low first. We indicate this special case by listing (Q) and Q in the bottom line of the truth table. If both inputs went low simultaneously (an unlikely but still possible event), the outputs would remain high.

Now using point A (left) as a reset input and point C (right)

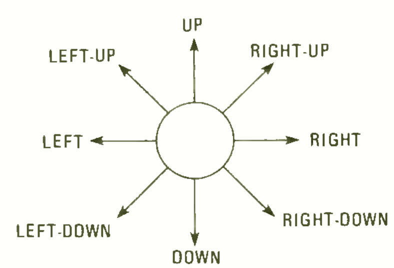


FIG. 2—THERE ARE ONLY NINE POSSIBLE joystick switch positions—if you count only eight, you forgot the center-off.

as a set input in U3-a, output (Q1) will follow the levels at point A, and output Q1 will follow point C, as long as only one of the points is low. If both points are low, the outputs will be determined by the point that went low first. The outputs will remain in that condition until either the first low point or both points return high. With the same restriction, output (Q1) will follow point B, and output Q2 will follow

PARTS LIST
FOR SPEED-SWITCH TOUCH CONTROL

SEMICONDUCTORS

D1-D16—1N914 silicon diodes
U1, U2—4049 CMOS, hex-inverter, integrated-circuit chip
U3—4013 CMOS, dual, flip-flop, integrated-circuit chip

ADDITIONAL PARTS AND MATERIALS

B1—9-volt, DC, transistor battery
C1-C4—.05-µF, 16-WVDC ceramic disk capacitor
R1-R8—10-Megohm, ¼-watt, 10% resistor
R9-R12—1-Megohm, ¼-watt, 10% resistor
S1—Normally open, momentary-contact, pushbutton switch
Perfboard, integrated-circuit sockets, plastic case or chassis box, 9-volt transistor battery clip, 8 bolts with 16 nuts (3/16-in. or 5mm, ½-in. or 12.5-mm length, hex-head) two 6-pin male connectors and one 6-pin female matching connector, double-sided foam tape (2 × 1-in.), insulated wire, solder, hardware, decals, paint, etc.

point D. Figure 5 shows the voltages present at each of the four Q outputs when each of the plates is touched. (Note: Reference to Q1, etc., refers to an output signal of the 4013 chips and not some transistor, of which the circuit has none.)

Diodes D13-D16 isolate the flip-flops' higher output voltage of 9 volts from the computer's 5 volts. Each diode will conduct only when the Q output connected to it goes low, thus grounding its computer input. When any Q output is high, its diode will be reverse-biased, and the computer input remains at 5 volts.

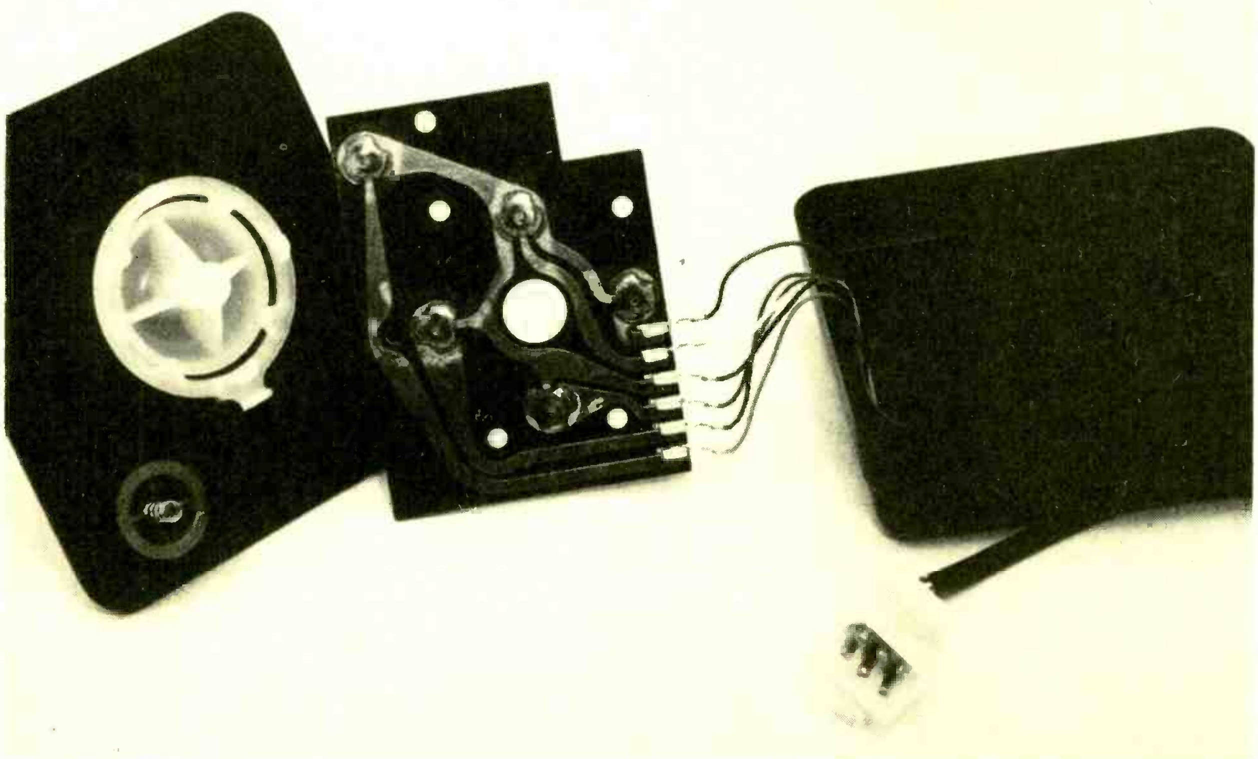
Switch S1 replaces the pushbutton switch of the joystick box, and its operation is identical. No on-off switch is needed for the 9-volt battery, since the current drain is very minute. However, if you are fussy, you could use an 8-pin connector and loop the 9-volts DC through the connector terminals. That way, when the connector is unplugged, the DC path will be interrupted.

Technical Notes

These technical notes will give you a more detailed understanding of the Speed-Switch Touch Control and an opportunity to evaluate circuit changes you may initiate.

In the Speed-Switch Touch Control, the inverters of the 4049 integrated-circuit chips are being used as high-impedance, high-gain amplifiers. Thanks to on-chip Zener diodes, any excessively positive input voltage is clamped to 30 volts, and any negative voltage is clamped to − .5 volt (as referred to pin 8, ground). The input protection allows the use of the inverters as touch switches without harm to the integrated-circuit chips.

The high impedance of the reset and set inputs of the 4013 flip-flops permits the use of a 1-megohm resistor and a .05-µF capacitor as a 60-Hz filter. When the associated inverter produces a 60-Hz, 9-volt peak-to-peak squarewave, the minimum, low-level voltage at this filter will be .6 volt (one diode forward voltage drop), and the peak, low-level voltage will be 1.9 volts (produced when the rectifier diode has been reverse-biased on the high half-cycle of the 60-Hz squarewave and the .05-µF capacitor has partially charged through the 1-megohm resistor from .6 volt, as per the universal time constant chart). The maximum low-level input voltage of the 4013 is 3 volts, and since the peak, low-level voltage of the filter is still under this maximum voltage, the 4013 sees it as a low-level input.



PEEKING INSIDE THE ATARI joystick reveals the simple, snap-together, plastic construction used in the toy industry. Disassembly causes no damage at all to the joystick, and it can be reassembled quickly. Colored wires make circuit tracing very easy.

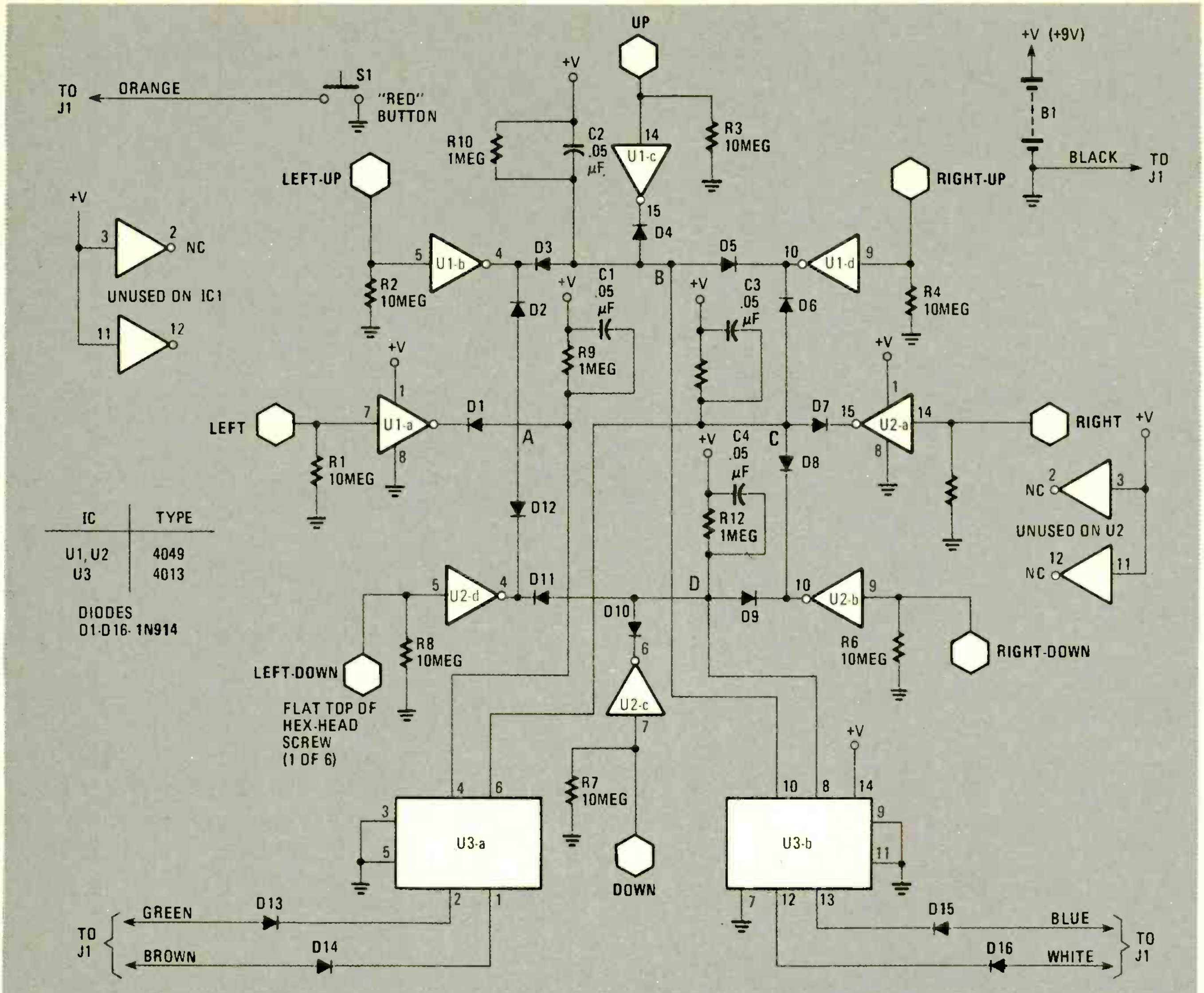
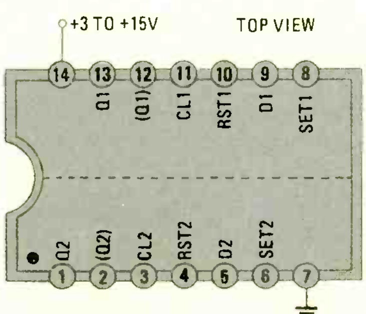


FIG. 3—THE SCHEMATIC DIAGRAM for the Speed-Switch Touch Control will be very easy to understand when you reduce it to its basic parts. Eight identical inverters sense the 60-Hertz hum pickup from a finger touch, and two flip-flops provide the up-down and left-right switching action.

For any touch input activated (finger touched), the maximum high-to-low level switching time of the related output is .01 second—the approximate time of one half-cycle of the 60-Hz squarewave. For any input deactivated (finger removed), the maximum low-to-high level switching time of any output is .1 second—the approximate time of one half-cycle of the 60-Hz squarewave plus the time for the .05-μF capacitor to charge through the 1-megohm resistor to 7 volts (the minimum high-level input voltage of the 4013) from .6 volt. The longer low-to-high level switching time is used to "debounce" each touch switch when a plate is touched, thus providing smooth switching while maintaining a quick response capability (under .15 sec.).

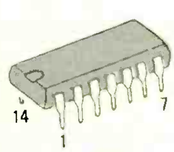
The diode-interface outputs do not actually ground the computer inputs, since .6 volt will appear across any biased diode. However, the computer accepts that .6 volt as a low-level input and will respond accordingly.

The reverse voltage placed across each isolation diode (D13-D16) is 4 volts, well under the maximum PIV specified for the 1N914.



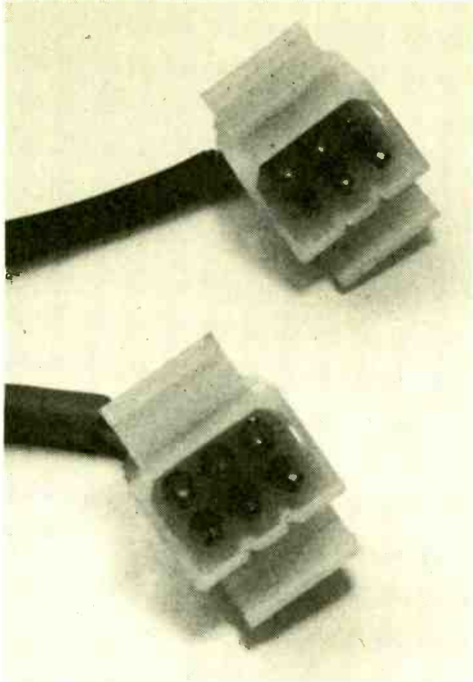
RESET	SET	$\bar{Q}$	Q
1	1	1	1
0	1	0	1
1	0	1	0
0	0	$\bar{Q}$	Q

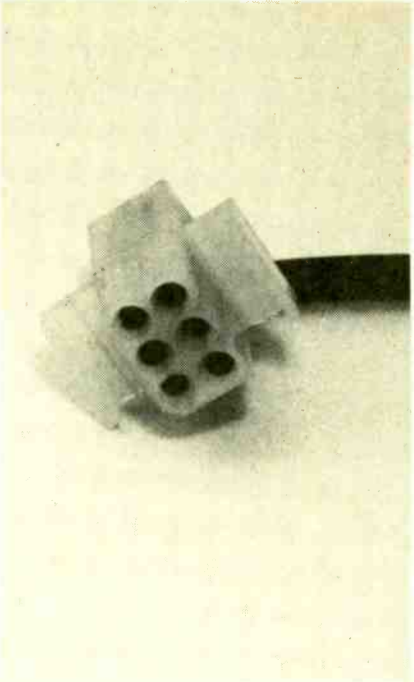
1 = HIGH LEVEL
0 = LOW LEVEL



4013
14-PIN
DIP PACKAGE

FIG. 4—PRACTICALLY all you need to know about the 4013 chip is presented here. The simple truth table is discussed in the text. Note that the pin diagram divides itself into two similar flip-flops. Refer to U3-a and U3-b in Fig. 3.





HERE'S WHAT YOUR CABLE ENDS will look like after the 6-pin connectors are installed. The black cables in the photos left and right are from the original joystick assembly. Here, all that was done was cutting the cable and installing matching male and female connectors. Then, shown in the lower-left photo, the Speed-Switch Touch Control cable has a similar connector. The text gives complete details.

The "on" power requirement (when any plate is touched) is 500 microamperes. The "off" power requirement so low that it can not be determined with typical electronic hobbyist equipment.

Construction

Before you begin building the Speed-Switch Touch Control, decide the enclosure size you want to use. The author used a 4¾- × -2½- × -1½-inch plastic chassis box available at Radio Shack. Whatever size you use, make sure that it is small enough to be held comfortably in the palm and large enough to house the components.

Once you have your box, cut a perfboard so that it will fit flat against the bottom of the box. On the upper half of the perfboard, mark the eight touch positions as you will want them to be on the front of the box. A circular design was used for Speed-Switch Touch Control, but any similar positioning will work, such as a square or diamond design, as long as all eight positions are represented. Now drill a 1/16-inch hole at each position on the perfboard. Turn the perfboard over and place it on the front of the box in the same position as if it were inside the box. Using the perfboard as a template, mark the eight positions on the face of the box. Remove the perfboard and drill a 7/32-inch hole at each marked position on the box. Now position the perfboard flat against the inside bottom of the box and align the holes. Enlarge each perfboard hole to 7/32-inch while all the holes are aligned. First, enlarge the top and bottom holes; then, fasten the board to the box with two bolts, and then enlarge the remaining six holes. Remove the board and install eight bolts from the front of the box and fasten with eight nuts. Position each bolt head in whatever symmetrical pattern you wish and tighten each nut.

Now find a convenient location for the pushbutton switch, S1 on the left side of the box (on the right side for left-handers). Drill a mounting hole large enough for the switch. On the top side of the box, drill a ¼-inch hole which will be used later for a 6-wire cable. Jack J2 will connect to this cable. Set the box aside temporarily.

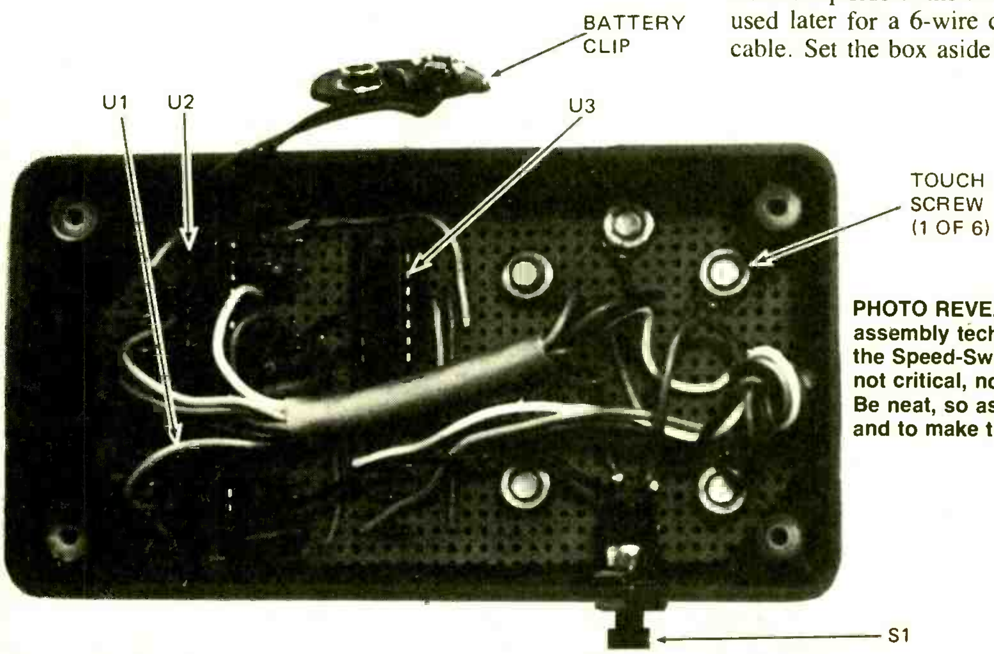


PHOTO REVEALS THAT author used a perfboard-assembly technique to assemble his version of the Speed-Switch Touch Control. Wiring is not critical, nor is placement of parts. Be neat, so as to avoid mistakes during assembly and to make the unit attractive to use.

Mount the parts on the lower left half of the perfboard using point-to-point wiring. Parts placement is not critical, but try to conserve space. Use sockets for the integrated-circuit chips, and, if possible, use color-coded wiring to avoid confusion. Connect a 6-inch wire to each inverter input used. Strip ¾-inch insulation from the free end of each wire. Form each bared end into a circle and solder. With another 6-inch wire, connect one terminal of the switch to the perfboard's ground. Connect the battery clip to the perfboard at +V and ground locations. Next, make a 6-wire cable by wrapping 6 different colored wires of 2-foot lengths together. The wires can be held together with heat shrink tubing or electrical tape. Connect one wire of the cable to the perfboard's ground, one to the switch's other terminal (high of S1) and the other four to the anodes of the output diodes, D13-D16.

When the perfboard wiring is complete, install the integrated-circuit chips and mount the perfboard in the box, component side up. Next, connect the looped end of each of the eight inverter input wires to its correct bolt and fasten with a nut. Mount the switch in its hole. Now, tie a knot in the 6-wire cable as a strain relief and route the cable through its hole.

Now cut the cable of the manufactured joystick box at its midpoint. To the cable half which plugs into the console, attach the 6-pin female connector P1. To the other half, attach a 6-pin male connector J2, being careful to connect the proper colored wires in the proper positions as determined by the female connector. Now, in the same manner, attach a 6-pin male connector, J1, to the 6-wire cable of the Speed-Switch Touch Control.

Finally, tape a double-sided, foam-tape strip to the inside back of the enclosure cover, and mount the 9-volt battery, B1. Connect the battery clip to the battery, and now you're ready for testing.

Testing

It would be wise to test the Speed-Switch Touch Control with a voltmeter before using it on your computer. First, make sure that the computer ground is connected to the board ground via a jumper cable. (Note: The ground of the Speed-Switch Touch Control must be connected to the ground of an AC-operated power supply for it to function properly.) You can use Table 1 as a guide to test each of the Q outputs. Make certain that no part of your body is touching the circuit's ground while you are testing, because that will reduce the AC field at your finger to the point where the inverters cannot detect it.

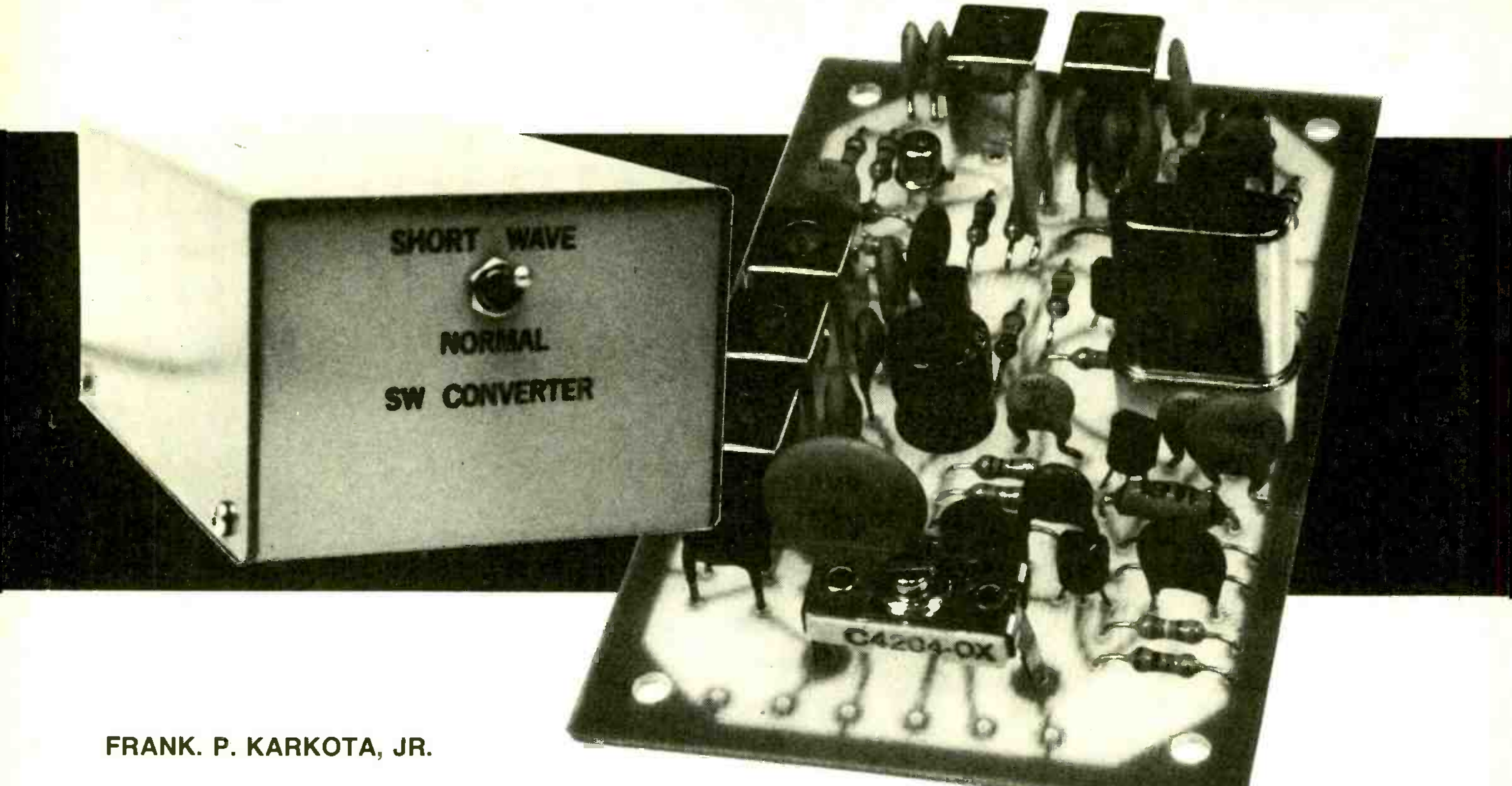
To make sure that each flip-flop is correctly wired, first touch the left plate. The Q1 output should be a 0 volt and all of the other outputs should be at 9 volts. Now, while your finger is on the left plate, touch the right plate with another finger. The outputs should remain the same. Now remove your finger from the left plate only. Now, the Q1 output should be at 0 volt and the other outputs should be 9 volts. Perform the same test for the up and down plates and their outputs.

When you are sure that the circuit is working properly, you can plug the Speed-Switch Touch Control into the female connector of the console cable. It will take a little bit of practice to get used to the touch controls. By using the index, middle, and ring fingers, you can switch to any position quickly. In two-player competition, the Speed-Switch Touch Control will give you a definite edge over the joystick, so you might want to build one for your opponent, but then, let him build his own and keep the edge. **SP**

TABLE 1—CONTROL VOLTAGES

Control	Meter Reading (+V)			
Plate Touched	(Q1)	Q1	(Q2)	Q2
None	9	9	9	9
Left	0	9	9	9
Left-up	0	9	9	0
Up	9	9	9	0
Right-up	9	0	9	0
Right	9	0	9	9
Right-down	9	0	0	9
Down	9	9	0	9
Left-Down	0	9	0	9

THE BATTERY is cemented to the case cover with a drop of RV adhesive. To replace battery, just pry up old unit with a knife or wide-blade screwdriver.



FRANK. P. KARKOTA, JR.

SHORTWAVE LISTENING TRANSPORTS YOU AROUND THE world. It provides you with many different rewards, such as the excitement of hearing a broadcast from the other side of the world, or hearing a weak signal from a small, remote country. A foreign broadcast can tell of a distant country, its people, its culture, and its politics. Many of the broadcasts directed to the United States are in English; however, if you tune to the right frequencies, you can hear virtually every other language.

Unfortunately, most inexpensive shortwave radios can only receive the strongest stations and then only with considerable fading and interference. A quality receiver costs hundreds of dollars—a cost that usually cannot be justified for casual listening.

There are several important requirements for a quality shortwave receiver. It should have a high enough sensitivity so that a long antenna is not required for good reception. It should also have high selectivity, because stations in the shortwave bands are very closely spaced. Equally important: It should have high-image and spurious rejection; the bands are crowded enough without having interference from signals outside the desired bands. The automatic gain control (AGC) must be highly effective, because there is considerable fading that occurs over the long distances. Because many signals are very strong, overload protection is important; and it should be automatic without the need of input attenuators. Frequency accuracy is important in locating desired stations, but it need not be more accurate than +5 kHz. Finally, it should be possible to tune the receiver without constantly having to adjust a preselector.

The typical automobile AM radio is probably the best receiver available to the average consumer. It is highly sensitive and well shielded, making it ideal for use with a converter. The selectivity of many models is as good as possible without degrading audio quality. It has effective AGC and overload rejection. The radio's pushbuttons may be used for shortwave settings. When connected to the One-Bander Shortwave Converter described in this article, all of those characteristics add up to a quality shortwave receiver.

The One-Bander Shortwave Converter described in this article is designed to be connected to any AM car radio, to create a high-quality, single-band, shortwave receiver. Limiting reception to a single band allows optimum performance without requiring complex switching or tuning. The converter features a special matching network to use the existing car radio antenna. Five stages assure maximum rejection of images and spurious responses. A high-gain, low-noise, MOSFET RF amplifier provides high sensitivity and another MOSFET is a mixer. The converter includes an IF amplifier to provide a strong signal to the car radio. An ABC in the converter prevents overload when there are strong signals present, and a crystal oscillator is used for the local oscillator to make tuning stable and accurate.

Theory of Operation

The One-bander Shortwave Converter circuit is shown in Fig. 1. The RF signal, picked up by the automobile antenna, is transferred by coaxial cable to the converter. The electrical characteristics of the coaxial cable is series inductance and parallel capacitance. The inductance cancels the capacitance of the coaxial cable when each end of the cable is terminated by a certain specific impedance. That specific impedance is referred to as the characteristic impedance of the coaxial cable. Because the auto antenna is electrically very short, it has a very high impedance, many times the characteristic impedance of the cable. The result is that the coaxial cable appears as a shunt capacitor to ground. To compensate for that capacitance, the antenna is coupled to L1 in a manner that makes the shunt capacitance part of the tuned circuit, thus neutralizing the capacitance of the coaxial cable. Capacitors C2 and C3 determine the amount of coupling, and C1 permits adjustment to compensate for different lengths of coaxial cable.

The signal is then coupled by C4 to L2 and C5, then through C6 to L3 and C7. Each tuned circuit increases the rejection of signals outside the desired band. The signal is

ONE-BANDER SHORTWAVE CONVERTER

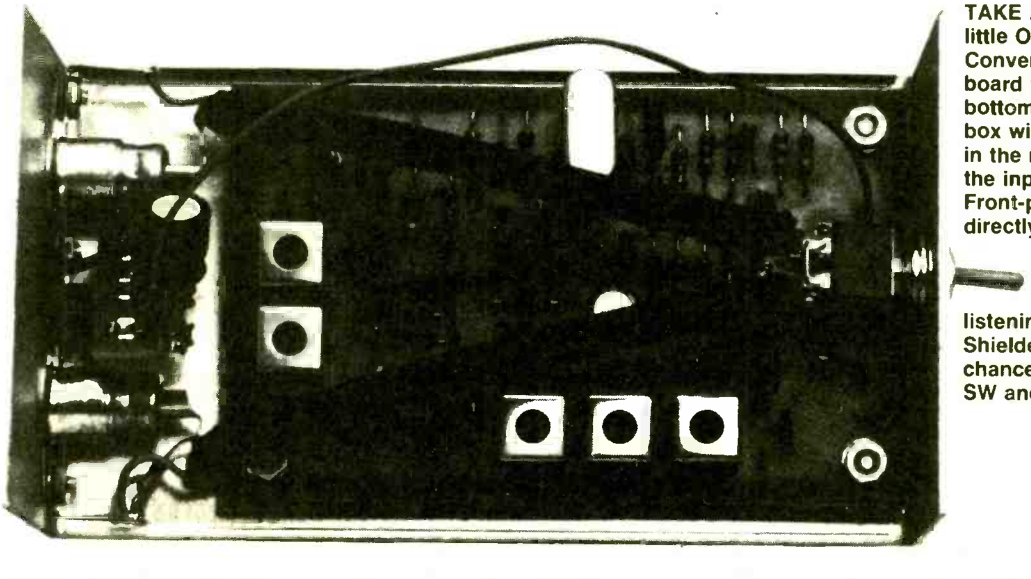
Here's an inexpensive way to tune in your favorite shortwave band while wheeling it down the road!

then applied to gate 1 of Q1, the RF amplifier stage, through the DC blocking capacitor C8. Resistors R1, R2, R3, R4, R5, and R6 form the biasing network for Q1. Those values have been carefully selected to maximize gain and AGC capability. Capacitors C9 and C10 are RF bypass capacitors used to reduce the feedback that would reduce gain and cause instability. The load of Q1 is L4 and C11, which resonate at the desired band and further suppress out-of-band signals. Resistor R7 and capacitor C12 are for RF de-coupling.

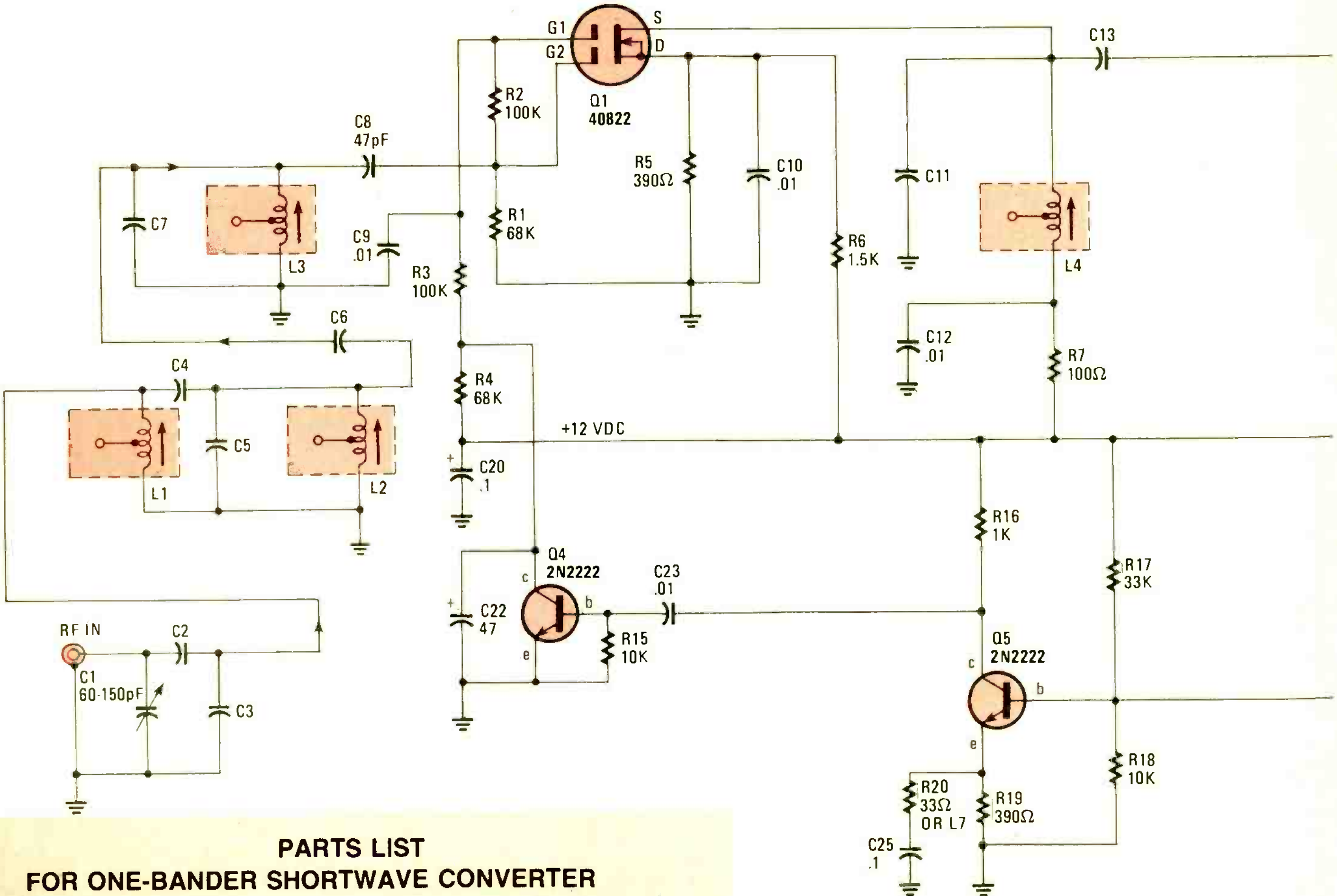
The signal is coupled through C13 to L5 and C14, and gate 1 of Q2, the mixer stage where the conversions of shortwave frequencies to the broadcast band take place. Resistors R8 and R9 provide bias for that stage so that when the local-oscillator signal is applied to gate 2, the amplifier is driven into non-linearity, causing mixing.

The outputs of Q2 are not only the amplified input signal and the local oscillator signal, but also the sum and the difference of the two frequencies and many other unimportant by-products. For example if the local oscillator is a 5-MHz crystal and a 6-MHz signal is present at the input, the significant outputs from the stage will be 5 MHz, 6 MHz, 11 MHz and 1 MHz. Since the output of Q2 goes through the tuned circuit of L6, C16, and R10, which is tuned to approximately 1 MHz, only the 1 MHz difference remains and is referred to as an intermediate-frequency (IF) signal. In that example, there could be a problem if a 4-MHz signal is also present at the input of the mixer. The resultant signals from the 4-MHz signal will be 4 MHz, 5 MHz, 9 MHz, and 1 MHz. Since one of the resultant signals is 1 MHz, the 4-MHz signal will interfere with the 6-MHz signal we want to hear. In that case, the 4-MHz signal is called an image.

Images are reduced by increasing the number of tuned circuits and the quality or "Q" of the tuned circuits between the antenna and the mixer. Also, increasing the intermediate



TAKE A PEEK inside the big, little One-Bander Shortwave Converter! Printed-circuit board fits snugly in the bottom of the aluminum chassis box with a little bit of room in the rear to take care of the input and output jacks. Front-panel switch (right) directly connects input to output terminals when converter is not used and radio listening is preferred. Shielded cables reduce any chance of crosstalk between SW and BCB programming.



PARTS LIST
FOR ONE-BANDER SHORTWAVE CONVERTER

SEMICONDUCTORS
Q1—40822 or 40673 MOSFET
Q2—40823 or 40673 MOSFET
Q3-Q6—2N2222 or PN2222 transistor
Z1—1N4744, Zener diode at 15-V

RESISTORS
(Note: All fixed resistors are 5%, ¼-watt units)
R1, R2—68,000-ohm
R2, R3, R8,—100,000-ohm
R5, R13, R19, R101—390-ohm
R6—1500-ohm
R7-100-ohm
R9, R10, R14, R16, R24—1000-ohm
R11, R15, R18—10,000-ohm
R12, R17—33,000-ohm
R20—33-ohm
R21—2200-ohm
R22, R102—47,000-ohm
R23—15,000-ohm

BAND-SELECTED CAPACITORS

Band	49	30-31	25	19-20	16	13	11
C2	220	120	120	68	47	27	20
C3	220	46	20	—	—	—	—
C4, C6, C13	15	5	5	2.2	2.2	1	1
C5, C11	330	120	82	47	27	20	12
C7, C14	330	120	82	47	27	15	7
C26	100	56	47	33	27	10	5

CAPACITORS
(Note: The tolerance for fixed capacitors less than .01 µF is 10%. The tolerance of the remaining capacitors is not critical. Capacitors should be selected suitable size to fit printed-circuit board.)
C1—16-150-pF, trimmer capacitor
C8, C17, C18—47-pF
C9, C10, C12, C23, C27—.01-µF
C15, C25—.1-µF, 12-WVDC
C16, C24—220-pF
C19, C20—.1-µF, 16-WVDC
C21—5-pF
C22—47-µF or 100-µF, 12-WVDC electrolytic
C101—100-µF, 16-WVDC, electrolytic

CRYSTALS

X1—49-meters	5000-kHz fundamental
30-31-meters	8500-kHz fundamental
25-meters	10500-kHz fundamental
19-20-meters	14000-kHz fundamental
16-meters	16500-kHz fundamental
13-meters	20500-kHz 3rd overtone
11-meters	24500-kHz 3rd overtone

INDUCTORS
L1-L5—10.7-MHz IF transformers (Goldwell 42IF124, or equivalent)
L6—100-µH inductor
L7—4.7-5.0-µH inductor (See text)

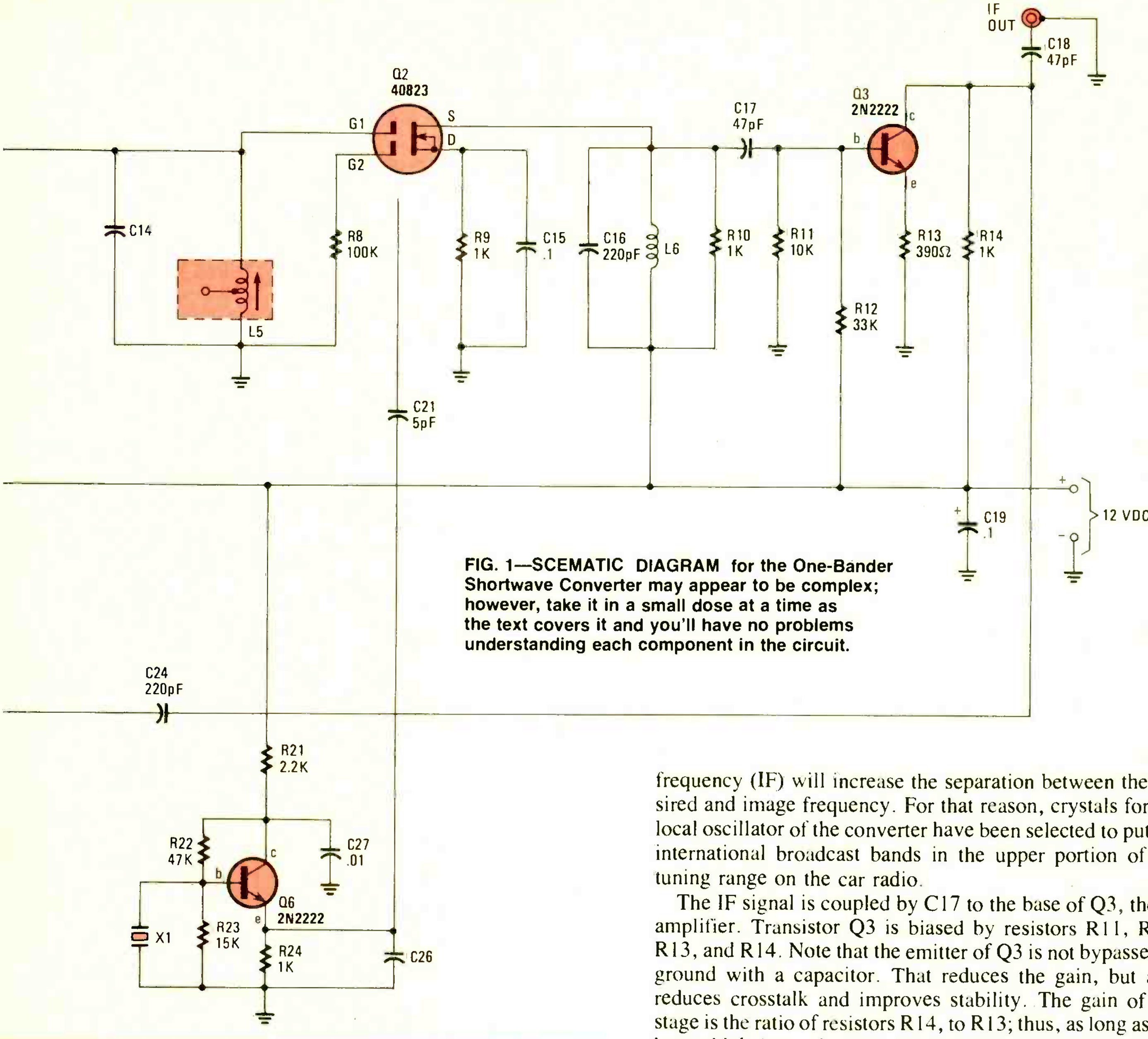


FIG. 1—SCEMATIC DIAGRAM for the One-Bander Shortwave Converter may appear to be complex; however, take it in a small dose at a time as the text covers it and you'll have no problems understanding each component in the circuit.

ADDITIONAL PARTS AND MATERIALS

J101, J102—Motorola antenna RF connector
S101—DPDT switch
Cabinet, crystal socket, RG-58 or RG-62 coaxial cable, hardware, wire, printed-circuit board, solder, etc.

The following parts and materials are available from Communications Poly Services, Inc., P.O. Box 3251, Westford, MA 01886:

Printed-circuit board, $5.00
IF transformers, $.50 each
Crystal (see frequency listing above), $7.00
Complete kit of parts, including printed-circuit board, crystal, and printed-circuit board mounted components (Specify shortwave band listed in Table 1), $25.00
Pre-drilled cabinet and hardware, $12.00
Completely assembled and tested One-Bander Shortwave Converter (specify shortwave band listed in Table 1), $50.00
Add $2.00 to all orders for handling and shipping. Massachusetts residents add 5% sales tax.

frequency (IF) will increase the separation between the desired and image frequency. For that reason, crystals for the local oscillator of the converter have been selected to put the international broadcast bands in the upper portion of the tuning range on the car radio.

The IF signal is coupled by C17 to the base of Q3, the IF amplifier. Transistor Q3 is biased by resistors R11, R12, R13, and R14. Note that the emitter of Q3 is not bypassed to ground with a capacitor. That reduces the gain, but also reduces crosstalk and improves stability. The gain of the stage is the ratio of resistors R14, to R13; thus, as long as Q3 has a high beta, the gain of the stage is unrelated to the individual characteristics of the transistor. The signal at the collector of Q3 is coupled to the car radio by C18.

The signal from Q3 is also coupled through C24 to Q5 for AGC amplification. Resistors R16, R17, R18, and R19 bias that amplifier. R20 and C25 reduce the negative feedback and increase the gain of the stage without affecting DC bias. The gain of the stage is the ratio of R16 to the equivalent impedance between the emitter and ground. When the converter has a local-oscillator frequency less than 6 MHz, some of the local-oscillator signal gets through L6, C16, and R10. That signal is unrelated to the strength of the incoming signal and should not be applied to the AGC detector, because it will be interpreted by the AGC as an overload. To remedy the problem, R20 should be replaced by L7 when the local oscillator frequency is less than 6 MHz. Coil L7 has a higher impedance at higher frequencies, therefore, causing a lower gain at the higher frequencies, and preventing the local-oscillator signal from being amplified

The signal from Q5 is coupled by C23 to the base of Q4, the AGC detector. The base of Q4 is normally held to 0-volts by R15. But when strong signals are present at the input of the converter, the converted and amplified signal forward

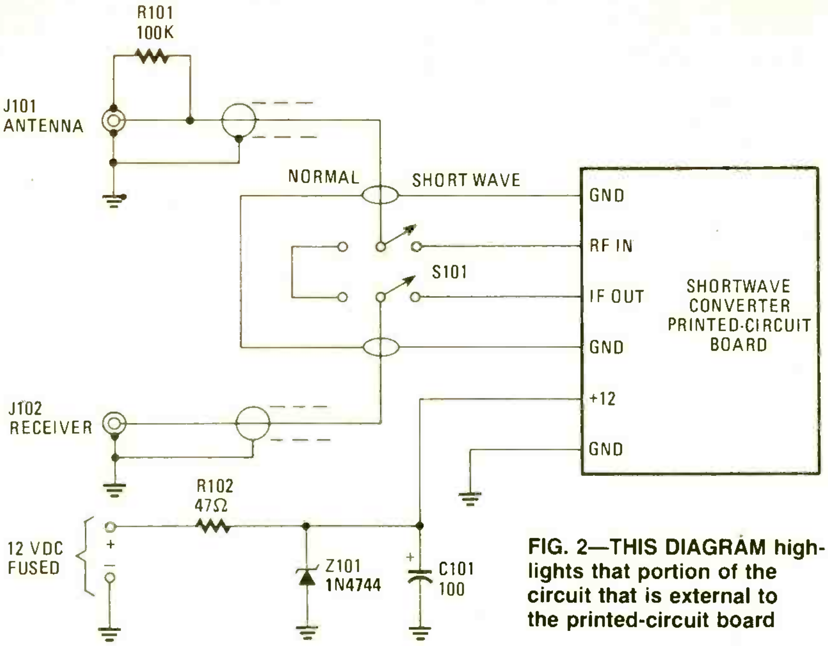


FIG. 2—THIS DIAGRAM highlights that portion of the circuit that is external to the printed-circuit board

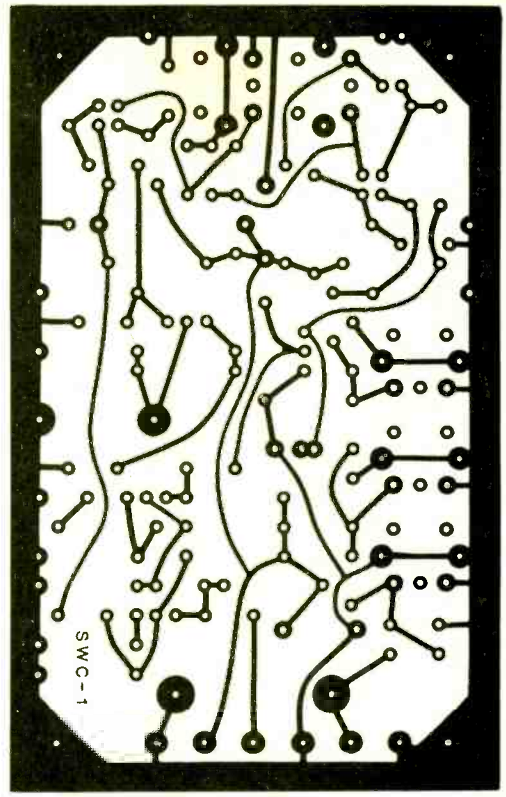


FIG. 3—FOIL TEMPLATE is shown here in exact size. You can make your own printed-circuit board or purchase one directly from a supplier. Details are in the Parts List.

biases the base of Q4 during positive peaks. Transistor Q4 goes into conduction and partially discharges C22, which recharges through R4. The voltage drop across R4 reduces the bias voltage in Q1 and reduces the gain of that amplifier stage. The gain of Q1 will be reduced to the point where the input signal to Q4 is just barely enough for forward bias. The gain of Q1 will be adjusted automatically as the strength of the input signals changes.

The local oscillator uses a crystal for high stability. Transistor Q6 is an amplifier, biased by resistors R21, R22, and R23. Crystal X1 is a fundamental or overtone crystal placed between the input and output of transistor Q6, providing feedback at its series-resonant frequency. Capacitor C6 determines the level of feedback and the frequency at which oscillation can be sustained. The output is taken from the emitter, through C21 to gate 2 of Q2. The de-coupling

Fig. 4—PRINTED-CIRCUIT BOARD parts layout is given here in detail. Be sure that transistors Q1-Q5 are positioned correctly in their mating holes to avoid damage to them.

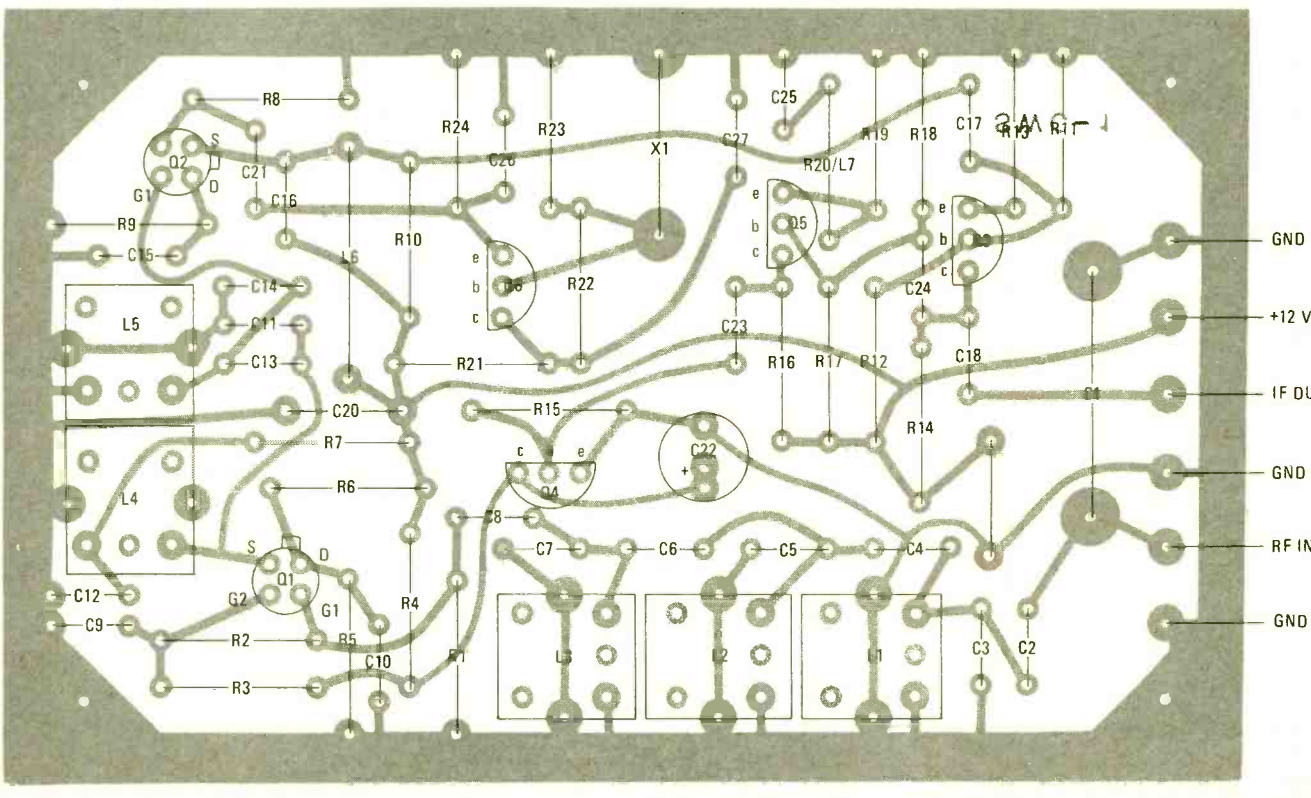


TABLE 1
INTERNATIONAL SHORWAVE BROADCAST BANDS

Meters	Freq. (kHz)	Crystal (kHz)	IF (kHz)	Characteristics
49	5950-6200	5000	950-1200	Usable only during the night. Not used worldwide. Subject to severe static during summer nights.
31	9500-9775	8500	1000-1275	Best during the night, usable during early morning and late afternoon. Most popular and reliable band.
25	11700-11975	10500	1200-1475	Best during the night, usable most of the time.
19	15100-15450	14000	1100-1450	Best during the day, usable most of the time. Unusable during extremely low sunspot activity.
16	17700-17900	16500	1200-1400	Best during the day, occasionally usable during the night. Unusable during low sunspot activity.
13	21450-21750	20500	950-1250	Best during the day, occasionally usable at night. Usable only during high sunspot activity.
11	25600-26100	24500	1100-1600	Best during the day, rarely usable at night. Usable only during extremely high sunspot activity. (This is not Citizen's Band.)
—	10000	8500	1500	WWV Standard time and propagation reports.
—	15000	14000	1000	WWV Standard time and propagation reports.

network consists of R21 and C27.

The inputs of many of the amplifiers are biased directly from the power circuit. Capacitors C19 and C20 shunt to ground signal voltages from other amplifiers that are present in the power circuit, thus improving stability.

The Skyhook

One of the problems often experienced with outdoor antennas, such as the car radio antenna, is static buildup. Resistor R101 is placed across the input connector to the converter to provide a DC path to ground, as shown in Fig. 2. That eliminates the hissing and popping that can occur if there is a static discharge through leaky dielectric material. Also, R102 and C101 form a lowpass filter to eliminate noise in the supply voltage from the car's electrical system. Zener diode Z101 protects the converter from high-voltage transients in the electrical system.

Band Selection

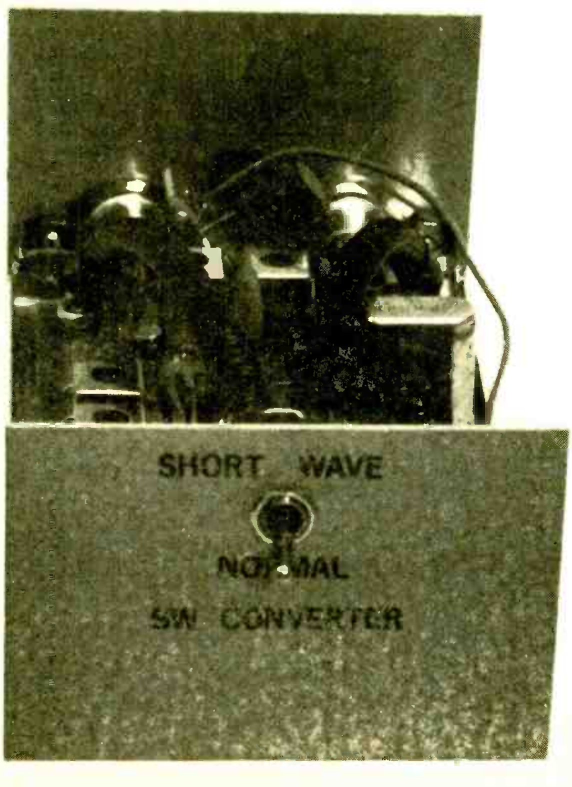
Before constructing the One-Bander Shortwave Converter, select one of the shortwave bands. Each band has different propagation characteristics. Most countries transmit on several bands to reach the largest audience. Therefore, although multi-band capability is desirable, it is not required for reception of broadcasts from most countries. Table 1 shows the various bands, the frequency of the crystal and the IF output, and the characteristics of the bands. Note that the 13-meter and 11-meter bands are highly dependent upon sunspot activity and are often unusable for months or even years at a time. When those bands are usable, however, they provide excellent reception from virtually everywhere in the world. There are other shortwave broadcast bands, but those are generally limited to local broadcasts which are not in English.

Most of the remaining spectrum is used for commercial and amateur communications, which use specialized forms of modulation. Amplitude modulation (AM) is used only by broadcast stations and is rarely used by the other services. Because a car radio cannot detect those specialized forms of modulation, there is little that can be received with the converter on a car radio outside the international broadcast frequencies.

Construction

Building the One-Bander Shortwave Converter requires good RF construction techniques. The printed-circuit board shown in Fig. 3 is recommended. Also, see Fig. 4. Another approach is to use a piece of single-sided copper-clad board.

The coils used for L1, L2, L3, L4, and L5 are the primary windings of 10.7-MHz IF transformers. The capacitors may be removed, or the transformers may be purchased, without capacitors. The builder should be aware that the inductance of the transformer varies from one manufacturer to another,



FRONT VIEW OF THE One-Bander Shortwave Converter is all that you need to see in your car. Switch should be within easy and safe reach.

with the actual inductance ranging from 2 μH to 7 μH. The values of capacitors C2, C3, C4, C5, C6, C7, C11, C13, and C14 were based upon a transformer with a nominal inductance of 2.1 μH. The choice of a transformer with a different inductance requires the recomputation of the capacitor values. Trimmer capacitor C1 should be positioned so that the top plate is grounded, thus allowing the use of a metallic screwdriver for adjustment.

Alignment and Installation

The assembled One-Bander Shortwave Converter can be mounted in an aluminum box or other suitable cabinet that shields the converter from local AM stations. A DPDT switch can be used to switch the converter into the antenna circuit, as shown in Fig. 2. Cables between the antenna jack and the converter, as well as between the converter and the car radio, should be RG-59 or RG-62, and should be kept as short as possible.

The converter requires 12-volt filtered DC at about 30 milliamperes. That should be taken from the same source as the car radio. A fuse is not included in the converter; therefore, the power must be taken from a fused source to prevent possible damage to the car in the event of a short circuit.

The One-Bander Shortwave Converter may be aligned with actual signals or with a signal generator. To align it with a signal generator, connect the converter to a 12-volt supply and connect a voltmeter between the junction of R3, R4, and C20, and ground. Connect the signal generator to the input of the converter and set the signal generator for the center of the shortwave band. Adjust C1 for maximum capacitance and adjust L1 through L5 for a minimum reading on the voltmeter. It may be necessary to adjust the output of the signal generator to keep the voltage within a usable range. Adjustments will have to be made very slowly because of the slow response of the voltage to changes in signal level.

When the One-Bander Shortwave Converter is aligned with actual signals, the ABC in the converter and in the car radio will compensate for the adjustments. Temporarily placing a 47-ohm resistor across the output of the converter will reduce the signal to below the radio's AGC threshold. Before aligning the converter, set C1 to midrange if the auto antenna is being used, or to maximum capacitance if a short length of wire is being used. Next, find a known signal in the center of the shortwave broadcast band and tune L1 through L5 for maximum signal. Be sure that the signal you are using is in the desired band and is not an image; otherwise you would be tuning the converter to the image band and not the band originally selected. Be particularly careful when tuning up the 16-meter converter, because the image frequencies are in the 19-meter band. With most IF transformers, the higher-frequency signal will be tuned with the slug in the higher position. It is best to make final adjustment when the band is weak, so that there will be minimum AGC action.

Once installed in the car, C1 should be adjusted for maximum signal. Also, the car radio's antenna trimmer should be readjusted for the extra length of coaxial cable, with the converter switched out of the circuit.

Test Results

Yes, the project worked, and our SWL results were excellent. A bit too good to just write adjectives about, so, we ran some tests on the 19-meter version of the One-Bander Shortwave Converter. Here are the results:

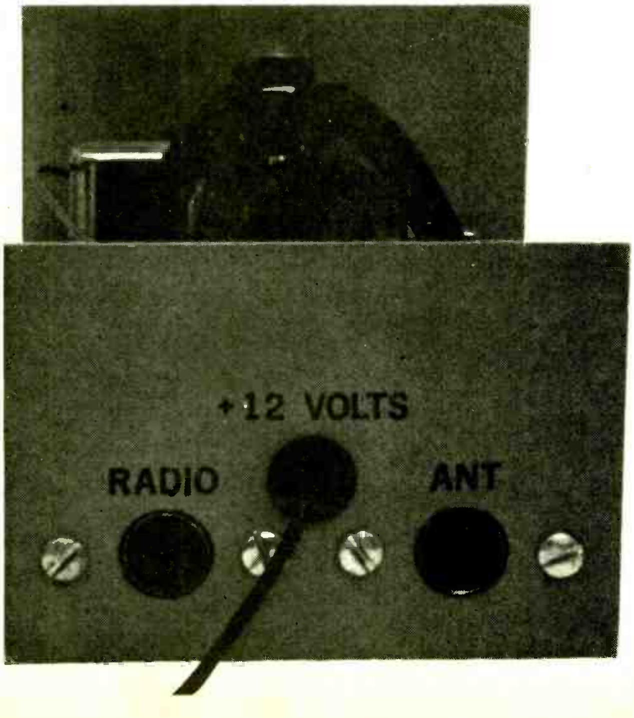
Sensitivity:	0.4 μV/10 dB quieting
Image rejection:	85 dB
Overall gain:	40 dB with an input less than 100μV
AGC threshold:	100 μV
AGC overload:	200 mV
Output level:	15 mV with 200 mV input

Use It Indoors

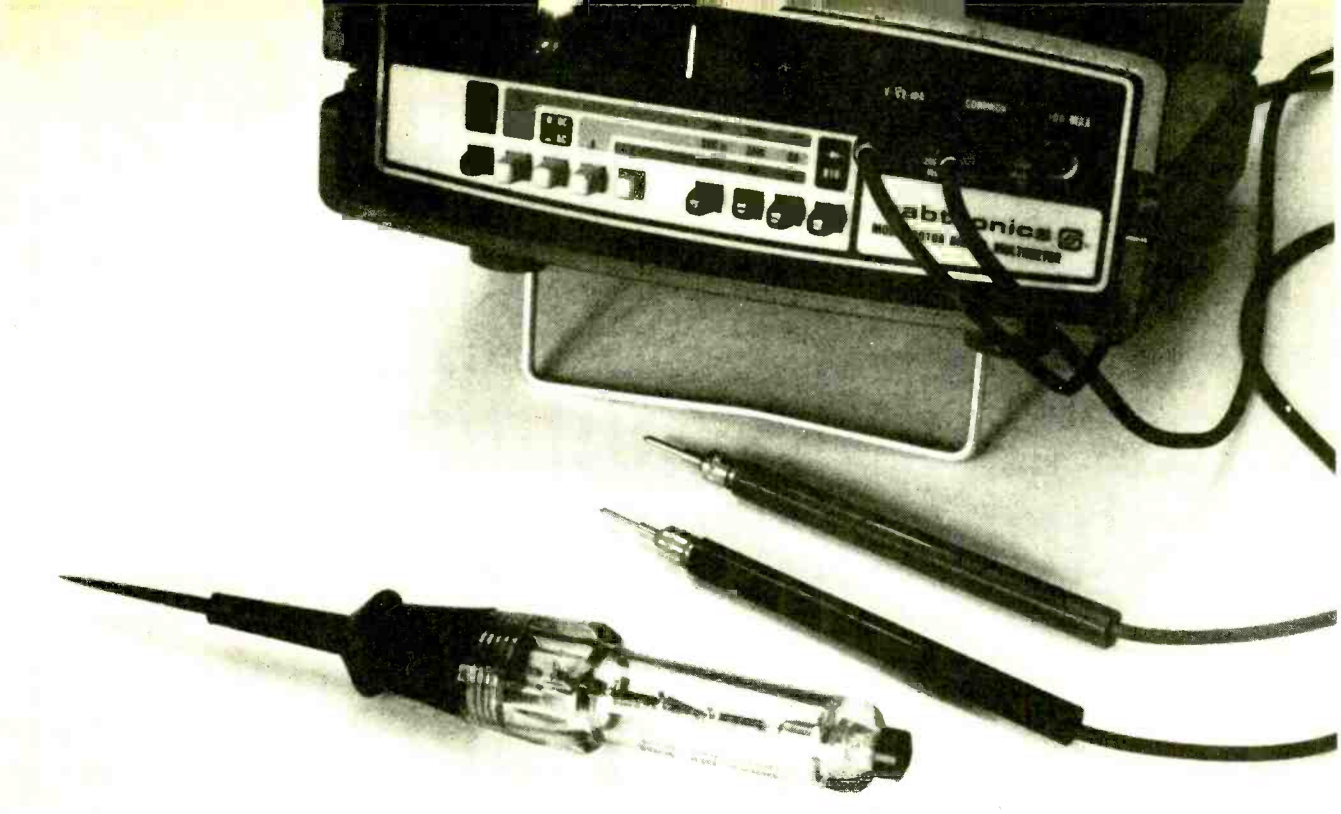
That One-Bander Shortwave Converter can also be used in the home. Unfortunately, most receivers found in the home are undesirable because of the poor selectivity and poor AGC, and the inability to shield the loop antenna from broadcast stations. A car radio can be used in the home with the addition of a small 12-volt DC, 1- or 2-ampere power supply and, in some cases, the addition of a speaker. Inexpensive, second-hand AM car radios can be obtained from bargain/surplus electronics dealers, as well as from automobile junk yards. Since the quality of car radios vary from one model to another, it might be worthwhile to try several radios before making a final choice. When used in the home, a six-foot length of wire for the antenna will provide good reception.

The radio's tuning dial can yield the shortwave frequency simply by adding the local-oscillator frequency to the frequency on the dial. For example, if the local-oscillator crystal is 5 MHz or 5000 kHz, and the radio is tuned to 1000 kHz (usually marked as 10 on the dial), then the receiver's frequency is 6000 kHz. And when the radio is tuned to 1100 kHz, it becomes 6100 kHz; etc.

The One-Bander Shortwave Converter used with a good car radio provides the best performance possible without requiring an expensive receiver. It should enable reception of interesting shortwave receptions as you wheel down the highway, or lounge in your radio shack. **SP**



THE AUTHOR used a single lead to connect the +12 VDC. Ground contact was achieved by the "Radio" shield hookup.



X10 PROBE

With this 90-megohm probe in series with your DMM, you can increase its voltage range by ten

ROBERT H. JOHNS

TODAY'S DIGITAL MULTIMETERS ARE REMARKABLY SENSITIVE and accurate, but they don't measure high voltages. Maximum readings of 1000 volts are typical, with many specifying even less on AC voltage. Yet there are many places where the experimenter would like to read greater voltages. This simple probe is just the answer: it is a X10 attenuator that will extend the voltage-measuring capability of your DMM or DVM up to 10,000 volts (10 kV).

Many manufacturers are offering high-voltage probes as an accessory to their DMM's, but those probes are quite expensive and also too bulky to be practical. The reason for their large size is the voltage rating. They are intended to measure up to 40 kV for checking TV picture-tube supplies. For testing unknown transformers, or power supplies for

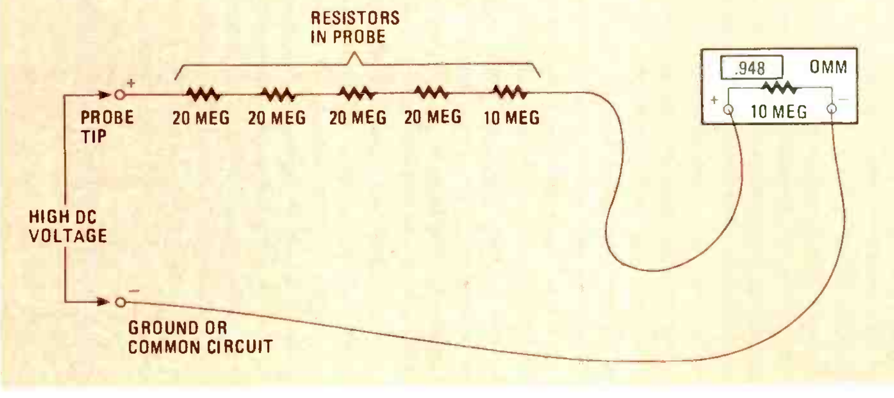


FIG. 1—THE 90-MEGOHM INTERNAL resistance of the probe in series with the 10-megohm internal resistance of the digital multimeter make up a voltage divider that reduces the voltage read by the meter to one-tenth of the voltage applied to the terminal points at left. The total series resistance is 100 Megohms.

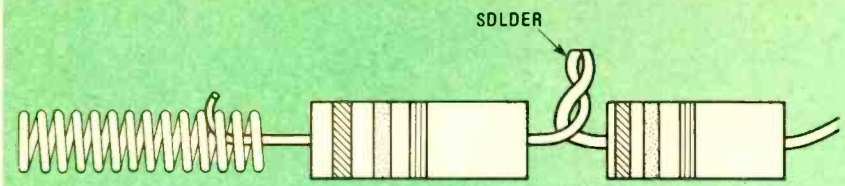


FIG. 2—THE END OF THE RESISTOR string is passed through the coils of the small spring that comes with the probe handle. This spring is passed over the end of the probe tip inside the handle. Notice that the resistor leads are twisted tightly and cut short after soldering.

transmitters, the smaller size and cost of the X10 Probe shown in photos is more reasonable.

How it works

The input resistance of most digital voltmeters is 10 Megohms. That means that the voltmeter probes have 10-Megohms resistance connected between them, which presents a load, or burden, on the voltage being measured. A small current flows through the resistance and the meter, to enable the meter to measure the voltage. That resistance load

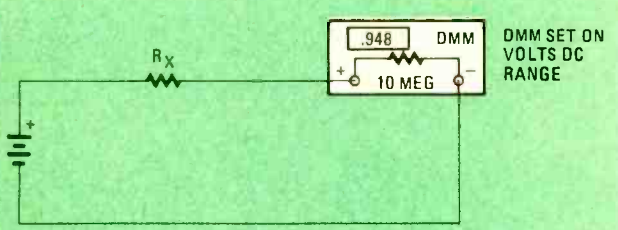


FIG. 3—CIRCUIT FOR MEASURING RESISTORS beyond the range of the ohmmeter functions of a DMM. The meter is set to read *voltage*, not resistance. By comparing the battery voltage to the voltage read through the unknown resistor, R_X, the resistance of the unknown can be determined as given in text.

seen at the DMM's output terminals is the same on all voltage ranges, not like the load presented by analog multimeters that changes with the voltage range selected.

The X10 Probe contains a 90-Megohm series resistor. When the DMM probe is plugged into its handle, a series circuit of 100 Megohms is produced, as shown in Fig. 1. The meter is connected across one-tenth of the total resistance, and therefore indicates only one-tenth of the voltage applied to the whole series string of 100 Megohms. The probe by itself is only a resistor, but with a 10-megohm input-load DMM, it forms part of a X10 attenuator, dividing the unknown voltage by ten.

The operator must remember to mentally multiply the meter reading by ten when using the probe. That is a nuisance, but doing it should become second nature to electronics experimenters, because X10 probes are very commonly used with oscilloscopes.

Construction

The probe is built into a plastic handle that has a metal tip moulded into it. It is available in auto-parts stores as part of a low-voltage test light. The bulb and socket are removed and discarded, as well as the wire and alligator clip; but the small coil spring is saved to connect the resistor string to the probe tip. A tip jack with a long barrel is used at the base of the handle in which to plug the regular DMM red (hot) lead. Drill a hole in the handle base slightly larger than ¼ in. so that the ¼-inch diameter barrel of the tip jack will pass through.

The series 90-megohm resistor is made up from smaller resistors in series, as shown in the photo. 20 Megohms is the largest standard resistor value that will be found at parts distributors. Four ½-watt carbon resistors are used, plus one additional smaller resistor to bring the total series resistance up to 90 Megohms.

After the four 20-Megohm resistors are joined together by twisting their leads, solder the leads close to the bodies of the resistors (see Fig. 2). Then cut off all but about a ¼-inch of the leads. The string of four resistors is soldered to the tip jack, again using only as short a lead as possible.

The resistance value of this nominal 80-Megohm resistor is checked before adding the final resistor, since its value will not be exactly 80 Megohms.

The 5% resistors used to assemble the resistance string will probably be within 2 or 3% of their labeled value, and their errors probably will not cancel out. Also, the heating of the resistors by soldering raises the resistance of the carbon composition resistors by 5 to 10% for those high-resistance components.

To measure the actual resistance of the 80-megohm resistor string, measure the voltage of a battery through the string, as shown in Fig. 3. With the 10 Megohms of the DMM, that preliminary probe doesn't give a 10-to-1 division of the battery voltage; but we can calculate the unknown resistance,

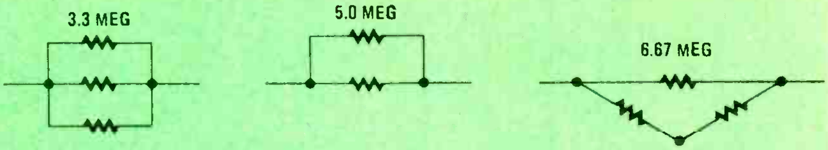
PARTS LIST FOR X10 PROBE

4—20-Megohm, ½-watt carbon-composition resistor
1—High-Megohm, ½-watt carbon-composition resistor whose exact value is determined by test—see text. Select nearest available value.
1—Combination tip jack that accepts both regular probe-tip plugs and banana plugs, with long, threaded shaft: Allied 920-0221, Calectro F2-883, or equivalent.
1—¼-in., external-tooth lockwasher
1—Chek-Point Circuit Tester No. 21000 available from S&G Tool Aid Corp. (distributors); Pep Boys (retailers) or most auto accessories stores

THE X10 PROBE with 1% accuracy is available assembled and tested from R.H. Johns Scientific Instruments, 3379 Papermill Road, Huntingdon Valley, PA 19006 for $12.50 plus $1.00 for shipping. Pennsylvania residents must add 75¢ sales tax.

A 1-MILLIOHM SHUNT for use with DMM's is also available from R.H. Johns Scientific Instruments. By measuring millivolts across the shunt a voltmeter can measure currents up to hundreds of amperes. Only $14.50 plus $2.00 for shipping. Same address as above.

FIG. 4—PARALLEL CIRCUITS for combining 10-megohm resistors to get smaller values. Those may be added to the 1.0 or 2.2 Megohm resistors that are stock at electronic parts stores to get intermediate values. If a 4-Megohm resistor was needed to complete a string, the 3.3-Megohm circuit above could be placed in series with a 1.0-Megohm resistor—the resulting 4.3-Megohm resistor introduces an error too small to detect on the DMM.



R_X, in Megohms from the reading on the DMM, since the voltages are proportional to the resistances, then:

$$\frac{V_B}{V_M} = \frac{R_X + 10}{10}$$

$$R_X = \frac{10V_B}{V_M} - 10$$

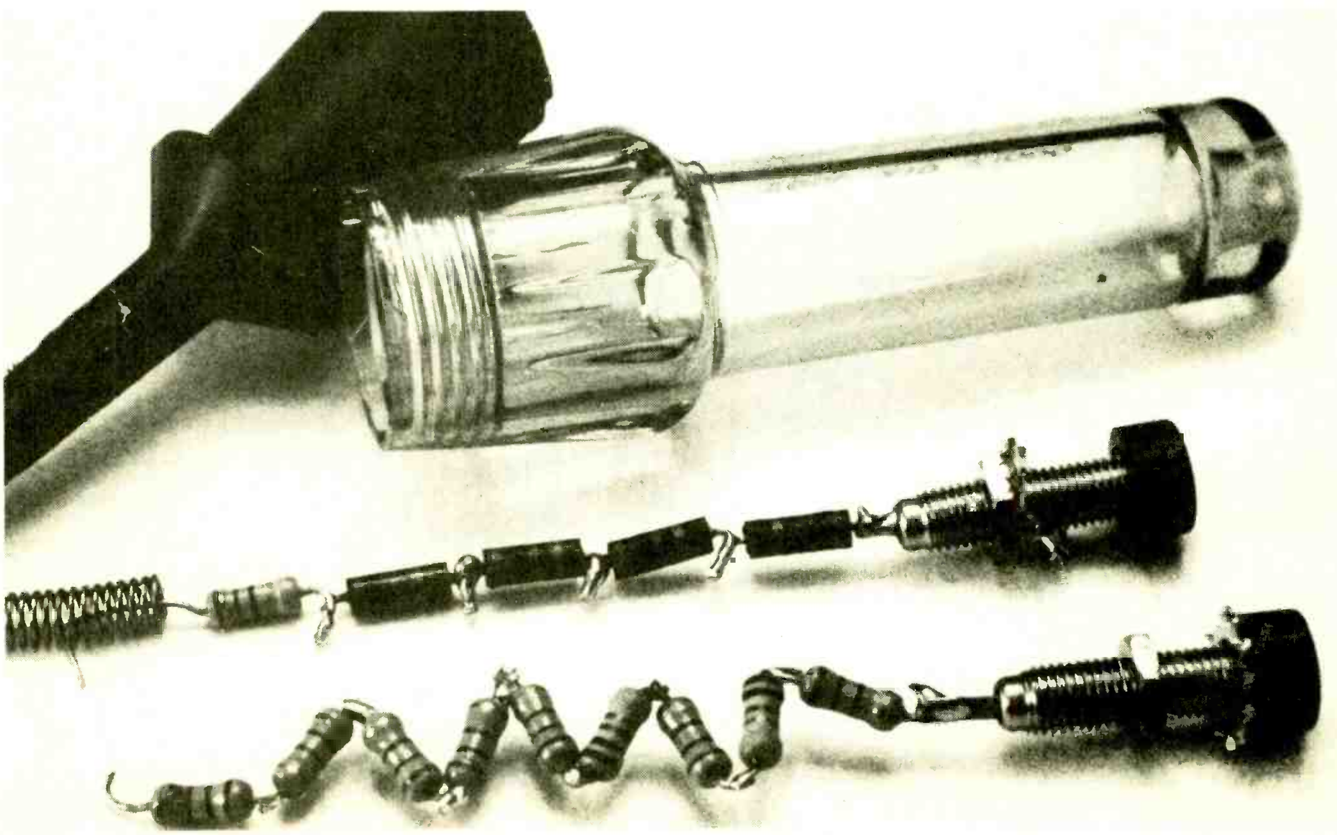
where V_B is the voltage of the battery, read by the DMM directly across it, and V_M is the voltage read by the DMM when it is connected to the battery through the unknown resistor R_X as shown in Fig. 3, and R_X is given in megohms. After calculating the unknown resistor (probably around 85 Megohms) the final resistor of the string can be added to bring the total up to 90 Megohms (5 Megohms needed if the four had come to 85). The error caused by the final resistor's tolerance and heating will be small enough to make the total less than 1%, even though it might amount to 5 to 10% of the smaller resistor added.

If you do not have access to a resistor stock or an electronics distributor, the 90-Megohms resistor string can be made up of 10-Megohm resistors that are available locally. Although they may be rated as 10% tolerance for the ½-watt resistors, you will find that most of a batch you select from, are within 3%. They are also film resistors rather than composition, and those do not change their resistance after being heated and soldered.

There is room in the probe handle for a string of nine resistors if they are laid in a zig-zag pattern (see photo). It would be advisable to assemble eight of those 10-Megohm resistors in a 80-Megohm resistor string and measure their resistance. The final resistor can then adjust the total resistance to 90 Megohms. Fig. 4 shows how 10-Megohm resistors can be paralleled to produce 3, 5, or 6.67 Megohms, since the next smaller value usually available locally is 2.2 Megohms.

Final calibration of the probe can be done before assembling the resistors into the handle, and you can make the

TWO DIFFERENT RESISTOR STRINGS that add up to 90 Megohms. The five-resistor string has four 20-Megohm, ½-watt carbon resistors with a fifth chosen to make the total add up to 90 Megohms within 1%. The zig-zag string is made up of nine 10-Megohm resistors, the largest size available from most local electronics parts stores.



accuracy of the probe as great as you wish by trimming the resistor string. There is some satisfaction in having the probe so exact that a 9.25 volt battery reads.925 volts through the probe. Such accuracy isn't warranted if the meter accuracy is only 1%.

Assembly

Push the lead of the end resistor of the resistor string through the small spring that came with the handle, as shown in the photo. The spring is a snug fit over the end of the tip inside the handle. The clear-plastic half of the handle is slipped over the resistor string and the tip jack fed through the hole in the base. Some tricky toying of the nut on the tip jack inside the handle will be needed to get the nut to grip the threads of the tip jack. You may want to use a pair of chop sticks, drink stirrer, or the like, to help you get the job done. The plastic cap needs to be on the outside so that the operator doesn't touch the DMM tip while using the X10 Probe. That is to preserve reading accuracy rather than protect against shock. You won't feel much of any current shock through 90 Megohms.

The steel tip of the probe has been blued; that is an oxide coating that prevents corrosion. The film is so thin that the metal is still a good conductor, and the coating need not be scraped off.

Using the probe with other meters

The probe can be used with other meters besides DMM's; the only requirement is that the meter present 10-Megohms resistance in series with the probe. A 10,000-ohms-per-volt multimeter on a 1000-volt range will work, as will a 20,000-ohms-per-volt meter on a 500-volt range. Watch out on AC measurements, however, because most analog meters have a lower sensitivity on AC ranges.

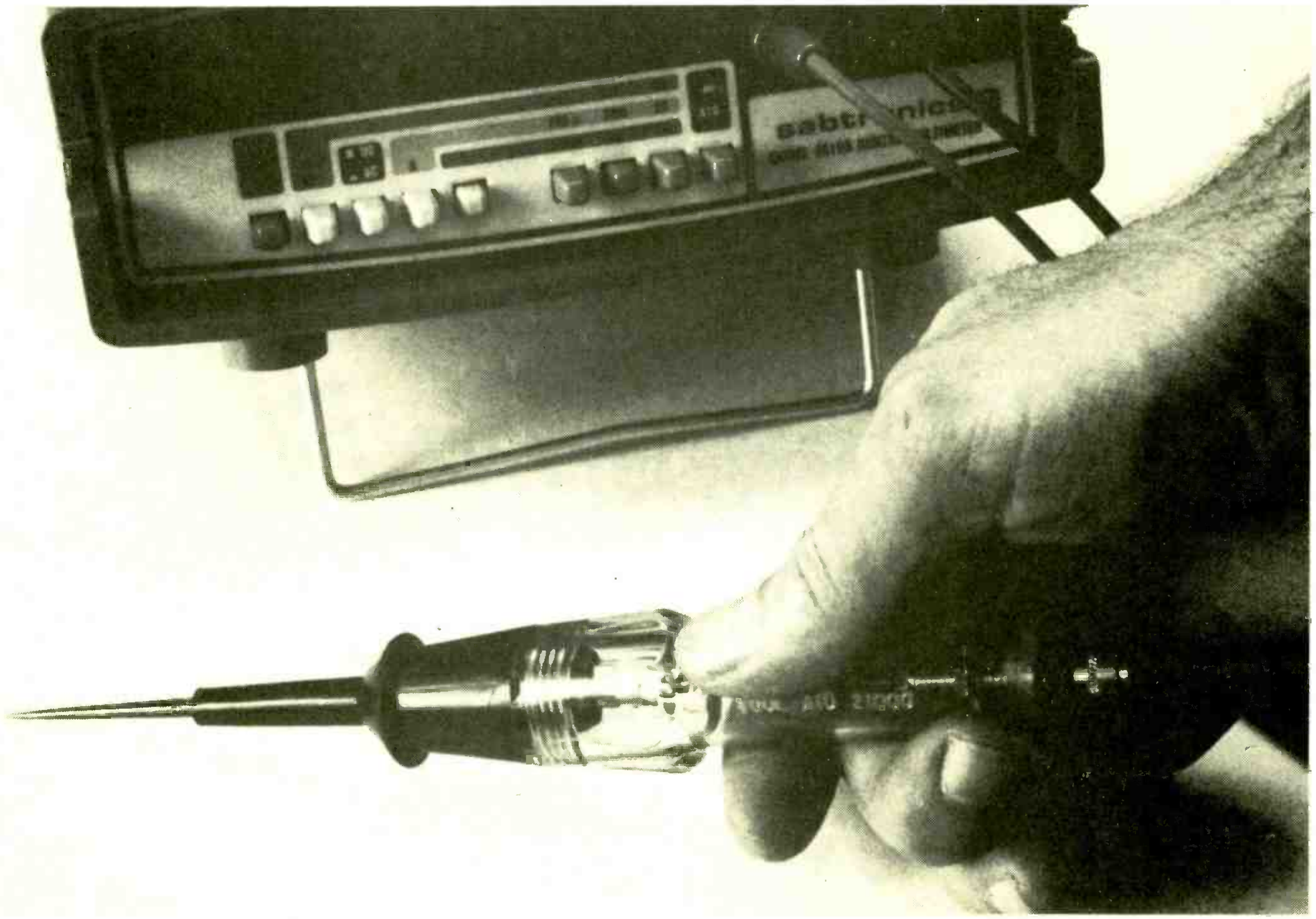
Measuring very high resistances

You may have noticed that the method for measuring the resistance of the 80-Megohm group of resistors will work for even larger resistances. As the unknown resistor becomes larger, the reading on the voltmeter gets smaller, and a DMM can measure down to very small voltages. If a 9-volt battery is used, and the DMM can resolve tenths of millivolts, the ratio of those voltages can be 10,000 to 1. And the formula for R_X shows that the unknown resistance in series with the meter is ten times that ratio, and that is in Megohms! For example, if V_B = 9.25 volts and V_M = .0028 volts, R_X is 33,000,000,000 ohms.

Instead of being limited to measuring resistances up to 20 Megohms, which is the highest of the ohmmeter ranges on most DMM's, you can measure resistances with two-digit accuracy up to 100-thousand Megohms—and even higher by using higher battery voltages.

The reason the method works so well is that DMM's have extremely good voltage sensitivity, measuring down to .0001 volts. Although you may never wnat to measure an in-circuit voltage that small, a ten-thousandth of a volt, the sensitivity is useful in comparing voltages and measuring very large resistors with the ratio of voltages. The voltage sensitivity also permits you to measure high currents with a DMM and a simple shunt listed in the Parts List. **SP**

BY PLUGGING the digital multimeter lead into the X10 Probe, voltages can be read up to ten times the DMM rated value.



Dynamic Noise Reduction System

Obtain up to 14 dB hiss rejection!

□OVER TWO MILLION SYSTEMS USING DNR™ (DYNAMIC NOISE reduction™) have been produced by more than 105 major equipment-manufacturing companies on a world-wide basis in the past year. DNR has been designed into many audio products ranging from autosound, stereo TV, personal hi-fi, boom boxes, telephone-answering systems, satellite receivers, theater sound systems, micro-cassettes, military radio systems, doppler sound systems, cassette changers, and more—which speaks well for the universal aspects of the DNR system.

There are two ways to reduce noise in a sound system. The first of those is generally referred to as a complementary, or companding type. In it, signal encoding takes place before transmission or recording: the signal is decoded during playback. The second type of noise-reduction system is referred to as non-complementary, or single-ended: it operates during playback only. As a result, it does not require any special encoding of the program material.

For consumer audio equipment, the most popular noise-reduction system to date has been the Dolby B system, which falls into the complementary category. While Dolby B provides only 10 dB of noise reduction at high frequencies (not enough to make tape hiss totally inaudible), it's widely accepted because it is a "compatible" noise-reduction system. One can listen to a Dolby-encoded program source without using a Dolby decoder and still find the music somewhat acceptable.

However, the fact that Dolby B does not render tape hiss *completely* inaudible has prompted other designers to come up with companding systems that deliver greater amounts of noise reduction. Among those are the *dbx* companding system and, more recently, the Dolby C system.

Over the years, some designers have concentrated on single-ended, or non-complementary noise-reduction systems as well. Perhaps the best known of those is the Dynamic Noise Filter developed by Burwen. Now, National Semiconductor has developed a noise-reduction system, called DNR, (*D*ynamic *N*oise *R*eduction) based upon the same Burwen Dynamic Noise Filter that does not require signal encoding and, as a result, is effective for cassette, FM, phonograph, videocassette, videodisc, TV, and others.

While companding noise-reduction systems are capable of reducing noise that is added to a program source during the recording process itself, they can not eliminate noise that is already *in* the program source. When it is necessary to remove or reduce noise levels in a program source, a non-complementary type of noise-reduction system is preferred and, since such a system requires no encoding, complete compatibility is retained.

How DNR works

The National Semiconductor noise-reduction system can provide up to 14 dB of noise reduction in stereo program-material and is based upon two principles. The first of those states that noise output is proportional to system bandwidth. Suppose that system noise is caused solely by resistive noise (noise added by the circuit resistors). In such a system, noise amplitude is uniform over the frequency bandwidth. Thus, if the bandwidth of the system is reduced, the noise content is also reduced.

Unfortunately, there isn't a simple correlation between the amplitude of the noise signal and the amplitude of the noise perceived by the listener. As shown in Fig. 1, the ear is most sensitive to noise in the 600-Hz to 6-kHz frequency range.

Note: DNR™ and Dynamic Noise Reduction™ System are trademarks of the National Semiconductor Corporation.

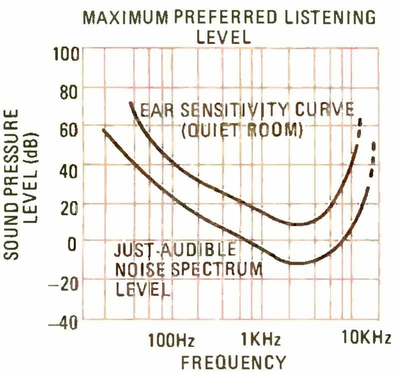


FIG. 1—TYPICAL hearing threshold level for pure tones heard in a quiet room.

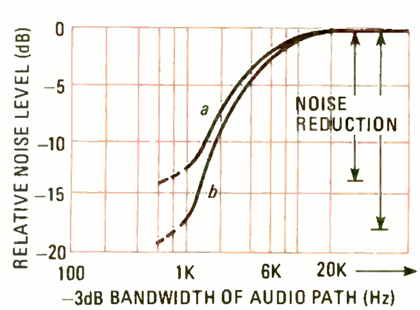
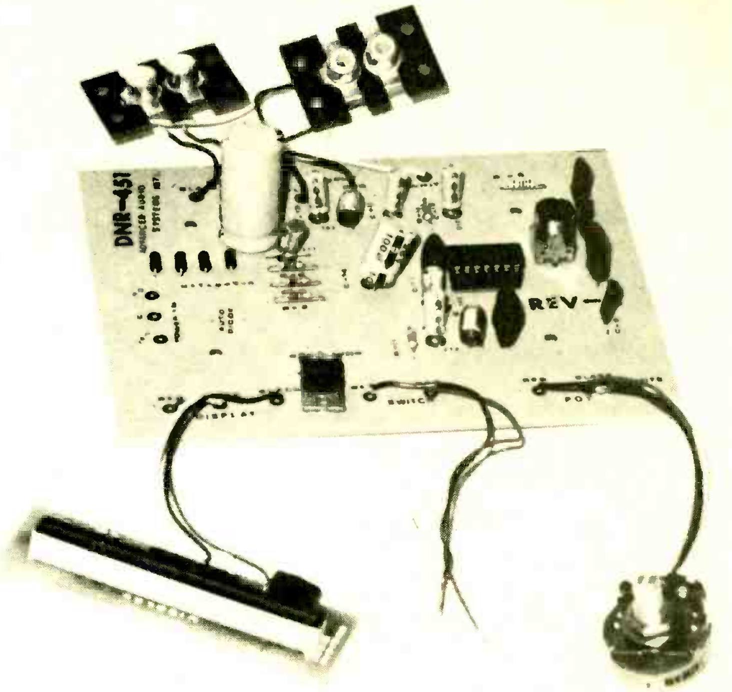


FIG. 2—GRAPH INDICATES how descreasing bandwidth affects noise reduction when the Dynamic Noise Reduction System is configured as a single-pole (a) or double-pole (b) lowpass filter.



THE PRINTED-CIRCUIT BOARDS for the Dynamic Noise-Reduction System are shown here ready for insertion into a customized cabinet. The two unconnected leads attach to a +12-volt DC power supply—that's all there is!

For that reason, when measuring noise content in a system, a weighting filter is usually inserted in the measuring instrument to give better correlation between the measured signal-to-noise ratio and the subjective impression of noise. When a CCIR/ARM weighting filter (commonly used when measuring signal-to-noise ratios of cassette tape and decks) is used, it will yield noise-reduction numbers of between 14 and 18 dB when the bandwidth of a system is restricted to 1 kHz with single-pole and two-pole low-pass filters, as shown in the curves of Fig. 2.

Auditory Noise Masking

The second principle that DNR is based on is the fact that whenever we hear one sound, that sound decreases our ability to hear another. White noise (random noise that contains all audible frequencies at equal amplitude), for example, raises the threshold of hearing a pure tone by a level that depends on the frequency of that tone, as shown in Fig. 3. At a high frequency, a tone has to be increased in amplitude (compared to a 1-kHz tone) to be heard. That is because a wider range of noise frequencies contribute to masking as the tone's frequency increases. But regardless of the tone's frequency there will be some range of noise frequencies that will be capable of masking that tone.

Additionally, experimental results show that extremely high sound-pressure levels of a single tone are required to provide masking of noise. Even at the most effective frequencies (between 700 Hz and 1 kHz, near the natural resonance of the ear), sound-pressure levels in excess of 75 dB are required to mask noise at a very low 16 dB SPL (*S*ound *P*ressure *L*evel). Fortunately, those results apply only to pure single tones. With the complex speech and music signals, masking effects are much better.

From all of that, the designers of DNR concluded that if source material is at least 29 dB above the noise floor, adequate masking can usually be obtained. Therefore, any noise-reduction system that dynamically restricts audio bandwidth (by virtue of its previously calculated 14-dB improvement) will insure a minimum perceived signal-to-noise ratio of 43 dB (29 dB + 14 dB) without audibly degrading the music program. A cassette tape recorded at a mean signal level of around −10 VU (volume units, as on a VU meter)— −40 to −45 dB above the noise floor of the tape/system—

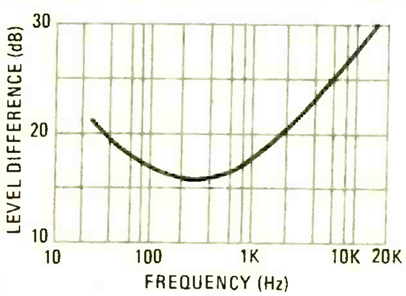


FIG. 3—WHEN NOISE IS PRESENT, the volume (amplitude) of a tone must be increased for it to be heard. How much that volume must be increased depends on the frequency of the tone.

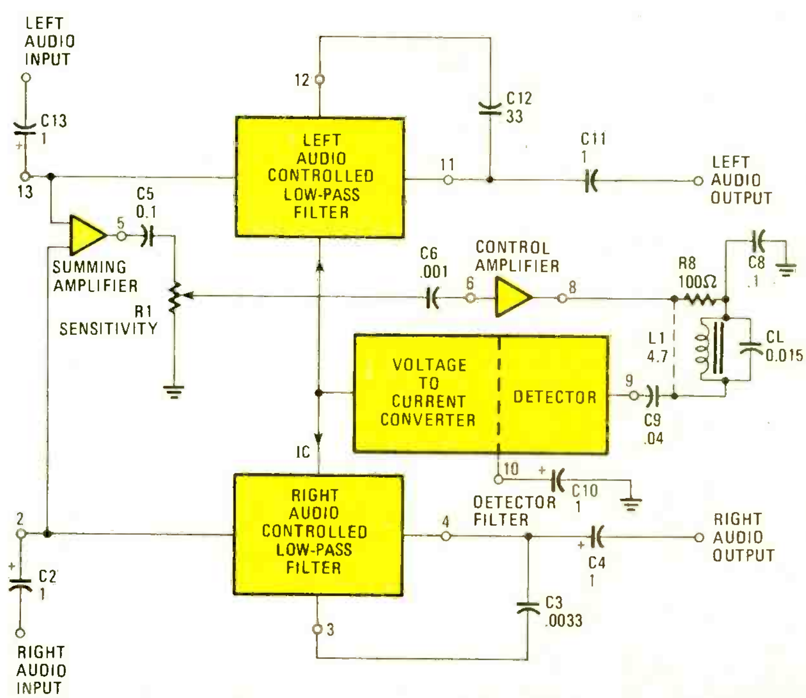


FIG. 4—FUNCTIONAL BLOCK DIAGRAM for the Dynamic Noise-Reduction System illustrates the fact that the bulk of the circuitry is contained in one integrated-circuit chip. Numbered terminals indicate connection of external circuit components to the National Semiconductor DNR chip.

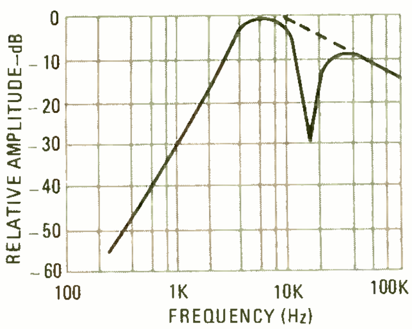


FIG. 5—FREQUENCY vs. AMPLITUDE response curve for the control path includes an optional notch at 19 kHz that is required when the source material contains an FM pilot signal.

will, with the aid of a bandwidth-varying noise-reduction system, be improved to a perceived signal-to-noise level of between 55 and 60 dB. If the recording was made at 0 VU, the improvement can be expected to provide a signal-to-noise ratio of better than 65 dB

DNR Audio Filters and Control Path

The general arrangement of the DNR system, the bulk of which is located in chip U1, is shown in the block diagram of Fig. 4. Two lowpass filters (one for each stereo channel) are placed in the audio-signal path, their –3-dB bandwidths are controlled by the amplitude and frequency of the incoming signals. Each filter response is flat below its cut-off frequency, with a smooth single-pole roll off above its corner frequency for any control setting. The resulting –6 dB-per-octave slope produces the most satisfactory results with modern and classical music that has a wide frequency range. Steeper slopes can produce greater amounts of noise reduction for a given bandwidth, but are more suited to program material that does not have substantial high-frequency content. Cascading two filters will give a –12 dB/octave slope with noise reduction as great as 18 dB.

Figure 5 shows the frequency-versus-amplitude response of the DNR control path. The DNR system uses a highpass filter with a –3 dB corner frequency of 6 kHz and –12 dB/octave roll-off slope. An optional notch at 19 kHz is for when the source material contains a stereo-FM pilot signal that might tend to increase minimum bandwidth above 800 Hz when the detector threshold is set at the noise floor.

The control-path frequency-response is weighted in that manner because program material varies substantially in harmonic content, depending both on relative loudness and on the particular instruments being played. As an example, consider the case of a French horn. Most of the energy produced by that instrument is below 1 kHz. If a lowpass filter were used in the control path, it would respond to that energy and open up the filters to full bandwidth, unmasking noise in the 2-kHz and above region.

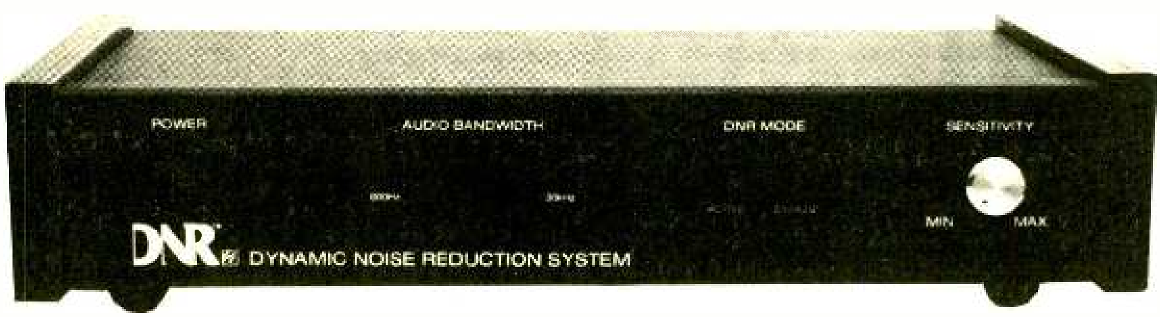
To avoid that, the system looks for high-frequency energy in the music source and, in the case of the French horn, not finding any higher harmonics, the noise remains filtered out and bandwidth remains restricted. Multiple instruments, or a solo instrument such as a violin, for example, may have significant high-frequency energy that will not only provide good noise masking but will require a wider system bandwidth. To summarize, then: When high frequencies are detected in the control path, it is an indication that large levels of energy are presented at the same time in the critical masking-frequency range, so that audio bandwidth can be safely increased as required to prevent audible degradation of the music. The noise, however, remains masked. To make up for the relatively fast decrease in spectral energy with increasing frequency, the control-path response is increased at a 12-dB-per-octave rate.

Attack and Decay Times

If the detector of the DNR system were allowed to respond instantaneously to any input signal, ticks or noise bursts of short duration but with rapid rise times would be able to open up the bandwidth of the system without simultaneous program masking. Also, different instruments have widely differing rise-time characteristics. With that in mind, the DNR system was designed with an attack time of 0.5 milliseconds to minimize potential loss of high-frequency transients. That *does* constitute a trade-off, in that the system is susceptible to impulse-noise interference. Impulse noise, having fast rise- and decay-times, and quite a bit of high-frequency energy, must be eliminated by using other techniques.

Once the detector has responded to a given musical transient, it must decay back to its inactive level when that transient is over. Once again, a compromise in parameters was required for the DNR system. Too slow a decay time would mean that system bandwidth would remain "wide open" for some period after the decay of the transient. A noise burst would be heard at the end of each musical transient since there would be nothing to mask it. If the decay were too rapid, on the other hand, a loss in apparent ambience would occur because harmonics occurring at the end of a transient would be suppressed. The DNR system decays to within 10% of final value in 50 milliseconds. The ear's inability to recover sensitivity for 100 to 150 milliseconds following a loud sound prevents the noise burst that is present at the beginning of each transient from being heard.

The third section of display-system DNR is the bandwidth bar-graph display. A bar graph was used instead of a meter



FRONT-PANEL VIEW of the Dynamic Noise-Reduction System assembled with the parts available from Advance Audio Systems. Only three controls appear on the front panel and one light-emitting-diode display that indicates bandwidth.

because of the millisecond reponse time of the control signal. The National LM3915 bar-graph display driver was chosen as it requires only a few external parts and contains all the necessary circuitry for a 10-point logarithmic bar-graph display. The common control voltage at the top of pin 10 has upper and lower limits of 9.3-volts DC and 1.1-volts DC, respectively. Therefore, the upper and lower limits of the LM3915 are set accordingly at pins 4 and 6 (internal logarithmic resistor string between these two pins sets the DC levels at which each of the internal comparators drives its associated LED). The left-hand LED corresponds to an 800-Hz bandwidth and the right-hand LED corresponds to a 30-kHz cutoff. The LED's between those two extremes represent steps of approximately 1.5 times the frequency display by the preceding step.

A logarithmic display was selected because it was the most indicative of the audible action of the filter. It should be noted that the LED bar graph, DIS1, does not indicate signal level, but rather the instantaneous bandwidth of the two filters and, as such, should not be used as a signal-level indicator. Fig. 6

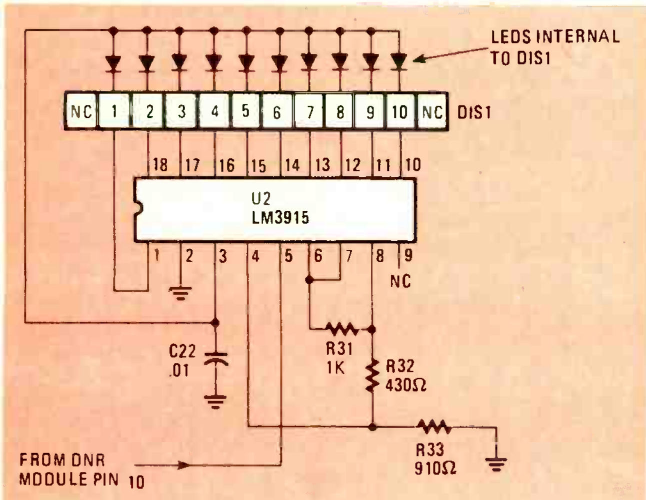


FIG. 6—SCHEMATIC DIAGRAM of the display module illustrates how simple this bandwidth-indicator circuit is.

shows the special display-module circuit used in the DNR system which uses the LM3915N chip, U2.

Circuit Operation

The LM1894 integrated-circuit chip has two (right and left) audio signal paths and a bandwidth control path. The main path of each audio signal is an audio-controller, lowpass filter comprised of a conductance (gm) block with a variable current, and an op amp configured as an integrator. See Fig. 4. Above the cutoff frequency of the lowpass filter, the output decreases at −6 dB/octave due to the action of the .0033-μF capacitor.

The purpose of the bandwidth control path is to generate a bandwith control signal which replicates the ear's sensitivity to noise in the presence of a tone. A single control path is used for both channels to keep the stereo image from wandering. That is done by adding the right and left channels together in the summing amplifier of Fig. 4. The 1000-ohm potentiometer, R1, adjusts the incoming noise level to open slightly the bandwidth of the low-pass filter. Control-path gain is about 60 dB and is set by the control amplifier and peak-detector gain. That large gain is needed to ensure the lowpass filter bandwidth can be opened by very low noise floors. The capacitors between the summing amplifier output and the peak detector input determine the frequency weighting, as shown in the typical performance curves. The 1-μF capacitor at pin 10, in conjunction with internal resistors, sets the attack and decay times. In FM stereo applications a 19-kHz pilot filter is inserted between pin 8 and 9.

Figure 7 shows interesting curves. Although the output of the DNR system is a linear function of input signal, the −3 dB bandwidth is not. That is due to the non-linear nature of the control path. The DNR system has a uniform frequency response, but looking at the −3 dB bandwidth on a steady-state basis with a single frequency input can be misleading. It

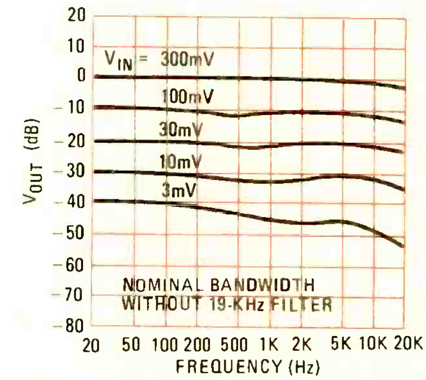
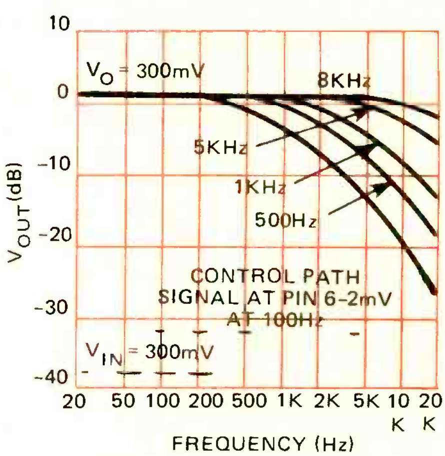


FIG. 7—OUTPUT vs. FREQUENCY curves for different levels of input signal.

FIG. 8—OUTPUT vs. FREQUENCY and control path show distinctive roll-off.



must be remembered that a single input frequency can only give a single −3 dB bandwidth, and the roll-off from that point must be a smooth −6 dB/octave.

A more accurate evaluation of the frequency response can be seen in Fig. 8. In that case the main signal path is frequency swept, while the control path has a constant frequency applied. It can be seen that different control path frequencies each give a distinctive gain roll-off.

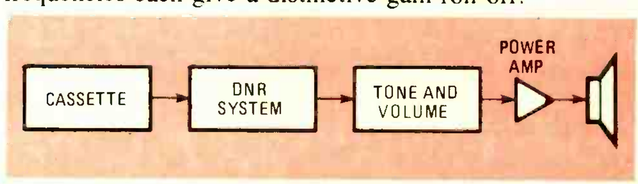
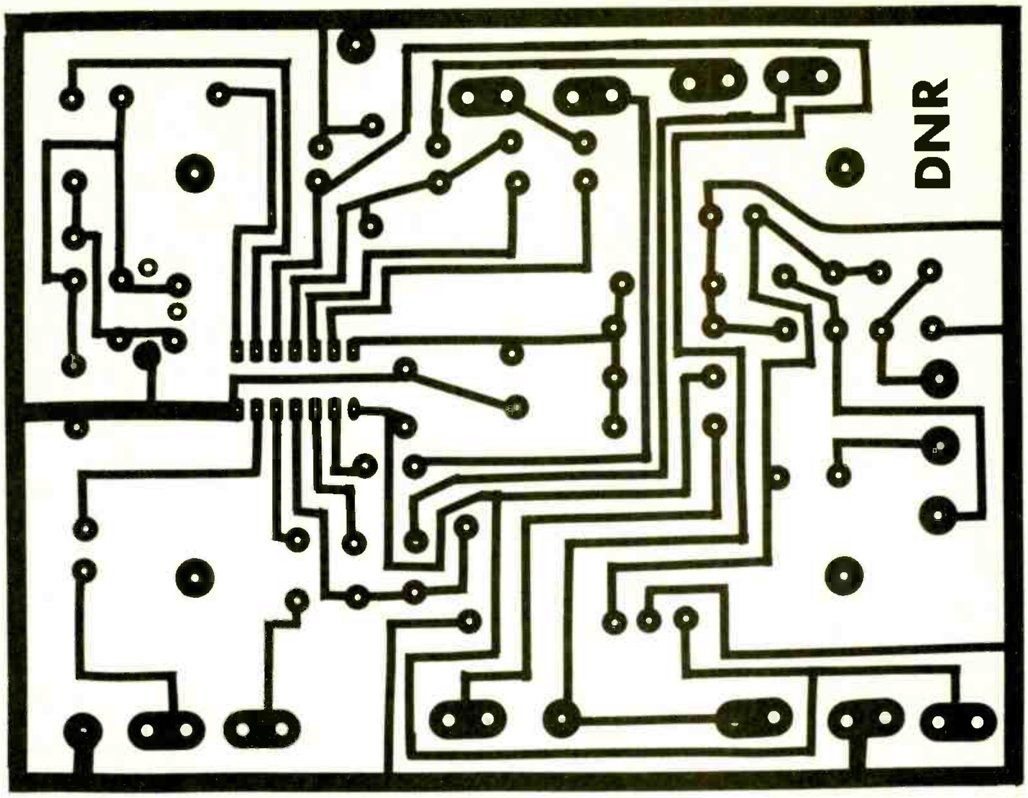


FIG. 9—SYSTEM block diagram illustrates position of DNR in hi-fi system.

FIG. 10—PRINTED-CIRCUIT board template is shown here full-size for project builders who like to make their own. Art is in the foil-up position. This board fully etched is available from Advanced Audios Systems—refer to the Parts List for details.



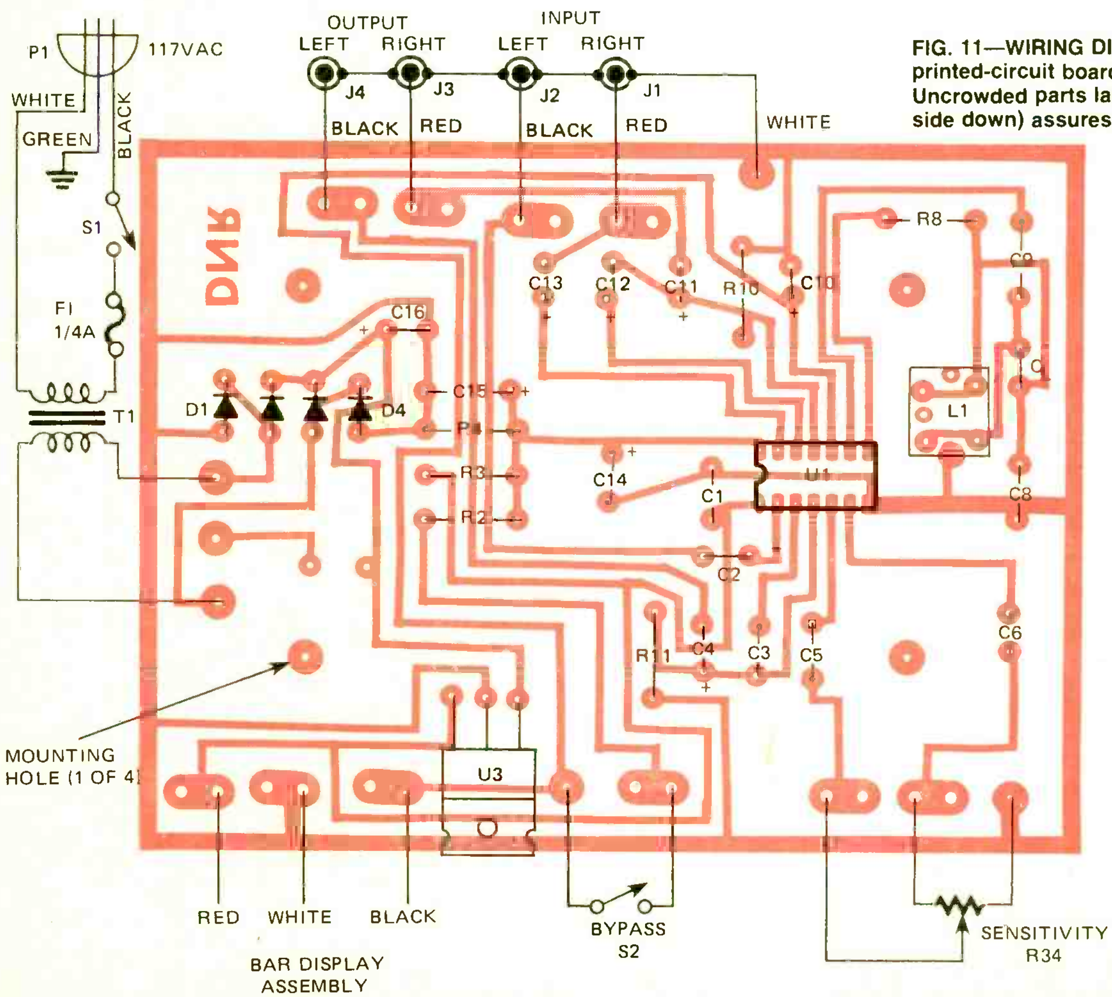


FIG. 11—WIRING DIAGRAM of the main printed-circuit board for the DNR System. Uncrowded parts layout (shown with foil side down) assures successful assembly.

PARTS LIST FOR DYNAMIC NOISE REDUCTION SYSTEM

SEMICONDUCTORS
D1-D4—1N4002 diode rectifier
DIS1—LED bar-graph display
U1—LM1894N Dynamic noise reduction integrated circuit chip (National Semiconductor)
U2—LM3915 LED bar-graph driver integrated-circuit chip
U3—LM341T12 12-volt regulator integrated-circuit chip

RESISTORS
(Note: All fixed units are ¼-watt, 5% values)
R1—1000-ohm audio-taper, potentiometer
R2-4, R31—1000-ohm
R8—100-ohm
R10, R11—47,000-ohm
R32—430-ohm
R33—910-ohm

CAPACITORS
C1-C5, C8, C31—.1-μF disc or Mylar
C2, C4, C10, C11, C13—1-μF, 50-WVDC electrolytic
C3, C12-.0033-μF disc or Mylar
C6—.001-μF, disc or Mylar
C9—.047-μF, disc
C14—100-μF, 25-WVDC, electrolytic
C15—10-μF, 16-WVDC, electrolytic
C16—470-μF, 50-WVDC electrolytic
CL—.015-μF, disc capacitor

ADDITIONAL PARTS AND MATERIALS
F1—¼-A, slow-blow fuse with panel-mount holder
J1-J4—RCA phono jacks (strip of dual jacks)
L1—4.7-mH tunable coil, Q=35 at 19 kHz (Toko CLN20-740HM)
P1—AC plug molded to 3-wire power cord
S1, S2—SPST rocker switch
T1—Step-down, power transformer: 117-VAC primary winding: 14.5-20-VAC secondary winding (Triad F122X)
Printed-circuit boards of materials, control knob, cabinet, rubber feet, hardware, solder wire, etc.

The following parts are available from Advanced Audio Systems, 4010 Moorpark Avenue, Suite 105, San Jose, CA 95117 (Tel: 408/248-9899)

DNR-200X complete kit including stamped cabinet: $98.50
DNR-240X semiconductors and coil L1: $35.95
DNR-280X main and display printed-circuit boards: $22.50

California residents must add state and local sales taxes—4-½%. All orders must be paid in cash, COD or credit card. Allow up to 30 days for delivery.

Application Hints

The DNR system should always be placed before tone and volume controls as shown in Fig. 9. That is because any adjustment of those controls would alter the noise floor seen by the DNR control path. The sensitivity potentiometer may need to be adjusted, depending on the nose floors of different sources, i.e., tape, FM, phono. To determine the proper adjustment in a tape system, for instance, apply tape noise (no program material) and adjust the potentiometer to open slightly the bandwidth of the main signal path. That can easily be done by viewing the capacitor voltage of pin 10 with an oscilloscope. That gives an LED display of the voltage on the peak-detector capacitor. Adjust the sensitivity potentiometer to light the LED's of pin 1 and pin 18. The LED bar graph does not indicate signal level, but rather instantaneous bandwidth of the two filters; it should not be used as a signal-level indicator.

To change the minimum and maximum value of bandwidth, the integrating capacitors, C3 and C12, can be scaled up or down. The bandwidth is inversely proportional to the capacitance, changing with C3 and C12 set at 0.0033 μF, the maximum bandwidth is typically 34 kHz. A double-pole double-throw switch is used to completely bypass DNR.

The capacitor on pin 10 in conjunction with internal resistors sets the attack and decay times. The attack time can be altered by changing the size of C10. Decay times can be decreased by paralleling a resistor with C10, and increased by increasing the value of C10.

Construction

Printed-circuit construction techniques should be followed in the assembly of the filter and the associated Display module. Two printed-circuit board foil patterns are shown in Figs. 10 and 12. The printed-circuit boards are illustrated in Figs. 11 and 13 to show the component locations. All components are mounted on the printed-circuit board with the exception of sensitivity potentiometer R1, switches S1 and S2, jacks J1-J4, power transformer T1 and fuse holder for fuse F1. Sockets or Molex strips will simplify integrated-circuit chip installation and avoid their possible damage.

Should the project builder desire to assemble the device on a custom-made printed-circuit board, boards are available, and details are provided in the Parts List.

The available metal housing (see Parts List) is prepunched and all silk screening is complete. The main printed-circuit board is assembled directly onto pre-assembled stand-offs with four screws through pre-drilled holes in the board. No metal work is required except the use of screws.

The schematic diagrams shown in Figs. 14 and 15 can be used by those technicians who feel more comfortable in

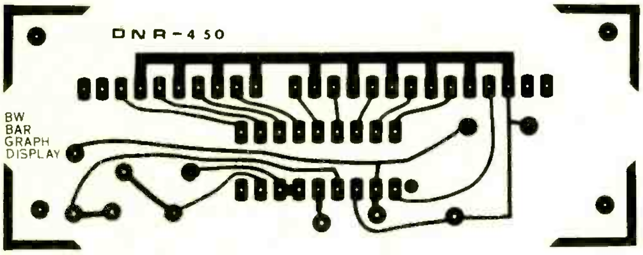


FIG. 12—FOIL DIAGRAM for the printed-circuit board used to mount the LED display and bar-graph driver chip.

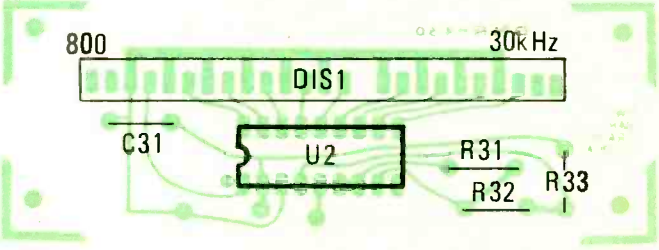


FIG. 13—PARTS LOCATION on x-ray view of bar-graph display printed-circuit board which mounts on DNR front panel.

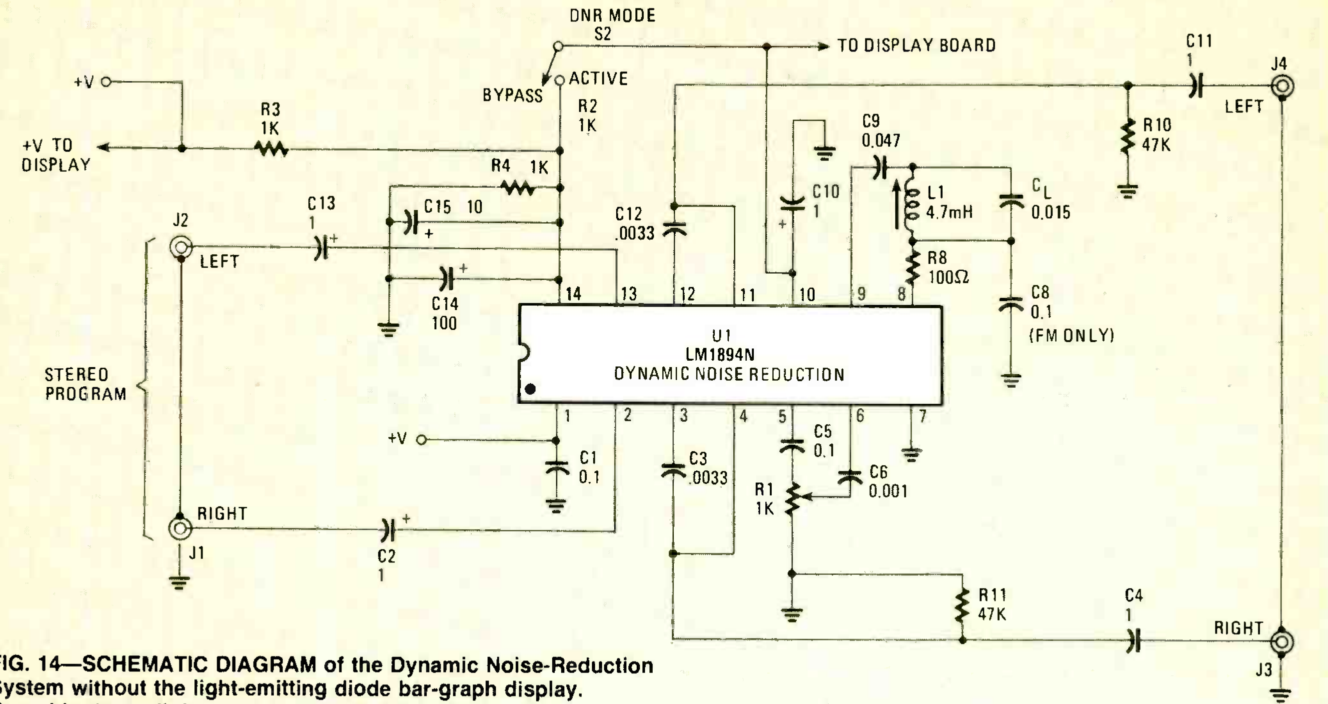


FIG. 14—SCHEMATIC DIAGRAM of the Dynamic Noise-Reduction System without the light-emitting diode bar-graph display. One chip does all the work in reducing detectable noise.

doing their thing their own way. The understanding of the circuit functions and troubleshooting procedures are simplified by the use of the schematic diagram. The power-supply circuit featured in Fig. 15 is quite standard and is centered on the LM341T12 chip, U3.

Using the Filter

The DNR can now be connected in the tape-monitor loop of a receiver or amplifier. The SENSITIVITY potentiometer R1 should be turned down completely and the source material placed in an area with no musical content (between cuts, for instance).

All but the first LED should be off in that condition. The SENSITIVITY control is then advanced until the next LED just begins to flicker. That is an indication that the filter is barely opening on the noise floor and is capable of reaching full bandwidth on musical information above this level. Alternatively, the control may be advanced until there is a barely perceptible increase in the noise level and then backed off very slightly.

The 19-kHz multiplex pilot tone present in all stereo FM broadcasts is attenuated by L1 and CL. The presence of that pilot tone will limit the noise-reduction capability since the noise filter will sense the level of the pilot tone rather than the level of the noise source.

The inductor provided with the kit of parts described in the Parts List is pretuned and should not be altered. If, however, you purchase L1 separately, then it must be tuned to within about +20 Hz of the 19-kHz pilot tone. The simplest way to obtain that reference frequency is directly from the FM broadcaster. Tune your FM receiver and wait for a quiet (no audio signal) interlude. Tune L1 for minimum noise filter bandwidth as monitored on the LED display, DIS1.

The DNR MODE switch, S2, can be switched between the BYPASS and ACTIVE positions to compare the action of DNR with that of a full system response. The difference should be quite dramatic, giving a subjective improvement in S/N of 12 to 14 dB. The action of the filter is most apparent between cuts where it removes nearly all of the annoying hiss.

You should be aware of a psychoacoustic effect that is common to all noise-reduction systems. The addition of high-frequency noise (such as tape hiss) to a music signal will seem to increase the high-frequency content of the music. Thus, upon first hearing DNR using noisy source material, the user will seem to hear a degradation of the music's high-frequency content. The system's actual effect on the high-frequency information can be observed by using a source with a good initial S/N and by switching the filter in and out.

It should be noted that the filter is designed for a 750 mV RMS average input level. Some tape decks are capable of much larger output levels at "0 VU" and should be attenuated accordingly to prevent overloading the filter inputs.

Television Sound

With the trend to improve sound quality for television receivers and the introduction of stereo transmissions it is appropriate to comment on the applicability of DNR in a television system. Similar to the VCR case, the presence of strong line-scan frequency components implies the need for a 15.734-kHz trap in the control path. Capacitor CL may be changed from .015 μF to .018-.022 μF and tuned to 15.734 kHz by adjusting the adjustable coil L1.

So now you have it—DNR knocking out the hiss from your audio program material. The next hiss you hear may be from your neighbor's expression of sheer jealousy. **SP**

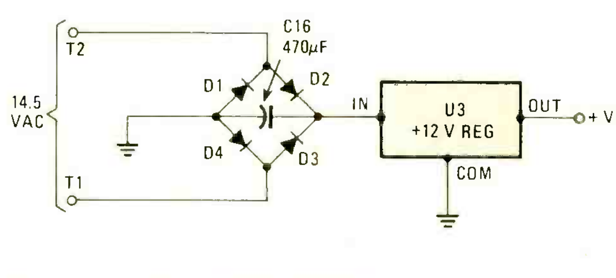


FIG. 15—+12-VOLT POWER SUPPLY shown here may be used should the builder be unable to tap power from hi-fi.

Build a darn fast COLOR VIDEO or DA AMPLIFIER

D.E. PATRICK

THE DISTRIBUTION AMPLIFIER (DA) CIRCUIT IN FIG. 1 IS USable with high resolution, color-graphic systems, digitizers, color cameras, color systems, VTR's, etc., where slew can be made high enough for some of the most demanding applications, let alone passing a 1-volt 4-MHz bandwidth video signal. And, the DA circuit will do better than many comparable high-priced commercial DA's costing several times the parts cost of this simple project. However, the same basic design may be reduced in cost farther for use in black-and-white systems by selection of IC1. More on that in a moment.

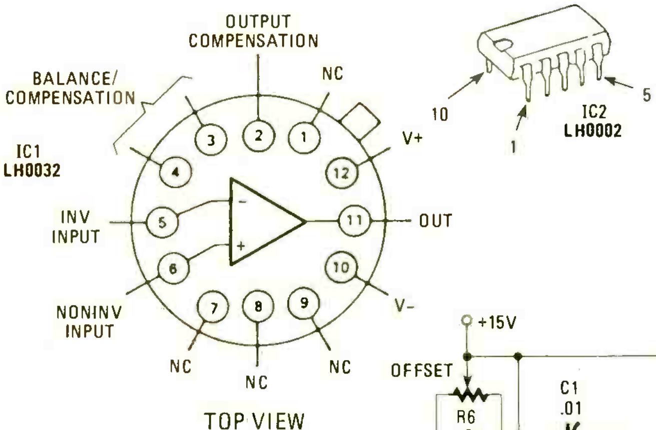
Going farther

Combining an ultrafast LH0032 FET op amp, IC1, with an LH0002 current amplifier, IC2, we have a high-impedance input, low-impedance output DA. See Fig. 1. The high-impedance front end allows signals to be looped through or terminated by their characteristic impedance, which is typically 75 ohms for video and service-grade stuff and 50 ohms for lab-grade stuff. On the other hand, the low-impedance output and current drive of an LH0002 chip, IC2, allows several outputs at a characteristic impedance determined by build-out resistors, R7 through R10.

The LH0032 has a slew of 500 volts/μsec, bandwidth of 70 MHz, input impedance of 10^{12} ohms, and rise times in the 8-nanosecond (nsec.) range. The LH0002 current amp has a slew of 200 volts/μsec, bandwidth of 30 MHz, output impedance of 6 ohms, and can deliver up to 400 mA of pulsed output.

Thus, using the LH0032, IC1, we can afford to get some optional gain via the feedback resistor R5, and gain, potentiometer R3, where R3 is made adjustable so input signal droop can be brought back to a preset level if desired. However, R3 could also be set equal to R5 when R4 is deleted using 1% carbon film or metal film resistors for unity gain if desired.

Frequency compensation adjust is provided by C5, with capacitors C1 through C4 acting as bypass capacitors. Optional offset adjust is provided via potentiometer R6, where V offset is 2 to 5 mV typical and 10 to 20 mV max, with a bias current at 10 to 25 pA (pica-amperes) typical and 100 to 200 pA maximum. However, in critical applications, the basic circuit can be reconfigured where a slower-precision DC amplifier is used to stabilize the offset voltage of the less-



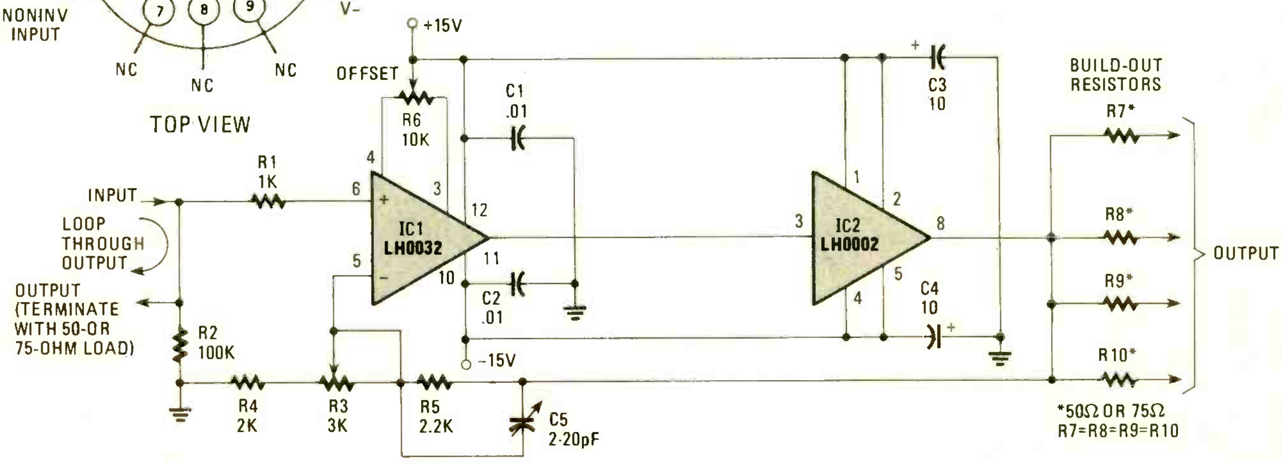


FIG. 1—THE COLOR VIDEO AMPLIFIER is so darn fast to build because there are so darn few circuit elements to wire.

PARTS LIST FOR DISTRIBUTION AMPLIFIER

SEMICONDUCTORS
IC1—LH0032 ultra-fast FET, operational amplifier, integrated circuit
IC2—LH0002 current amplifier integrated circuit

RESISTORS
All resistors ¼-watt, 5%, fixed, composition or carbon film types unless otherwise noted
R1—1000-ohm
R2—100,000-ohm
R3—3000-ohm, PC-board mount, potentiometer
R4—2000-ohm
R5—2200-ohm
R6—10,000-ohm, PC-board mount, potentiometer
R7-R10—50 or 75-ohm (see text)

CAPACITORS
C1, C2—.01-µF disc capacitor
C3, C4—100-µF tantalum electrolytic
C5—2-20-pF variable

POWER SUPPLY PARTS
C6, C7—200-500-µF, 50-WVDC electrolytic capacitor
C8, C9—1-µF, 35-WVDC, tantalum capacitor
D1-D2—1N4001 silicon rectifier diode
IC3—7815 +15-volt regulator integrated circuit
IC4—7915 −15-volt regulator integrated circuit
T1—Power transformer: 117-VAC primary winding; 20-30-VAC, .25-A secondary winding

The following is available from Electronic Technical Consultants, P.O. Box 29278, Denver, CO 80229:
Complete set of parts including printed-circuit board, less power supply and case—$45.00.
Complete set of parts, including power supply and case—$85.00.
Complete set of parts, including rack-mount case—$100.00.
Please include $5.75 for shipping and handling.

precise fast amplifier. That is, the slower precision amplifier supplies a correction voltage to balance the fast amplifier after sensing the voltage across its input terminals.

Another comparable op amp to the LH0032 is the Signeties NE/SE5539, with a slew of 600 volts/µsec and bandwidth exceeding 20 MHz.

Also, for marginal color or black-and-white systems, surplus LM318's costing under a dollar can be used. They have a small signal bandwidth of 15 MHz, a guaranteed slew of 50 volts/µsec, a maximum bias current of 250 nA and a 15 mV offset voltage. However you're really pushing an LM318 to slew color burst around 3.58 MHz when input signal exceeds 1 volt. On the other hand, you might consider selecting devices and if you could live with an inverted output they could be used in a feed forward compensation design that wil boost slew to something over 150 volts/µsec, where typical slew is around 70 volts/µsec.

An LH0062 which has about the same slew specifications as an LM318 might also be used, where it has a lower offset voltage of 2 mV and offset current of 1 to 5 pA, with a bias current in the 10 pA range. However, it is typically more expensive and bias current in this and other FET input units will double for every 10°C. So, on a cost-performance basis for this application, stay with the LM318 if you don't need the outstanding performance of the LH0032 or SE5535.

Power Supply

The DA can be powered by an on-board +15 and −15-volt DC regulated supplies using the common 7815 and 7915, respectively. Fig. 2 diagrams the power supply and if it looks familiar to you, it shold. It is a typical circuit used time and time again in experimenter's circuits. Physically locate the transformer T1, away from the DA circuit components to keep the possibility of introduced AC hum to a minimum, if not zero. **SP**

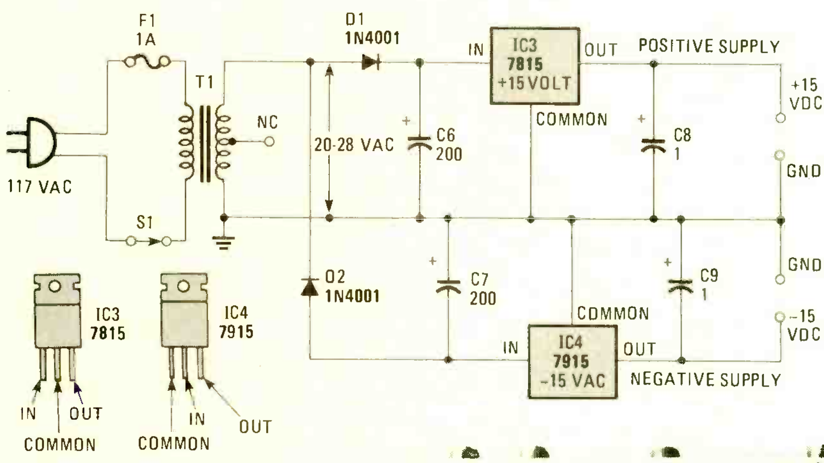
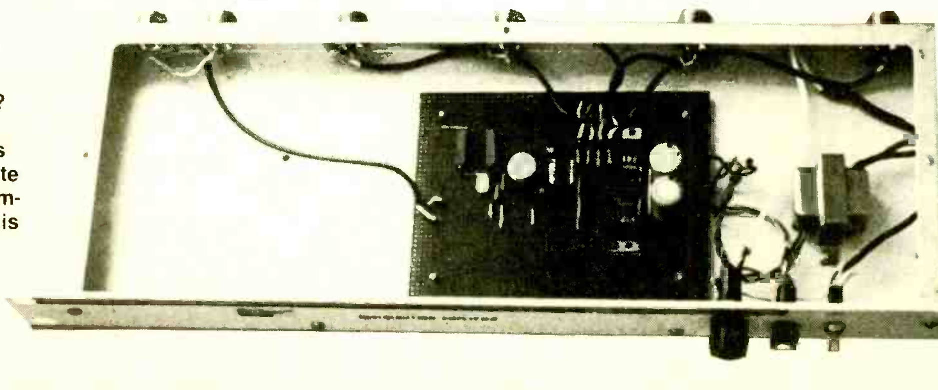
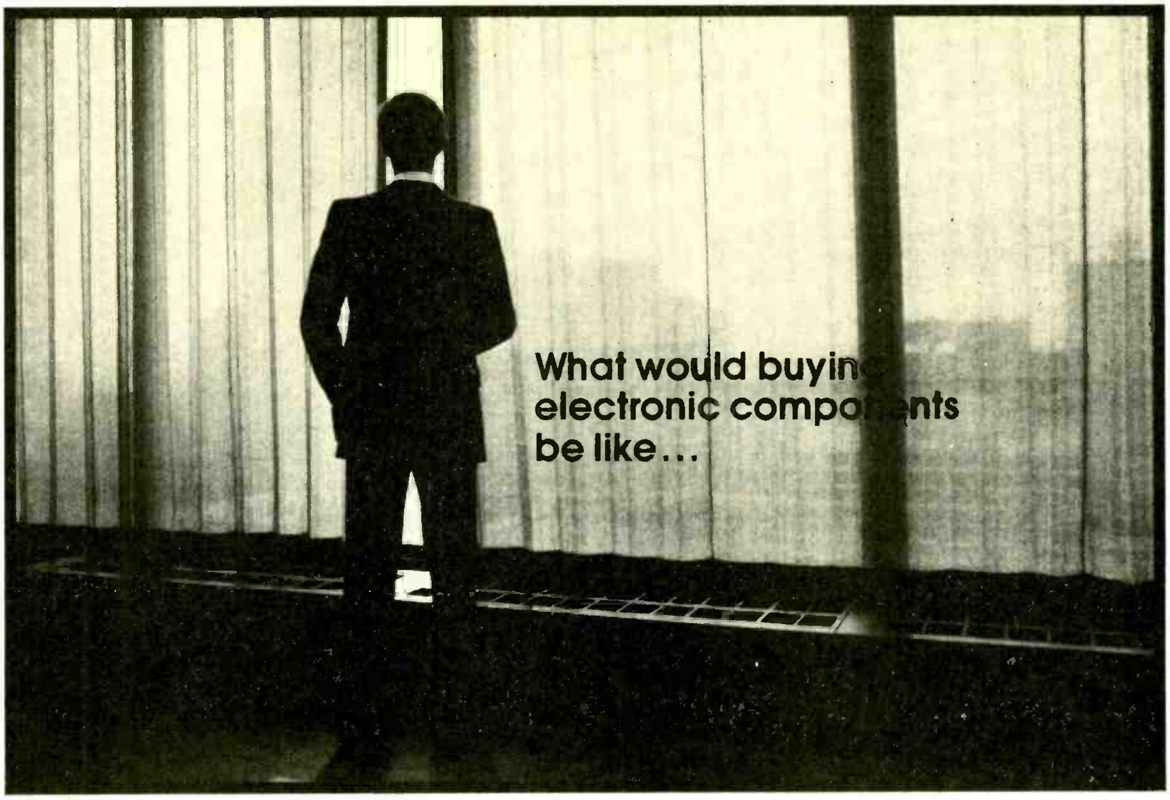


FIG. 2—NOW YOU SEE IT, and you'll see it again. This 15-volt, dual-voltage regulator is quite common. For 5 and 12 volts, use 7805 and 7812 chips for (+) voltages and 7905 and 7912 chips for (−) regulated voltages.



HOW SIMPLE can simple be? here is an inside view of the DA (Distribution Amplifier) as assembled by the author. Note the use of perfboard to assemble the circuit board. Author is preparing a printed-circuit board—details are given in Parts List.



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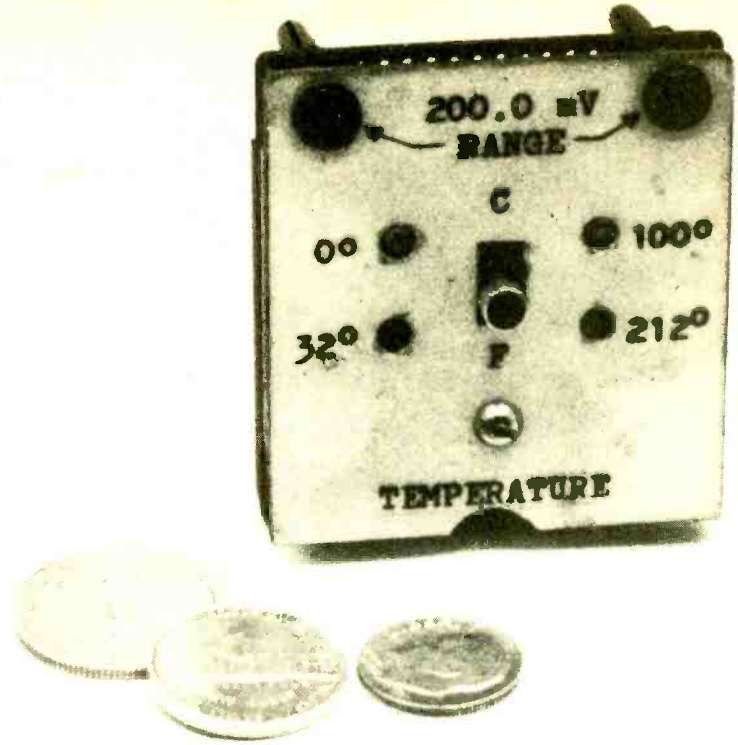
TEMP PROBE



TEMPERATURE-PROBE PROJECTS FOR DIGITAL MULTIMETERS (DMM's) are very popular and have inspired many construction articles. Most of such projects use the characteristics of a diode junction having a small forward bias. Its small, but very linear, change in voltage is proportional to temperature change. The sensing element may be a ready-made transistorized type of sensor, or just one of the junctions in an ordinary transistor. Unfortunately, even a TO-92 transistor package is fairly large, and has considerable thermal mass. That makes the probe thermally sluggish and slow to resond to temperature changes. It is worsened by the need to mount the sensor in some sort of a tube or handle, which adds more thermal mass and increases unwanted thermal conductivity to, or from, the sensor. Circuits for those sensors usually require at least a 9-volt battery supply, a voltage regulator circuit, and a housing or case for the circuit and battery.

Here is one temperature probe with a sensor/probe so small and light that it responds in seconds in liquid baths, or can even be fastened to a wall or other surface with masking tape. We call it DMM Temp-Probe. The unusual circuit draws only about 20 microamperes, and can be powered with a mercury watch battery. Mercury batteries are so stable that a voltage regulator circuit is unnecessary, and so small that the entire circuit and battery can be built on a 2½-in.-square, printed-circuit board which plugs directly into the DMM VOLTS jacks. A housing, or case, is not essential. Temperature reads directly in degrees and tenths, including negative readings, and can be switched to either Fahrenheit or Celsius readout. The parts will cost only $10, maybe $15.

The sensor/probe itself is a tiny 1N914 switching diode, D1, which is about as small an element as you can get. The 1N914 has axial leads, but by bending the leads sharply at right-angles, you make a single-ended sensor/probe out of it. The leads are then insulated with vinyl tubing, sealed to the diode body with epoxy, to allow the probe to be immersed in liquid baths. Being a high-impedance circuit, there must be an absolutely tight seal, and the sensor/probe assembly directions should be carefully followed.

Making the Probe

Before bending the leads, roughen the ends of the glass body of the diode by rubbing lightly against a fine oil-stone. The matte surface will bond better with the epoxy. Also, scrape the tinning from the iron wire leads close to the diode

All in one project, you find the features of a low thermal mass probe coupled to a passive voltage circuit that accurately senses °F and °C!

DON R. KING

body so that it will take solder.

The right size vinyl tubing can be stripped from #20 gauge, solid hookup wire. Even though the tubing seems quite flexible, you must preform the bends which will occur at the diode body. Insert a smaller wire into the vinyl tubing, make a sharp bend, and immerse the tubing in boiling water for a few minutes. When cool, remove the forming wire and trim the elbow ends of the tubing with a razor blade so that they will be an exact fit when in place. Cut the other ends to a length which will expose just barely enough lead for soldering connections.

The epoxy used should be the 4-hour curing type. The newer 5-minute curing type will start to gel before you can finish the job, and will not bond properly after gelling starts. Wash the diode in solvent and dry. Then thread the tubing about halfway up on the bent leads. Apply a little epoxy to the leads, just ahead of the tubing, and work the tubing up slowly with a slight back-and-forth and twirling motion so as to get this end filled with epoxy. Push the tubing all the way up and keep it in tight contact with the diode body by placing test clips on the exposed ends of the leads. Be sure to keep a snug fit.

For added insurance, dip the entire diode body in epoxy and hang upside-down in a warm place to cure. The extra warmth reduces the viscosity of the epoxy so that it flows and "wets" the surfaces to insure better bonding. If you don't have a warm place, use a heat lamp or hair dryer cautiously for a few minutes. While warm, dab off any excess of the thinned-down epoxy so as to leave just a thin film on the diode body. After full cure time, which can be at room temperature, solder a flexible cord to the exposed leads. It can be of any reasonable length. Bring the covered leads together, but keep the connections safely separated with a film of 5-minute epoxy or any quick dry cement.

Finally, slide a one-inch length of larger vinyl tubing over the cord and the two solder joints, filling with epoxy as you go. An ideal piece of cord for the tiny light-weight probe is the very flexible twisted pair sold as a ready-made extension cord for transistor earphones. Any leftover can be untwisted; it makes excellent flexible wire for miniature test leads.

Inside the Circuit

The schematic diagram for the DMM Temp-Probe is shown in Fig. 1. It is intended to feed the 200.0-milivolt DC range of the DMM. Resistor R1 puts a small forward bias on the diode, D1, but keeping it well below the critical bend in the voltage/current curve. Because the diode voltage varies inversely with the temperature, its voltage is used as a minus value (subtractive).

Voltage divider network "A" provides two series, positive voltages—equal to and slightly more—which are adjusted to give readings of 00.0 and 32.0 degrees with the diode D1 in an ice bath. Then, because the diode voltage varies by a little more than the desired 1.00 milivolt-per-degree F (1.80 mV/°C), the second divider network "B" proportions it to the exact value, and is used to calibrate the 212- and 100-degree readings in a boiling water bath.

Building it

A suggested construction layout for DMM Temp-Probe is shown in Fig. 2. The only thing unusual is that the double-pole, double-throw switch S2 is set into a slot in the board to permit bottom wiring, and is supported on spacers and "upside-down" screws. By that we mean that the screws are inserted into the threaded holes on the switch from the rear as opposed to the normal entry for the front-panel side. The socket for the sensor/probe's connecting cord can be a two-hole, socket-board block (A P Products) or a subminiature phone jack, or anything else small enough. Use color markings to polarize the A P socket-board block. Should you have a polarized subminiature jack in your junkbox—use it!

A top plate and a bottom cover mounted on spacers can be added (see Fig. 2), and the thin sandwich should be adequate protection for parts and wiring. At the battery location, an extra layer or two of printed-circuit board material is cemented in place and drilled through with a hole to loosely

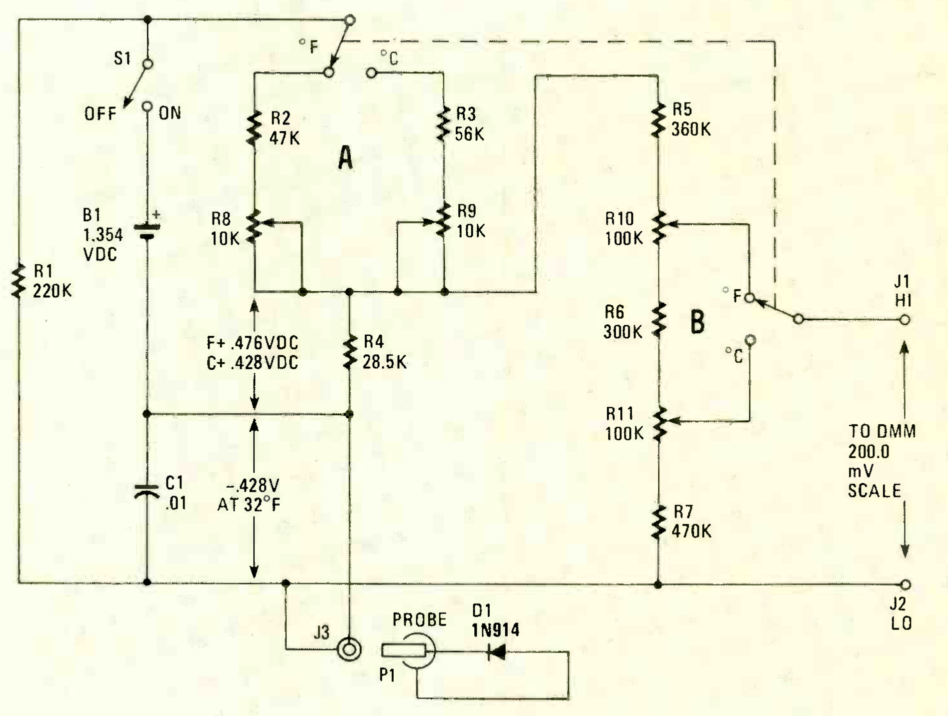


FIG. 1--A QUICK GLANCE at the schematic diagram of the DMM Temp-Probe tells you that only passive circuit elements make up the device. It's up to the DMM to sample the minute voltages and provide an accurate reading.

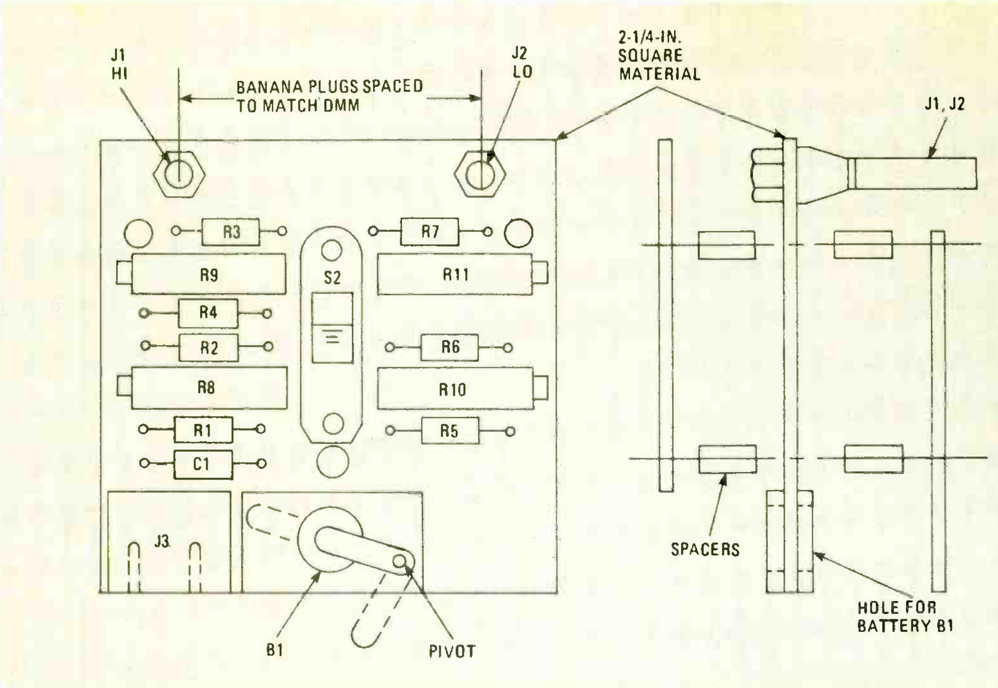


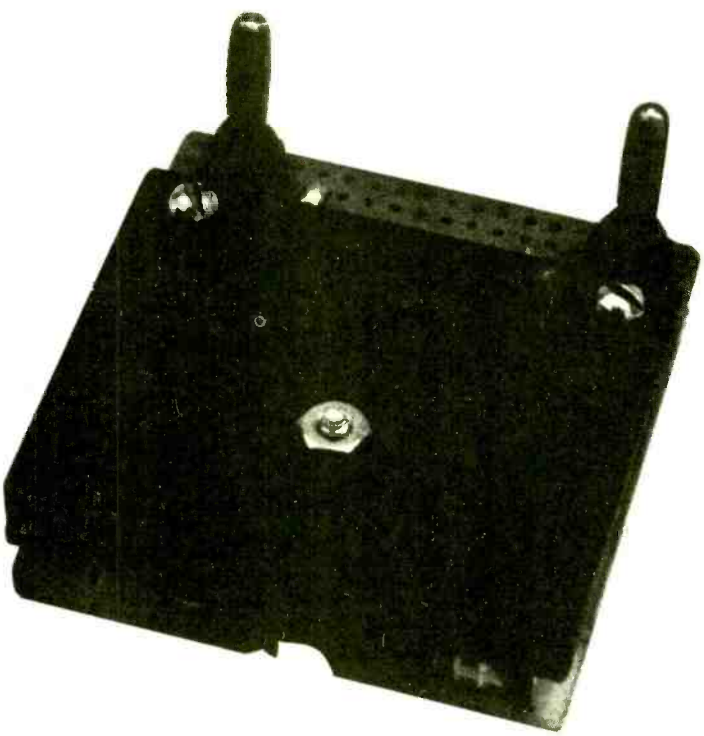
FIG. 2—THE DMM temp-sensor was painstakenly assembled on a scrap board to keep costs down. High-density packaging reduced the overall size to a simple plug-in adapter that takes up no bench space. Compare diagram to photos of author's prototype below.

fit and contain battery B1. Brass clips are riveted, top and bottom, for contacts. One clip should rotate for use as a switch (S1) and for battery removal. Note that battery B1 outer shell is the "plus" side, the reverse of most other types of batteries.

If 10-turn trimmer potentiometers are not readily available, it is possible to substitute single-turn, miniature trimmer potentiometers, but they must be lower values to reduce adjustment sensitivity—2,000-ohms for resistor network "A" and 20,000 ohms for "B". Also, resistors R2, R3, R5, R6, and R7 will become very critical and may require odd values. If you must use single-turn potentiometers, it will help to reduce R2 to 27,000 ohms and increase R5, R6, R7 to the next higher standard value. You probably will have to do some tinkering to insure enough trimmer-potentiometer voltage range for adjustment.

Try a rough calibration first. If you run out of potentiometer rotation, a moistened finger across each resistor will show where and in which direction a special selection of value or a combination of resistors may be necessary. For any rough calibration or tryout, you can avoid the nuisance of a boiling-water bath by using your oral body temperature instead. Check it with a fever (98.6° F = 37.0° C) thermometer. All main resistors should be low-temperature coefficient, metal-film types. Extra adjustment resistors can be regular carbon types.

Because commercial diodes vary a bit in sensitivity and other characteristics, for good linearity it is also preferable to adjust resistor R1 to an exact match with your diode and for the exact voltage of the battery used. After a rough calibra-



DVM'S VIEW of the Temp-Probe prior to being plugged into the VOLTS jacks. Meter is set at 200 millivolts scale.

THE DIODE SENSOR is assembled by carefully following the exact instructions given in text. Note how neatly the vinyl tubing fits and bends on the diode's leads. The 4-hour epoxy coating produces a very thin, glass-like coating over the diode adjoining vinyl tubing insulation that is waterproof and resistant to almost all strong chemicals. It can be immersed safely and removed without damage. When in doubt, test some of the chemical against a test patch of epoxy made from the same batch used on the probe.

PARTS LIST FOR DMM TEMP-PROBE

RESISTORS

(All resistosr are ½- or ¼-watt, low-temperature coefficient, metal-film, 5%)

R1—220,000-ohm*
R2—47,000-ohm
R3—56,000-ohm
R4—27,000-ohm*
R5—360,000-ohm
R6—300,000-ohm
R7—470,000-ohm
R8, R9—10,000-ohm, 10-turn, trimmer potentiometer
R10, R11—100,000-ohm, 10-turn, trimmer potentiometer

*Values may require adjustment or selection—see text for selection details

SEMICONDUCTORS

D1—1N914 diode

ADDITIONAL PARTS AND MATERIALS

B1—1.354-volt mercury battery, Timex type C or equivalent
J1, J2—Banana plugs
J3—Polarized, 2-terminal connector
P1—Polarized, 2-terminal plug
S1—SPST switch which can be fabricated to serve as switch and battery clamp
S2—DPDT miniature slide switch
Printed circuit-board material (see text), vinyl tubing, flexible 2-conductor cord, 4-hour epoxy, hardware, solder, rivets, etc.

tion, unplug from the DMM, but leave the sensor/probe connected and in an ice bath. Check the voltage directly across diode D1 (see fig. 1.). It should read −.428 V (−.460° R +.032° F). If the reading is off more than a few millivolts, revalue R1 by either paralleling a fixed resistor (usually in the Megohm range), or adding a few thousand ohms in series with R1. No potentiometer is provided for revaluing R1 as it is probably a one-time adjustment and it would be unwise to have a carbon resistive element with its high-temperature coefficient in this part of the circuit.

Preparing the Bath

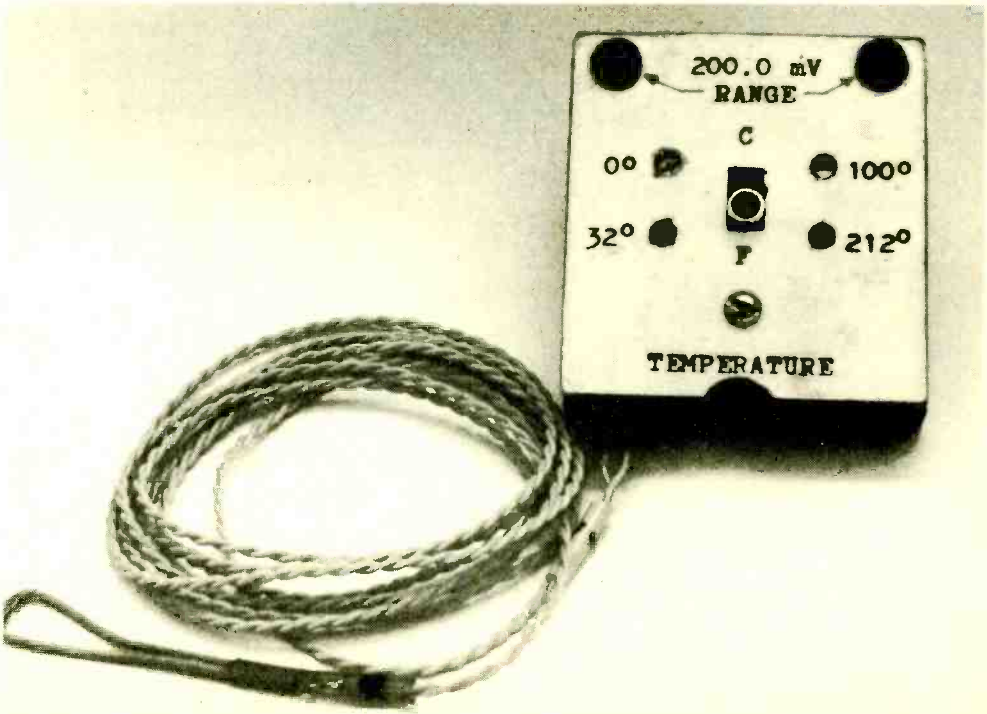
Now for a word on calibration baths. The ice bath must use crushed or shaved ice or snow. Note that ice taken directly from a freeze may be temporarily much colder than 0° C/32° F. Use an insulated cup or container to hold the ice and allow it to stand until a pool of water forms. Then stir or slosh while the sensor/probe is immersed in the slosh. Be sure the sensor/probe is not in a pocket of submerged air or located above the slosh's surface. When there is no further fall in the tenths digit, adjust so that the meter barely flicks down to 0° C/32F—no lower!

The boiling water bath must use clean water and be at a full rolling boil without being covered. When it is as hot as it will get, adjust so that the meter barely flicks up to 100/212°. Use the 2.00 volt scale for the °F reading (the decimal point will be off.) Your body temperature may be more reliable if you are not at sea level or the weather is not clear. The range of the device is from about −40° to 100° C/212° F with good linearity. (An interesting note is that at −40° the Fahrenheit and Celsius scales coincide and agree in that one instance only.) The diode itself would stand somewhat higher temperatures, but 105° C is the rated limit for vinyl insulation.

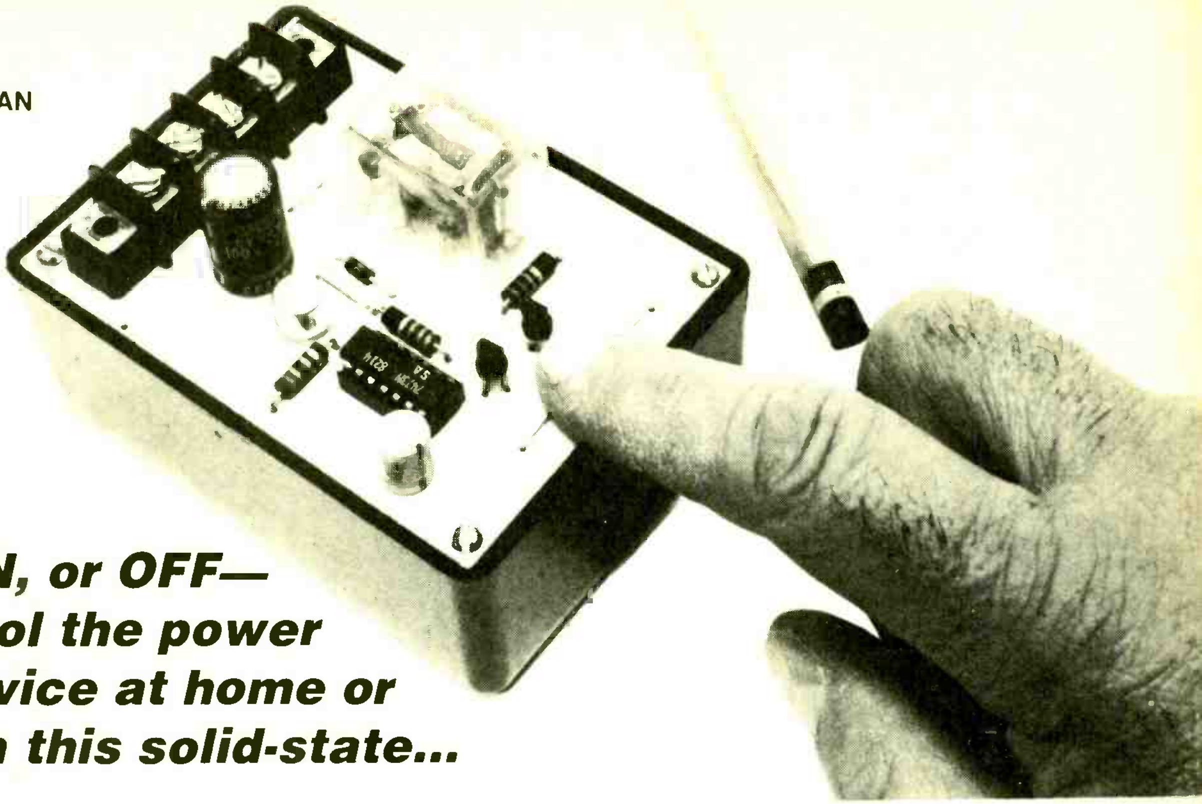
Any 1.35-volt mercury battery may be used, but do not use alkaline or silver oxide types.

A change in battery voltage or replacement will require recalibration, but mercury batteries are remarkably stable for long periods of time. Be very careful not to accidentally short these tiny mercury batteries. A split-second short across a mercury battery will do it in. **SP**

THE TEMP-PROBE shown in its finished state ready to be plugged into a DVM. The two screws at the top corners of the square device mount the two banana plugs that mate with the jacks on the DVM. In dead center is the slide switch used to switch from Celsius to Fahrenheit temperature scales. The four screw heads are the trimmer pots used to adjust the device to measure the temperature with unbelievable accuracy.



HERB FRIEDMAN



Turn it ON, or OFF— you control the power to any device at home or work with this solid-state...

TOUCH SWITCH

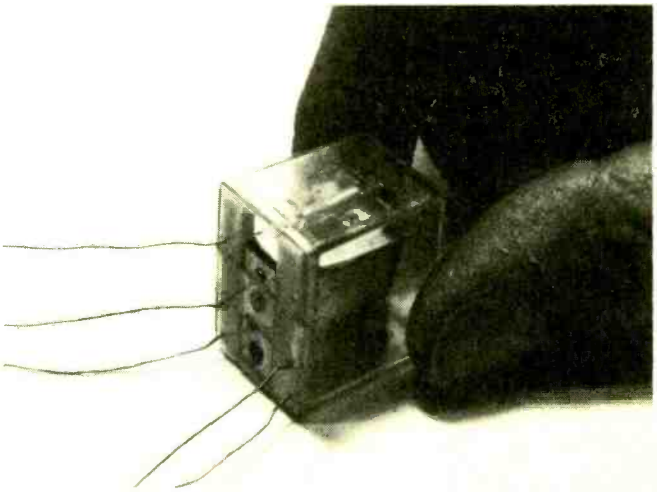
□TOUCH TO TINGLE, TURN ON, TURN OFF, OR WHATEVER—AND it will stay that way until you decide to change it.

Whether it's a device you want to control by simply brushing your fingers across a set of terminals or contacts, or a gizmo that depends on brief digital pulses, the Touch Switch will do it inexpensively, and with the least possible trouble.

The Touch Switch is a low-cost electronic version of an old hobbyist favorite, the latching relay. Back in the golden age of electronics project construction—when it was possible to purchase parts without mortgaging the family homestead—you could walk down to your local parts emporium and purchase a latching relay whose contacts would "flip" when a current (or voltage) pulse was applied; and the contacts remained "flipped" when the current was removed. The next current pulse flipped the contacts back to their original state. In that way a single pulse of current could be used to turn a device on or off.

Between inflation and the lack of parts distributors catering to the experimenter, the solenoid-operated latching relay is often just a memory. Even if you could locate a latching relay it could easily cost two days' wages, but you can build the Touch Switch, an electronic version of the latching relay, with components frequently found in the junkbox. In fact, the Touch Switch has a major advantage over the old mechanical-latching relays. The coil in the mechanical relays required 6, 12, 24, or 120 volts AC or DC, depending on the particular model; the electronic latching relay can be tripped by a current so low it would hardly budge the pointer of a microammeter.

But, like the rest of the world, the Touch Switch isn't perfect. While all current or voltage can be removed from a mechanical latching relay, the electronic version requires a continuously operating voltage source. However, the current



POWER CONTROL SWITCHING is achieved by the low-level control of a 6-9-volt DC relay available in most parts outlets and mail-order houses. The Parts List specifies a single-pole, double-throw relay that opens options for more than just on/off power-control purposes.

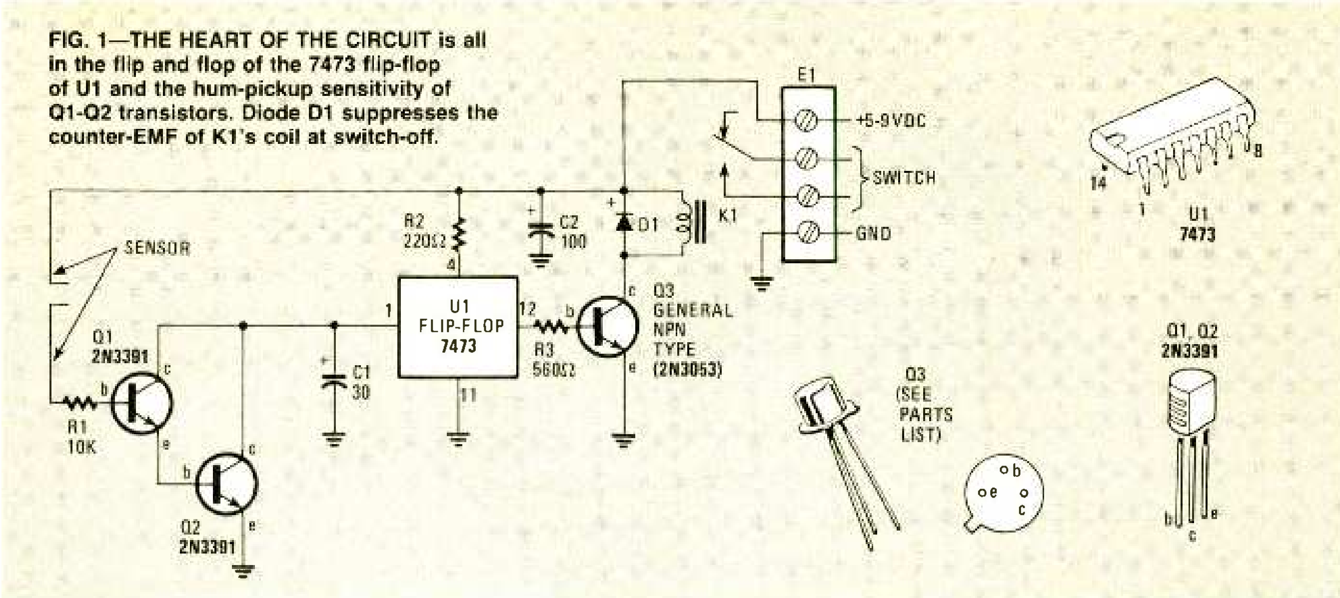


FIG. 1—THE HEART OF THE CIRCUIT is all in the flip and flop of the 7473 flip-flop of U1 and the hum-pickup sensitivity of Q1-Q2 transistors. Diode D1 suppresses the counter-EMF of K1's coil at switch-off.

drain of the Touch Switch is in the range of 12 to 25-mA—a value easily "stolen" from the equipment associated with the Touch Switch.

The Touch Switch is extremely sensitive. It can be triggered by simply placing your fingers across the sensing terminals, or by applying a positive-going TTL-level pulse to the input—the free end of resistor R1. The operating (power supply) voltage is from 5 to 9 volts DC, but you can go as high as 12 volts—no more unless you start changing component values for R2 and relay K1. Keep in mind, however, that if you use fingertip control you will be touching the power supply. Normally, that isn't a problem because the project was intended to be powered from one of those "AC adaptors" sold as surplus by many mail-order distributors. But if your supply is "heavy duty", it can deliver enough current to melt a steel bar. Play it safe, and install a 10,000-ohm resistor in series with the sensor and the power supply.

How it works

Integrated circuit U1 (Fig. 1) is a 7473 integrated-circuit chip with only one-section of a dual JK flip-flop used. When pin 1, the reset, is pulled to logic 0 (ground), pin 12 is flipped to the alternate state; if it was logic 0 it becomes logic 1; if it was logic 1, it becomes logic 0. Pin 12 controls relay K1 through transistor Q3. When pin 12 is high (logic 1), current flows to Q3's base, thereby causing Q3 to conduct. Q3's collector current flows through relay K1, causing the relay to close. Since pin 12's condition does not change until U1 is deliberately triggered, current will be maintained through Q1.

Pin 1 is controlled by the super-beta amplifier consisting of transistor Q1 and Q2. See Fig. 1. Applying any kind of positive voltage or current to Q1's base will cause Q2 to conduct (go low), pulling U1 pin 1 towards logic 0, thereby causing the flip-flop to flip. If pin 12 were high, it would drive pin 12 low; if pin 12 were low, a signal into Q1 would cause pin 12 to be driven high. Pin 12 maintains its state until pin 1 is deliberately driven by a pulse or application of a positive voltage or current.

The input circuit is "de-bounced" by capacitor C1; that is, an interruption to Q1's input of a few microseconds will not appear as a new trigger signal to U1. Refer to Fig. 1. Capacitor C1 more or less filters (smooths) the interruption so only a single "pulse" appears at U1, pin 1. Do not eliminate capacitor C1, because that would eliminate the de-bound feature and result in false triggering should your fingers wiggle on the sensors or the digital control pulse to Q1 is somewhat "ragged." Also, do not increase the value of C1 because the additional capacity would increase the decay rate and prevent rapid on-off switching.

Why dry contacts!

A relay rather than solid-state devices was used to control

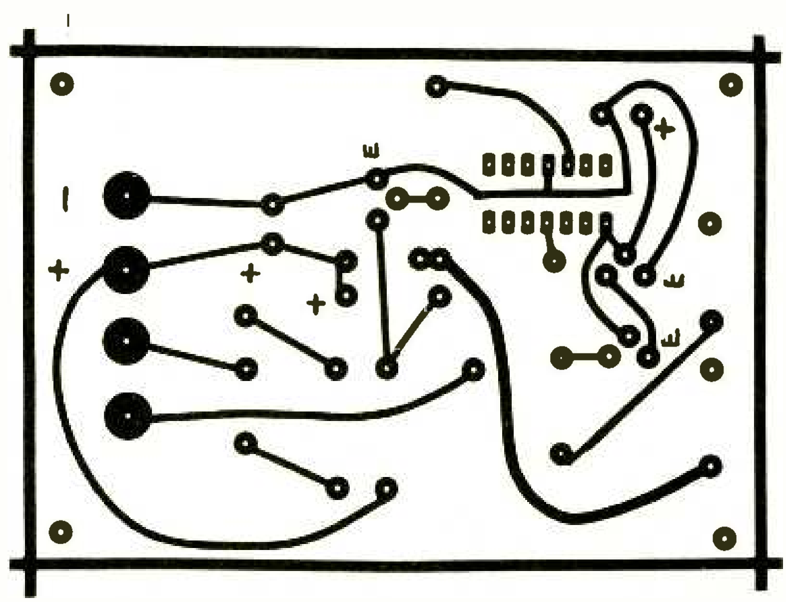
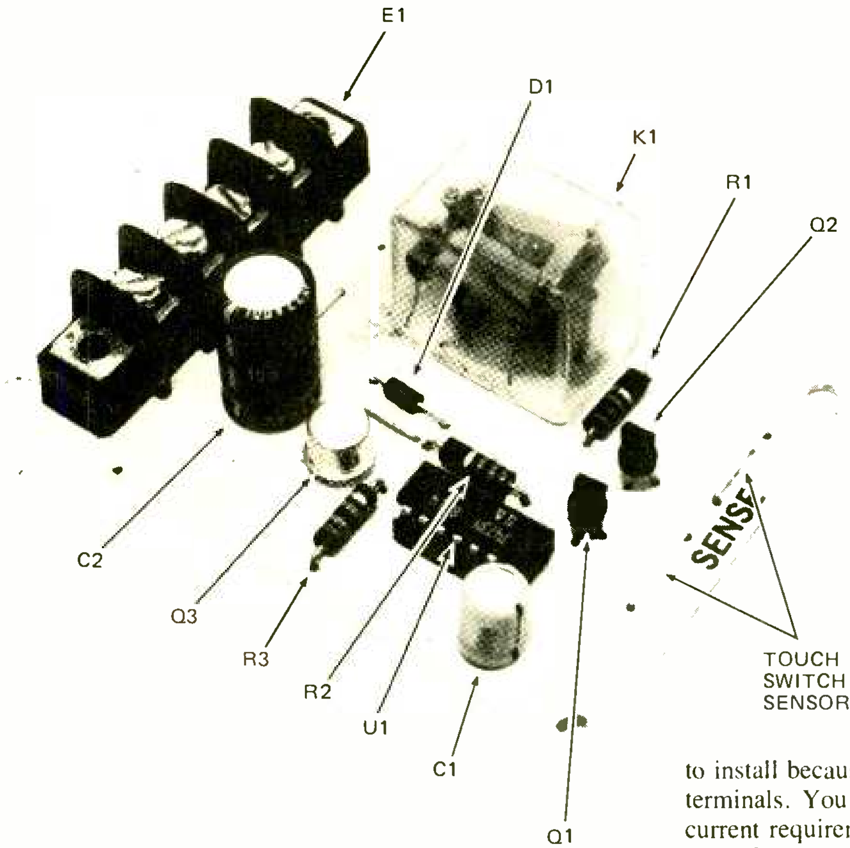


FIG. 2—COPPER FOIL SURFACE is diagrammed here for those experimenters who wish to build their Touch Switch on a printed-circuit board. A perf-board design is viable. Should the experimenter decide to assemble many switching units—he'd find the printed-circuit way the best!



PARTS LAYOUT for the Touch Switch on the author's printed-circuit board is loose, with ample room to compress the total volume into a smaller container. Should you decide to extend the touch sensors to a remote location, expect problems due to direct pickup from AC lines in the home and office. In fact, the circuit will respond to large AC transcients causing havoc with the circuit's reliability and sensitivity.

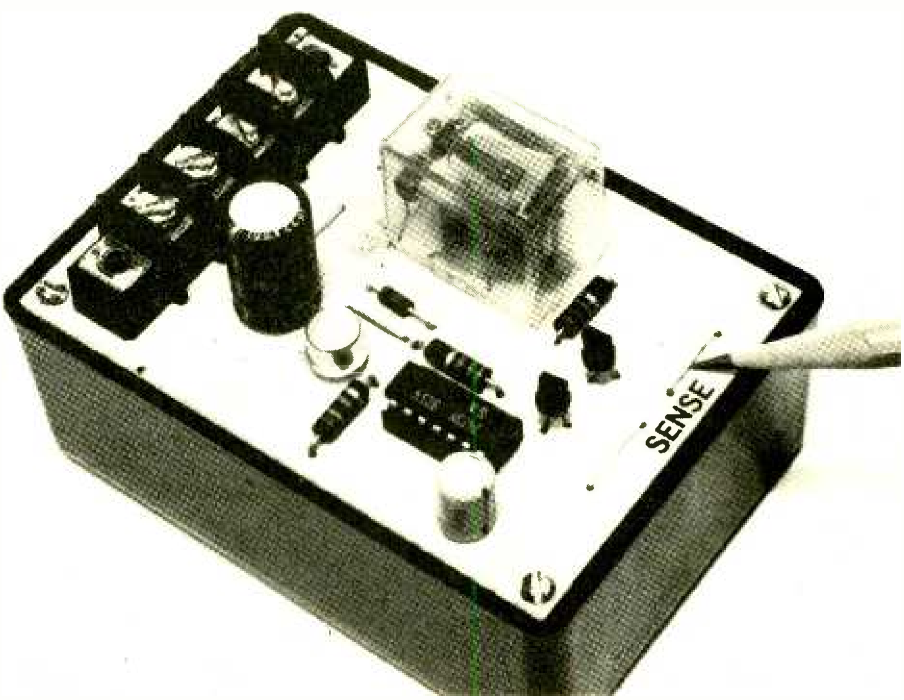
the output switching, in order to easily isolate the switching circuit from the Touch Switch electronics. It is actually less expensive to get relatively high-voltage control and isolation by using a relay having isolated (dry) contacts.

Building the Touch Switch

You can build the Touch Switch for stand-alone use, or you can integrate it into another project. An easy-to-build version with touch-sensor contacts is shown in the photographs, for which a printed-circuit template is provided. Almost nothing is critical. If you want fingertip control, you can substitute virtually any general-purpose transistor with a beta of 250 or higher for Q1 and Q2. If you're going to trigger the switch with positive-going TTL pulse, Q1 and Q2 can have a beta of 50 or higher. A beta of 50 or higher is satisfactory for Q3.

The specified relay has SPDT contacts, is inexpensive, and is easy to install because its connections are wire leads rather than terminals. You can substitute a 6-VDC relay but keep the current requirements in mind. The specified relay requires only 12-milliamperes, which keeps the power supply loading at a minimum. To simplify the wiring, and keep the terminal strip as small as possible, only the used relay contacts are brought out to the terminal strip; the printed-circuit has circuit foils for both the N.O. (normally open) and N.C. (normally closed) contacts. Simply use the appropriate wire jumper on the printed-circuit board for the desired contacts. If you want to bring out both the N.O. and N.C. contacts, you will need a larger terminal strip; make certain that it will fit on the printed-circuit board.

The printed-circuit template (see Fig. 2) is 2⅝-in. × 3¾-in.; it is intended for a bakelite cabinet of similar insider clearance. You can, however, modify the printed-circuit



TOUCH SWITCH is shown here completely assembled and ready for action. The pencil points to the copper-wire sensors that protrude through the printed-circuit board's surface. The barrier, terminal strip at the back of the unit is used to interconnect the external 5-9-volt power supply and provide access to the relay's contacts.

board's size and foil patterns to fit any desired cabinet. A DIP socket is recommended for U1; it will save possible destruction of the foils if you are forced to remove the integrated-circuit chip that's defective or incorrectly installed.

Double-check the installation of all transistors; make certin that the emitter-base-collector (e-b-c) leads are in the correct holes. Substitute transistors might have a different lead arrangement from the devices used in the model shown. For example, the specified Q1 and Q2 have an e-b-c lead arrangement; a substitute might have an e-c-b configuration.

The sense wires used for fingertip control are simply two open-ended wires on top of the printed-circuit board, "open-ended" meaning that one end of each wire isn't connected; it's simply soldered to a solder pad to keep it in place. If you plan to drive the Touch Switch with a DC pulse, replace the sense wires with small solder terminals, flea clips, or just a pair of wires.

Because K1 might be used to switch a high-voltage current, it is strongly suggested that the power and relay connections be brought out through a barrier terminal strip.

Checkout

Connect a 5- to 9-volt power supply to the Touch Switch. The relay will pulse once, or close and remain closed. Wet the tips of adjacent fingers and place them across the sense wires (refer to previous warnings). The relay should flip to the opposite state and remain there after your fingers are removed from the sense wires. If the relay fails to flip, connect a DC voltmeter from U1, pin 1 to ground. If should indicate about 4-volts DC. Place your fingers across the sense wires; the voltage at pin 1 should decrease close to zero. If it does decrease, the problem is either a defective integrated-circuit chip or the problem is located after pin 12. You can check the integrated-circuit chip by measuring the voltage from pin 12 to ground; it should flip when pin 1 is pulled low. If placing your fingers on the sense wires doesn't produce a drop in the voltage at pin 1, check the installation of Q1 and Q2. **SP**

PARTS LIST FOR TOUCH SWITCH

SEMICONDUCTORS
D1—Silicon rectifier, 25-PIV or higher, 1N4000 family
Q1, Q2—2N3391 NPN transistor, or equivalent
Q3—2N3053 NPN transistor (Radio Shack 275-004 or equivalent)
U1—7473 dual D-type flip-flop integrated-circuit chip

RESISTORS
(Note: all resistors are ½-watt, 10% units)
R1—10,000-ohm
R2—220-ohm
R3—560-ohm

ADDITIONAL PARTS AND MATERIALS
C1—30-µF, 10-WVDC or higher, electrolytic capacitor
C2—20-100-µF, 15-WVDC or higher, electrolytic capacitor
E1—Feed through barrier strip (Radio Shack 274-651 or equivalent)
K1—SPDT, 6-9-volt DC relay (Radio Shack 275-004 or equivalent)
Printed-circuit materials, cabinet, hardware, wire, solder, etc.

ONE EVENING PROJECT

D.E. PATRICK

Build this adjustable 20 amperes,

USING OUR ACTIVE DUMMY LOAD, WHICH IS NOTHING MORE than a transistor current sink, you can test power supplies and similar projects at their full-rated output current, without having to resort to strings of power resistors. An adjustable current sink allows the load to be varied quickly over wide range, regardless of the applied voltage, without using expensive non-inductive resistors. And that eliminates the usual fumbling around with power resistors, as in the case of power-supply testing, every time voltage and/or output current of the supplies or device-under-test output parameters are varied.

How it works

The collector current (I_C) of a transistor is virtually independent of its collector-emitter voltage (V_{CE}), so when configured as a current sink, current drain remains reasonably constant even as the applied collector-emitter voltage V_{CE} is varied over a wide range. Thus, the parallelled load transistors, QL1 and QL2, in Fig. 1 present a load to the device under test determined by the transistors' base current (I_B) multiplied by their Beta (h_{FE}) or DC current gain (I_B) (B) or (I_B) (h_{FE}).

Transistors, QL1 and QL2 share the current load, which is balanced by their emitter resistors, R1 and R2, whose nominal values should be something on the order of .2 ohm to .1 ohm. So, by simply placing power transistors QL1 and QL2 in parallel, we can increase the circuit's current-load capacity to anything we'd desire, limited only by the maximum limitations of the transistors used.

Some common junkbox-type load transistors, such as NPN 2N3055's, have a 60-volt V_{CE} with an I_C around 15 amperes and power dissipation at 115 watts. Therefore, all things being equal, when testing low-voltage supplies, power dissipation is the parameter you have to look at more than any other. For example, using four common junkbox 2N5885's in parallel with four 0.1-ohm, 5-watt emitter resistors, you could handle 30-volts at 20 amperes continuously with no problem. 2N5885's have about the same parameters as 2N3055's, but have a power dissipation in the 200-watt range, albeit collector current I_C is up there around 25 amperes. Further, when transistors with high V_{CE} specifications are used, high-voltage power supplies might be tested.

In any case, the load transistor's (QL1 and QL2) bases are controlled by a selected "adjust" current from a battery or

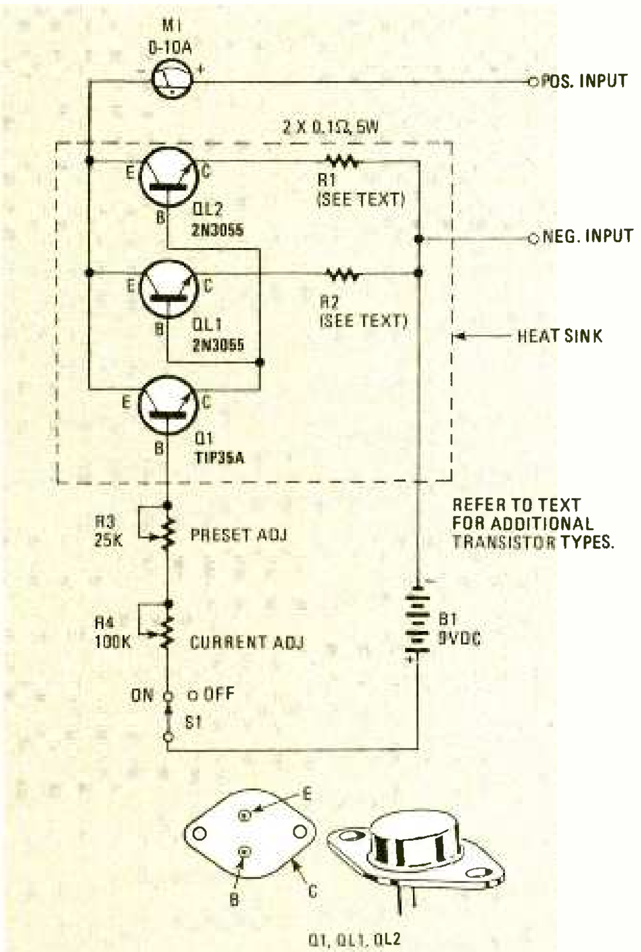
FIG. 1—THIS MAY BE THE CIRCUIT of your Active Dummy Load should the transistors specified match. But any NPN power transistor will work in this circuit, so play with the semiconductors you currently own.

ACTIVE DUMMY LOAD

active dummy load, usable at 10 amperes, and much more—from junkbox or spare parts!

DC supply. This preset current controls the current through Q1, which determines the base current of load transistors QL1 and QL2. The maximum possible current drain is determined by PRESET ADJ., potentiometer R3, while CURRENT ADJ. potentiometer R4 determines the current range of operation.

Transistor Q1 is a commonly available TIP35A, an NPN silicon power transistor that can handle voltages up to 350 with a rated one-ampere collector current. Most NPN silicon power transistors with an h_{fe} of 50-150 will do the job in this project. Another choice for Q1 is 2N5682.



THE ACTIVE DUMMY LOAD is a basic circuit stepped-up to handle very large current loads.

Construction hints

There's nothing critical about construction of this Active Dummy Load, except that all transistors must be adequately heat-sinked. If you believe the aluminum-finned heat sink is too large for the job—use it! The author used a heat sink yanked off the power supply of an old UHF transmitter. The enclosing case was made from a few pieces of scrap black Plexiglas thrown together. Should you prefer to build the unit from a complete kit of parts then send $45.00 plus $3.50 for postage and handling to ETC Co., P.O. Box 29278, Denver, CO 80229. Optional meter is $10.00 additional when ordered with kit of parts.

Some final notes

The PRESET potentiometer, R3, setpoint will be determined by the beta of the transistors used, and the upper-load limit determined by the load transistors. Potentiometer R3 will set the maximum load and that current level can easily be preset when an optional ammeter or external ammeter is used.

First, set current PRESET potentiometer R3 at maximum and CURRENT ADJ. potentiometer R4 to minimum resistance. Second, reading the current drawn from a suitable power supply connected to the active load, adjust current-preset for the maximum load you want to pull; and that's it!

The number and types of load transistors used will determine maximum power dissipation you require. So, when running a lot of voltage at a high current, don't exceed their maximum power dissipation for prolonged periods of time or you'll fry your load transistors. On the other hand, for short periods you *can* exceed the continuous power dissipation as long as you let your load transistors cool down. Use some reasonable duty cycle that won't exceed their safe area of temperature operation.

There is no Parts List with this project because a Parts List will defeat the purpose of the project—to be built with junkbox parts. A 9-volt transistor battery was used because it provides the ideal control-power supply that is electrically isolated—that keeps costs way down. Should you have an isolated power supply on the bench, any voltage from approximately 7 to 15-volts DC will do the job.

Remember, you are dealing with large currents, so use large wires to carry the currents. Use #12 solid copper wire (available from electrical supply houses) to handle up to 20 amperes of current. Higher than that, resort to doubling the #12 wire to obtain multiples of 20 amperes of capacity.

With this assembled, high-current Active Dummy Load on your workbench, whatever the force may be, the load will be with you. **SP**

PROGRAMMA V TIMER

It serves but one purpose—to time the events that take place in a darkroom

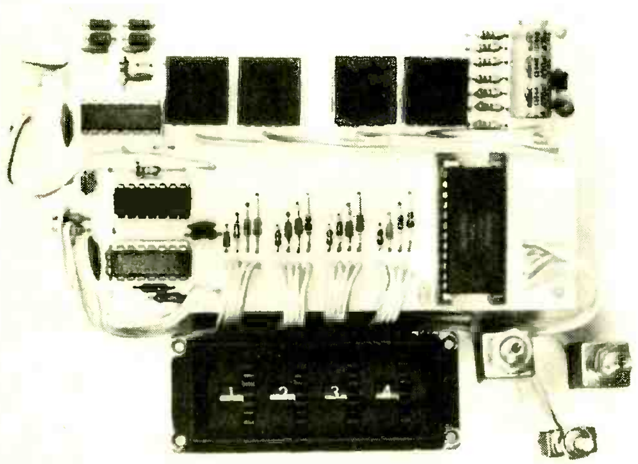
GARY McCLELLAN

☐ONE OF THE HANDIEST GADGETS YOU CAN HAVE AROUND THE home or shop is a programmable timer, and our Programma V Timer is just great for most general-purpose applications. Not only will it allow you to control your appliances effectively, but the Programma V Timer will save energy as well as wear and tear on them!

For example, in the photographic darkroom, the timer effectively controls enlargers, allowing the darkroom technician to turn out precisely exposed prints every time.

Hams can appreciate the Programma V Timer's capabilities, as it generates precise 10-minute station ID reminders with the touch of a button.

Householders will like the Programma V Timer, because it can control household appliances for up to an hour. For example, it's great for controlling a sun lamp—insuring that the lamp won't stay on too long, and the user get an overdose of ultraviolet rays. The timer is helpful for people who like to watch late night television shows. No more does the TV receiver have to run all night after the viewer dozes off. Simply set the timer before going to bed, and let it turn the set off as soon as the program is over. The Programma V Timer is also great for controlling unattended appliances such as fans, which may have been left running uneccessarily. No doubt you'll be able to find more applications for this programmable precision timer aorund the home, as well as applications in the office, factory, farm—wherever you may work.



THE PROGRAMMA V TIMER as it appears before insertion into a suitable cabinet or case. You may want to install it in an existing project.

Features You Should Know About

The Programma V Timer has a number of unusual features that set it apart from other timers, whether electrical or mechanical. The desired time, up to 59 minutes and 59 seconds, is entered via four thumbwheel switches. There is no need to enter the desired time again, unless you want to change it. That is fine for repetitive tasks such as photography and as found in industrial-control applications. Simply press the ENTER pushbutton, and the desired time is ready to go. In addition, a digital display shows the selected time.

When the START-STOP pushbutton is pressed, the display begins counting down to zero. At the same time, a solid-state relay energizes an appliance connected to the project. If desired, the timing cycle may be interrupted at any point, simply by pressing the START-STOP pushbutton. When the display reaches zero, the appliance turns off, and the display blanks. At that point the circuitry goes into a standby mode, and the power consumption drops to an insignificant value.

Other features include a manual RESET pushbutton to cancel an unwanted time sequence, and a power-control switch. The switch allows the appliance to be controlled conveniently from the timer. You can select MANUAL operation, OFF, or AUTO timer-controlled operation. That is great for controlling remote appliances, such as fans, pumps, and lights.

Finally, the Programma V Timer has a built-in power-on reset circuit. If power is interrupted while the timer is in operation, the project resets to zero, and turns off the appliance. That protects the appliance from damage, and prevents the timer from setting itself to an undesired time value.

The Programma V Timer is remarkably easy to build, and low cost, too! Just one printed-circuit board is used, and it contains most of the components. In addition, only five integrated-circuit chips are used, which makes this timer simpler than most other units. Most experimenters should be able to stuff the printed-circuit board, prepare the case, and complete the final assembly in three evenings of easy work. To make construction easier, the printed-circuit board is available—see the Parts List. The total project cost is low; about $50. You should be able to pare down that figure with careful parts selection and parts salvaging from old projects. Even if you don't, the project still costs half as much as the least expensive photography timer kit.

Theory

The Programma V Timer is simplicity in itself, thanks to a new CMOS LSI chip. The circuit is build around an Intersil type ICM7217C counter chip, which contains four down counters, latches, display circuitry, and zero detect-circuitry. If you were to duplicate that chip using TTL logic you would need at least twelve integrated-circuit packages, and the cost would probably be double that of the ICM7217C. So thanks to the new chip, you can build a programmable timer at a reduced cost. And, in addition, the construction is simplified because there are fewer chips to install. Refer to the functional block/schematic diagram (Fig. 1) as the circuitry is discussed. If you wish, you can follow the schematic diagram (Fig. 2) at the same time, or go through the discussion a second time for clarity's sake.

In operation, a power supply made up of C6, D1-D4, U5, and T1 provide a regulated +5-volt power source for the timer (see Figs. 1 and 2). The AC output from T1 is also tapped, and drives a divide-by-60 or divide-by-50 counter. That is the job of U1, a Motorola MC14566 integrated-circuit chip. By connecting one wire jumper, it is possible to select 60-Hz operation (North American users), or 50-Hz operation (European users). In either case, the output from U1 is a 1-Hz pulse.

When the RST input of U1 is low (refer to Figs. 1 and 2), the counter runs, driving the CL input of counter U4. The chip starts counting down to zero from a desired time that was previously entered. When U4 reaches zero, internal circuitry on the chip blanks the display, and the zero output goes low. That signal is coupled through C4 and R5 to the input of gate U3-a. The gate resets flip-flop U2-a, making the RST input of U1 high; that puts U1 in the reset state, stopping the counting.

AC coupling is required via C4 because otherwise the zero output would inhibit gate U3-a, preventing control of the timer by START-STOP switch S5. Switch S5 controls the coundown cycle of the timer. First, the switch contacts drive half of U3-b, a CD4013 chip wired as an RS flip-flop. That effectively debounces the noisy switch contacts, insuring there is only one output pulse each time the switch is pressed.

The output from U3-b drives the CL, or clock input of U3-a (see Figs. 1 and 2). The latter is wired as a D-type flip-flop. Pulses from the switch clock it, controlling both U1 and Q1. When the Q output of U2-a is high, U1 is reset. The (Q) output will be low, and Q1 driven to cut off. So the timer doesn't run, and the appliance is turned off. But when the Q output is low, U1 generates the 1 Hz pulse and the timer runs. The (Q) output will be high, of course, and Q1 is turned on. That energizes the solid-state relay, K1, turning on the appliance.

These gates generate a power-on reset for the timer. When power is first applied to the timer, a reset pulse is applied to

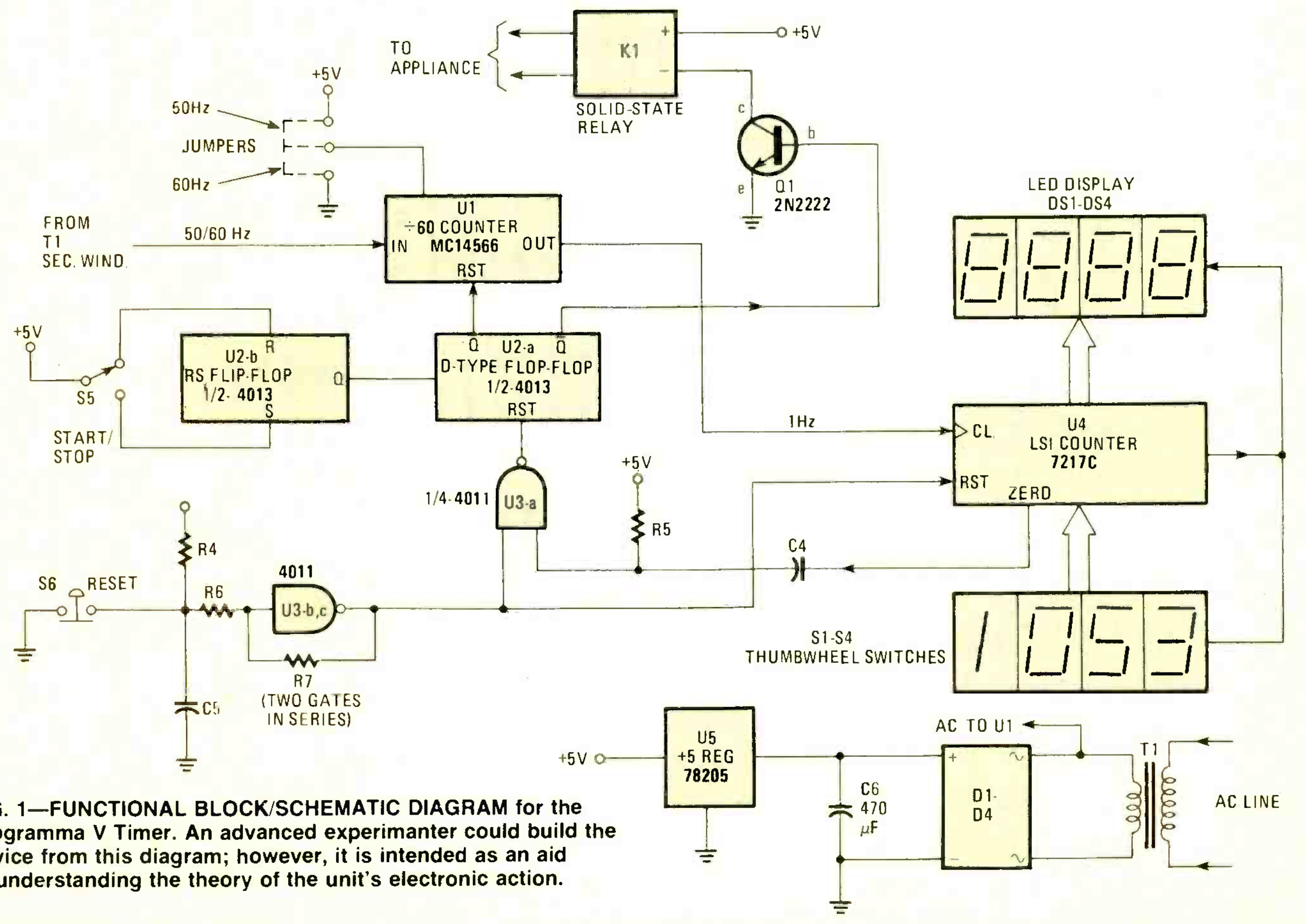


FIG. 1—FUNCTIONAL BLOCK/SCHEMATIC DIAGRAM for the Programma V Timer. An advanced experimanter could build the device from this diagram; however, it is intended as an aid to understanding the theory of the unit's electronic action.

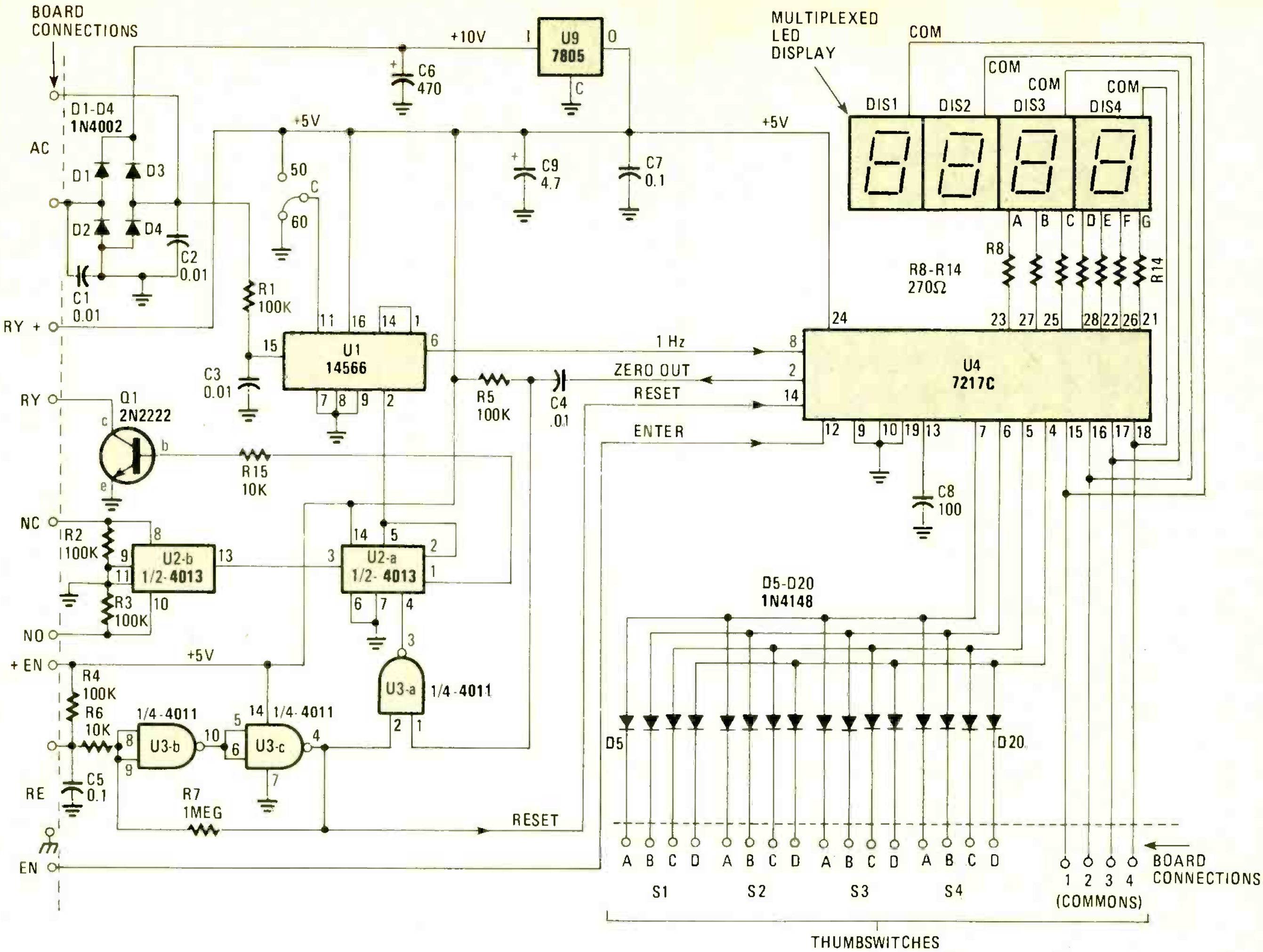


FIG. 2—SCHEMATIC DIAGRAM of the circuitry found on the printed-circuit board for the Programma V Timer.

U2 and U4. That forces the circuitry to start up in a desired manner, insuring that a power failure won't start the timer running. (That could be a serious problem if the timer is used with unattended appliances.) In operation, C5 starts to charge through R4. At about 45% of full charge, the output of U3 snaps high, removing the reset pulse. Note that two gates are wired to make up the Schmidt trigger shown. Resistors R6 and R7 set the trip point. After a brief delay, the output goes high, and reset is removed from U2 and U4. At that point, the timer is ready for use.

The desired time is programmed into U4 in a unique way. Standard BCD thumbwheel switches are used for entry, but their connection is unusual. The data is multiplexed into the chip, which has only four inputs. Diodes (not shown in Fig. 1, refer to Fig. 2) connect between the switches and the chip input lines. In that way all BCD "1" connections from the switches connect via diodes to a single BCD "1" from the chip. That is true of the other lines. There are four digit lines from the display, and each ones mates with a common connection pad on each switch. Thus, by making one digit line low at a time, the ICM7217C enables a switch, loading data into the chip.

Solid-state Relay

Relay K1 is unique in that it has no moving parts, and can control full line voltage with logic-level type signals. As a result, the device can be more reliable, and is a lot easier to work with. Another benefit is that they cost less than some mechanical relays, and are even starting to appear in surplus.

Solid-State relays basically contain an optoisolator, or LED/photocell combination, and a triac power-switching device. The LED is powered by the circuitry, and the light is detected by the photocell, controlling the triac. Solid-state relays are rated by line voltage and current. The unit specified will control up to 7 amperes, and up to 120-volts AC. Foreign readers with 240-volt power supplies will have to use another relay rated at 240 volts.

Assembly

The best way to start assembly is by obtaining the parts. Refer to the Parts List for component values. You should be able to find them through the mail-order parts distributors that advertise in **Special Projects** and **Radio-Electronics** magazines. For your convenience, a printed-circuit board is available, and may be ordered from the source listed in the Parts List. The board will speed construction, and give the circuitry a professional appearance (not to mention ease and speed in construction). Or, if desired, you can either make your own board from the artwork shown (see Fig. 3) or build the circuitry on a piece of perfboard.

Substitutions are permissible, providing that you have the know-how to make reasonable ones. Three parts that might cause confusion are U4 (ICM7217C), K1 (solid-state relay), and T1 (filament transformer). When you shop for U4, be aware that there is a family of ICM7217 devices. The ICM7217A versions count up to 9999, which may not be suitable for this project, unless you want to count in seconds. The ICM7217C version specified counts in minutes and

PARTS LIST FOR PROGRAMMA V TIMER

SEMICONDUCTORS

D1-D4—1N4002 50-volt, 1-A, rectifier diode
D5-D20—1N4148 switching diode
DIS1-DIS4—Fairchild FND503 common-cathode LED display
Q1—2N2222 NPN transistor
U1—Motorola 14566 CMOS counter integrated-circuit chip
U2—4013 CMOS dual D flip-flop integrated-circuit chip
U3—4011 CMOS NAND gates integrated-circuit chip
U4—Intersil ICM7217C/IPI CMOS counter integrated-circuit chip (Circuit Specialists/Jameco Electronics)
U5—78L05 5-volt, 100-mA voltage regulator integrated-circuit chip

RESISTORS

(All resistors are ¼—watt, 5% unless otherwise noted)
R1, R2, R3, R4, R5—100,000-ohm
R6, R15—10,000-ohm
R7—1-Megohm
R8-R14—270-ohm
R15—22-ohm, ½-watt

CAPACITORS

C1, C2, C3, C4—0.01-μF, 50-WVDC disc
C5, C7—0.1-μF, 16-WVDC, disc
C6—470-μF, 16-WVDC, axial-lead
C8—100-pF, 50-WVDC disc
C9—4.7-μF, 6.3-WVDC tantalum
C10—0.1-μF, 600-WVDC, Mylar

ADDITIONAL PARTS AND MATERIALS

F1—⅛-A fuse and holder
F2—5-A fuse and holder
K1—Relay, solid-state (Sigma type 226R1-5A1 (USA) or type 226R2-5A1 (Europe) (Newark Electronics type 27F1150 or 25F1157, respectively)
P1—AC chassis socket
S1-S4—BCD Thumbwheel switches (C K, Cherry, Unimax, etc. Use type BCD-1 from Circuit Specialists)
S5—SPDT, pushbutton switch (C K type 8121 from Circuit Specialists)
S6, S7—SPST, normally-open switches (Use C K type 8121)
S8—SP3T, toggle switch with 10-A contacts
T1—Filament transformer, 117-VAC primary; 6.3-VAC, 600-mA secondary (Thordarson model 21F21 or similar)
Printed-circuit board (see offer), 1-28 pin integrated-circuit socket, 2-14-pin sockets, 40-pin strip of Molex Soldercons, display bezel, 5- × 7- × 3-in. box (Cal Chassis type A-150), AC line cord with molded plug, hardware, ribbon cable, wire, solder, decals, etc.

The printed-circuit board for this project is available by ordering part number TMR-1 at $12.00. California residents please include 6% sales tax, and non-USA residents please include $3.50 for additional postage and handling.
Order from Technico Services, P.O. Box 20HC, Fullerton, Ca. 92633

seconds, so look for that version. As for the solid-state relay, a Sigma model 226R1-5A1 unit was specified. It is available from industrial supply houses such as Newark Electronics. In addition, surplus houses such as Poly Paks and B F Enterprises offer similar relays. For example, the B F number 1V0280 250-volt, 10-ampere relay looks promising, and no doubt there are many others. You want one that will operate on at least 5 volts, and can control at least 5 amperes at 120/240-volts AC.

European readers can either substitute a Sigma model 226R2-5A1 relay, which is suitable for controlling 240-volt AC power, or use a standard low-voltage relay. Transformer T1 is a common 6.3-volt AC filament transformer, and you should have no trouble finding it. However, since the transformer is powered at all times, be sure to get a top-quality unit, like the one specified. There are quite a few marginal transformers available that run hot and waste power. Stay away from them.

Stuffing the Board

Refer to Fig. 4 for parts locations on the printed-circuit boards, and refer to it often while you install the parts. Position the board as shown with the "AC" label on the foil side (face down during assembly) to your left.

Start by installing the integrated-circuit chips and display sockets. Install a 28-pin socket at the U4 location. Then

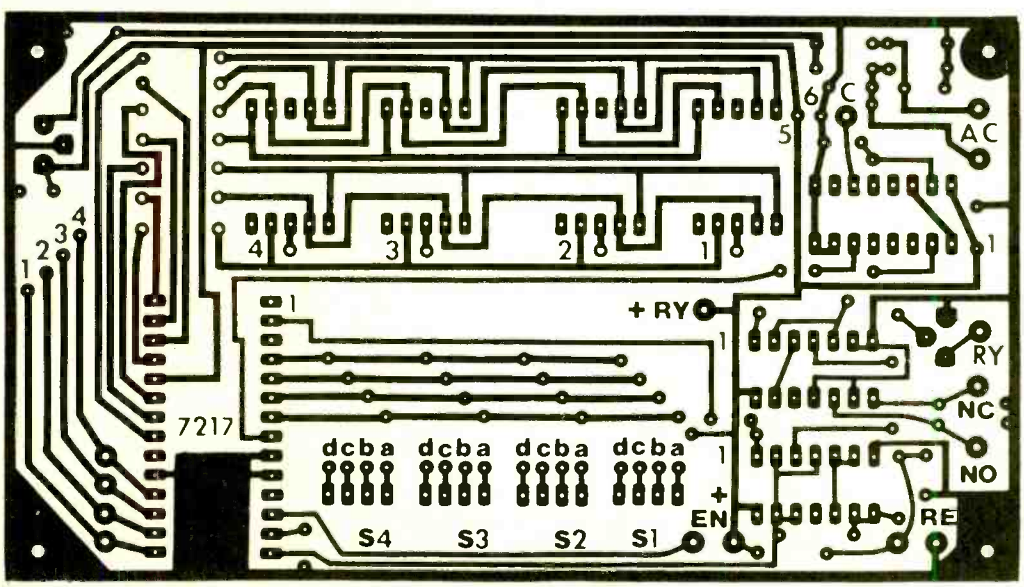


FIG. 3—FOIL-SIDE-UP diagram of the printed-circuit board used to assemble the heart of the timer circuit. Beginners should resort to using this printed-circuit layout.

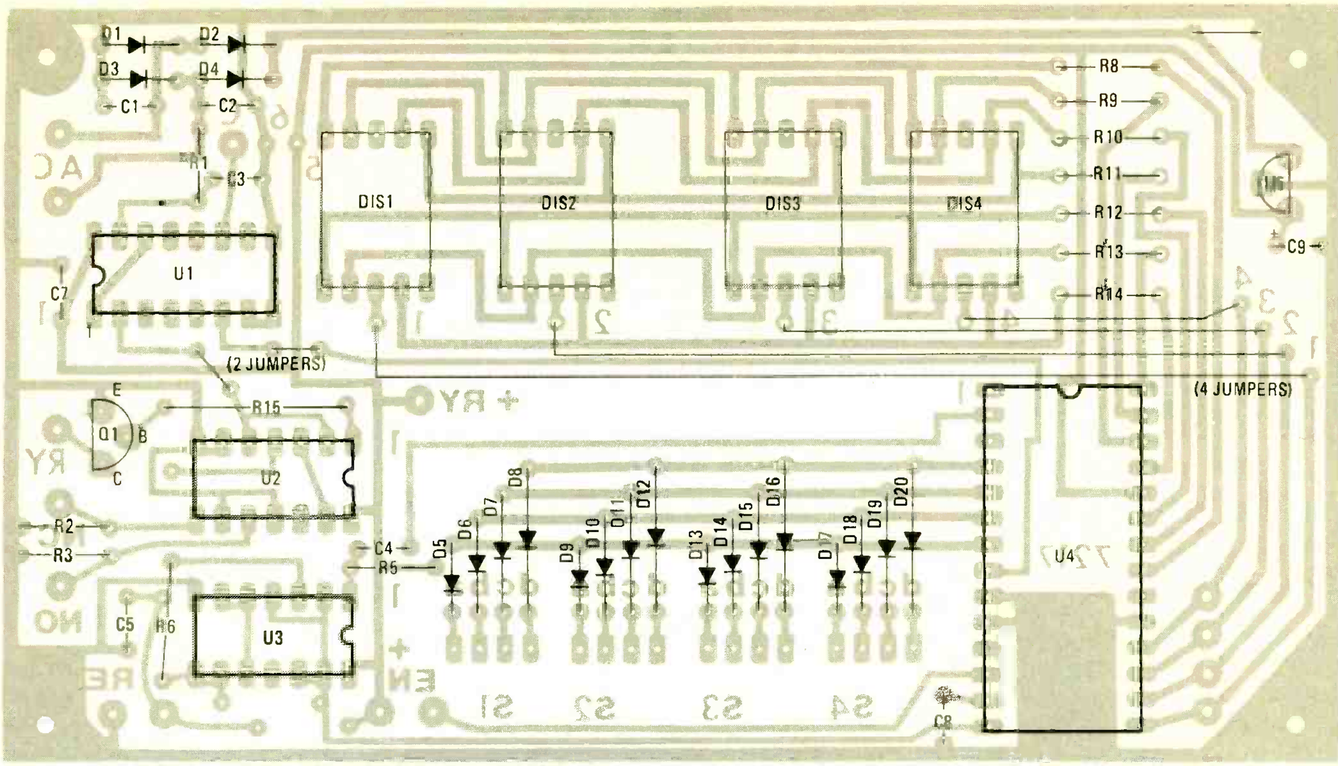


FIG. 4—PARTS LOCATION DIAGRAM with printed-circuit board shown foil-side down in this x-ray view.

install a 16-pin socket at U1. Move down and install two 14-pin sockets at U2 and U3. Do not install the integrated-circuit chips yet. Now for the display sockets: Cut a 40-pin strip of Molex Soldercon connectors into eight 5-pin strips. Then insert a strip in one DIS1 locations, and solder in place. Do not break off the tab yet. Likewise, install strips in the other DIS1 location, and in the other DIS2-DIS4 locations.

Diodes and Resistors

Start at the top of the board by installing four 1N4002 rectifiers at D1 through D4 (see Fig. 4). Be sure that the diode bands are positioned correctly before soldering. At the center of the board, install sixteen 1N4148 diodes in locations D5 through D20. Remember to recheck the position of the bands before soldering the diodes in place.

Install a 100,000-ohm unit at R1, which is just above U1. Then install a 10,000-ohm resistor at R15. Watch out for the two jumpers here; the resistor installs in the holes adjacent to U2. Next, install 100,000-ohm resistors at R2 and R3. Jump over to U3 and install a 10,000-ohm unit at R6. Move over to pin 1 of U3, and install a 100,000-ohm resistor at R5. Install a 1-megohm resistor at R7, and a 100,000-ohm unit at R4. Finish up the resistors by installing 270-ohm resistors at R8 through R14.

Capacitors and Jumpers

At the lefthand side of the board, install 0.01-μF disc capacitors at C1, C2, C3 and C4 (see Fig. 4). Install two 0.1-μF disk at C5 and C7. Next, install a 470-μF electrolytic capcitor at C6. Also, install a 4.7-μF tantalum capacitor at C9. Note that an electrolytic unit may be substituted. Check the polarity before soldering it in place. Lastly, install 100-pF disc capacitor at C8, next to C4.

Use leftover resistor leads for short jumpers where danger from shorts is not present. There are four jumpers that require insulated wire to be used. Those are the jumpers above U4. Cut a piece of wire to size, strip the ends, and install from point "1" under DIS1 to the "1" pad near the edge of the board. Follow up with other jumpers in the same manner.

Finishing Up

Install Q1, U5, and the displays, DIS1 to DIS4 (see Fig. 4). Install a 2N2222 NPN transistor at Q1 as shown, with the flat side of the case pointing to the edge of the board. Then turn to the right edge of the board and install a 78L05 regulator at U5 as shown. Check to be sure that you haven't transposed Q1 to U5. Now, break off the tabs on the Molex connectors. Carefully install FND503 displays as shown at DIS1 through DIS4. Note that the ribbed edge points up. Make sure that all of the display pins are inserted into the connectors when you are finished.

Check your work carefully. Look for the usual shorts, unsoldered connections, and improperly installed components.

Now configure your project for 50 or 60 Hz operation. Refer to Fig. 5 for details. All that is required is to install a jumper as shown.

Now the switches and power cables can be connected to the board. Short lengths of ribbon cable may be used for this

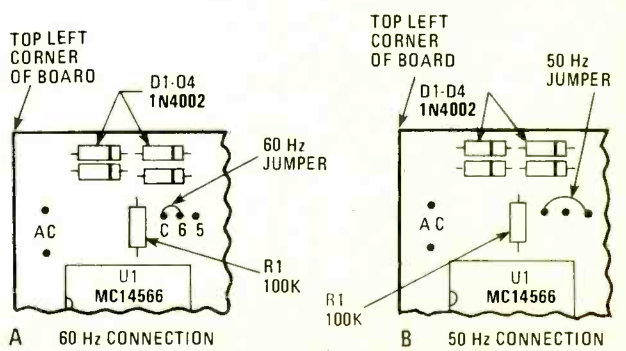


FIG. 5—SELECT the correct jumper location for the line frequncy (50 or 60 Hertz) in your area. Throughout North America the A configuration is used.

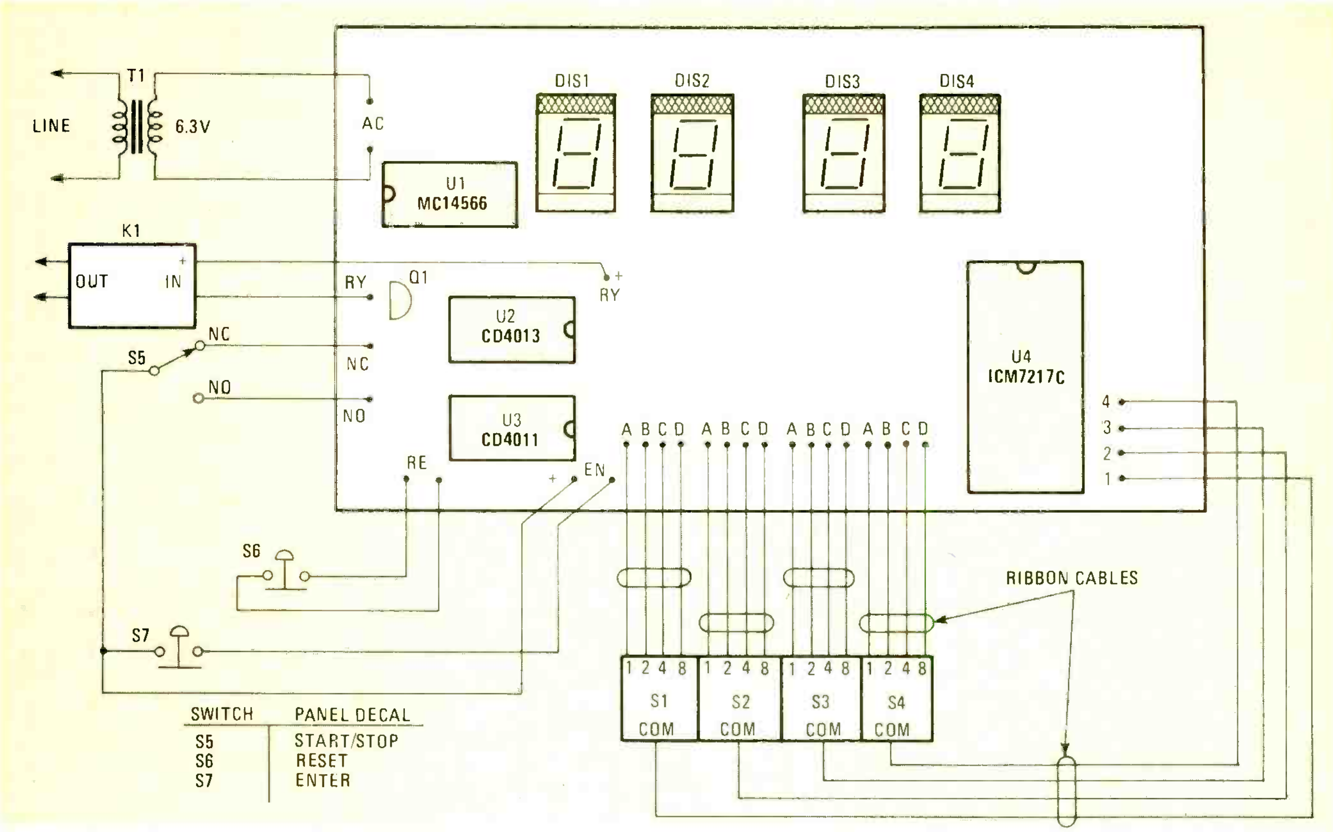
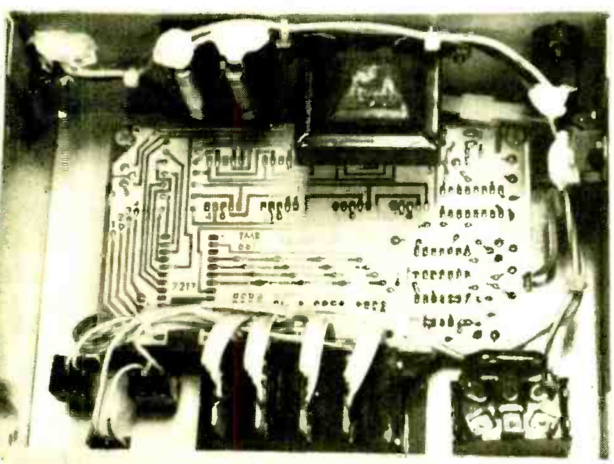


FIG. 6—THE EXTERNAL WIRING DIAGRAM that connects the printed-circuit board to the remainder of the circuit in the Programma V Timer.



WITH CAREFUL PLANNING the wired-circuit elements will drop neatly into the cutout areas in the plastic case used to house the Programma V Timer.

purpose. Refer to Fig. 6 for details. The thumbwheel switches are wired first. We used 4-conductor ribbon cable for the hookup. Cut four 4-in. lengths of cable, and one 6-in. length. Then strip and tin all cable leads. Install the four short lengths on the board first. If possible, arrange each cable so that all "A" leads are the same color.

After that, connect the other ends of the cable to the switches as shown. Note how "ABCD" on the board corresponds with "1248" on the switches. Then connect the longer cable to the board, and connect the other ends to the appropriate switches. Note how "1" on the board corresponds to S1, and so on.

After that come the switches, and this wiring is straightforward. Use 6-in. lengths of 2-conductor ribbon cable for the connections. Install the cables as shown on the board, and wire the switches to the other ends. Be careful with the two EN connections; if you get them transposed, the START-STOP switch, S5, won't work. And finally, connect short lengths of ribbon cable to the AC pads, and both RY (relay) pads. Mark the +RY wire for easier identification later.

The last phase of printed-circuit board construction is to install the integrated-circuit chips. Refer to Fig. 4 for locations, and install them accordingly. Once you are sure that the wiring is correct, you are done with the board. If desired, you can hook up transformer T1, and try the timer out.

Cabinet

Your particular application may allow you to build the project directly into a piece of equipment. For example, you may want to replace an ailing mechanical timer in a microwave oven with this project. However, in any case, it is imperative that the project be housed in some kind of enclosure to protect the user from contacting the circuitry. Understand that electrical safety takes first priority in this project, and that you must build it in an enclosure for protection. The type of enclosure is up to you. Also, the layout of the printed-circuit board and switches is non-critical, and may be arranged to suit your application.

The layout shown for the prototype is ideal for general-purpose applications, and you may wish to duplicate it. We used a 5- × 7- × 3-inch aluminum box, and that size is just large enough to contain the circuitry. A larger box could be used, and that would make installing the circuitry easier. The box was cut down so that the front edge is 2 inches high, while the rear edge is still 3 inches high. That is easily done with a hacksaw. Other than that, it is a simple matter to lay out the components on the box as shown, and drill them to

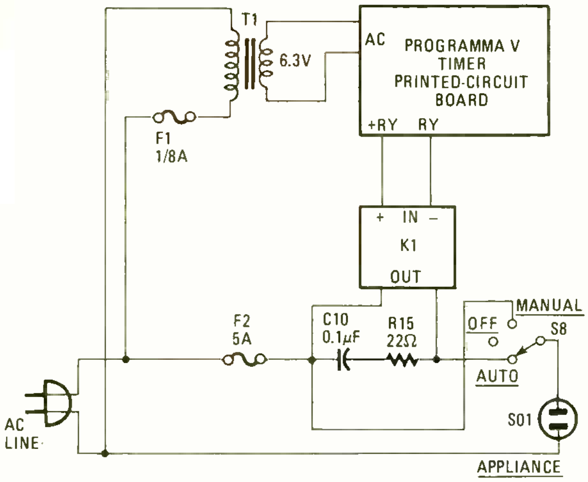


FIG. 7—FINAL HOOKUP is shown here. 117-volt AC line should be fused to protect the unit and the rated limit of the relay's switching contacts.

size. A red bezel is used to cover the LED display for a better appearance. On the rear side of the box, the power cable, fuse holder, transformer, and power connector are mounted. Then on one side, the solid-state relay is mounted. Layout of those parts isn't critical, but be sure not to cover up the mounting holes on the printed-circuit board. Finally, the completed box is spray-painted yellow, and labelled with press-on letters. A coating of clear acrylic spray protects the finish.

The final step is to install the parts in the finished box and wire a few connections. Start by mounting the bezel on the front panel. Then mount four ½-inch spacers for the circuit-board mounting holes. Position the circuit board over the spacers and secure it with hardware. Turn to the switches and mount them in the appropriate holes. After that, mount the thumbwheel switches in place, using self-tapping screws. Carefully dress the excess ribbon cables from the switches neatly against the box. Install the remaining components. When mounting the solid-state relay, rub silicon grease on the mounting surface, and place a mica washer over it. Use a TO-3 power transistor type washer. Then rub some more grease on the washer. Secure the relay to the box using Teflon (TM) screws. That is important as the relay mounting may be connected to one of the relay terminals, and thus carry line voltage. Now wire up the remaining components. Refer to Fig. 7 for details. Connect the line wiring, remember that it can carry up to 5 amperes. Be sure to use at least #18 stranded wire for these connections. Also, it is imperative that all solder connections be good, and that no wire strands contact the chassis.

Safety Check

When you are done with the wiring, a few important safety checks are in order. This procedure is recommended with any device that switches line voltage: Check your work carefully, and correct anything that looks suspicious. Use an ohmmeter to check for continuity from the line-plug prongs to ground. Repeat the continuity checks from connector P1 to ground. If you detect leakage, check your relay wiring; this is a potential trouble spot. Finish up the safety checks by applying RTV (silicon bathtub sealer) to the exposed fuse, P1, and K1 terminals.

Insert the fuses and you are all set to enjoy your Programma V Timer.

Operation

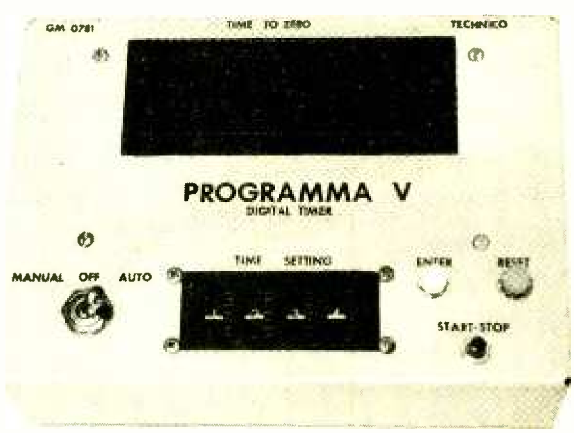
The Programma V Timer is easy to use, because the controls are self-explanatory. Just for the record, though, let's go through the use of the project to insure that it is working properly.

Connect the project power plug to a convenient outlet. The display should blink, and then go out. Connect an appliance, such as a table lamp to P1. Switch the MANUAL/OFF/AUTO switch S8 through its positions, and note that the appliance turns on only in the MANUAL position. Return the switch to the AUTO position. Set the thumbwheel switches (S1-S4) to 0100. Press ENTER pushbutton S7, and the display should indicate 0100. Press RESET pushbutton S6, and note that the display goes out. Press ENTER (S6) again, and then press START/STOP (5). The appliance should turn on, and the display start counting; 100-59-58-57 and so on. Press START/STOP (S5) again, and note that the appliance turns off, and that the display stops counting down. Press START/STOP (5) again to resume counting. At the end of the one-minute time period, the appliance should turn off, and the display go off.

That's all there is to it. If you run into trouble, note that reset problems can be caused by U3, number entry and display problems by U4, and START/STOP switch problems by U2. If the timer does everything but count down, the problem could lie with U1. In general, use that basic guide and refer to Figs. 1 and 2 to pinpoint any troubles you might have.

Some tips for the use of your new timer. When you are finished using it, and don't expect to be using the project for a lng time, set the MANUAL/OFF/AUTO switch S8 to OFF. That will protect the appliance in the remote chance that something might go wrong with the project.

There are several shortcuts you can take when entering time periods with the thumbwheel switches. First, if you decide to change the value while the timer is in operation, simply set the new time, and press ENTER (S6). The project will start counting from the new value. If you must stop the timer immediately, press RESET (S6); that is the project's "panic button." If you need the full time period of 59 minutes and 59 seconds, there's no need to set the switches. Note that this shortcut will work ony when the display is blank: Simply press the START/STOP switch (S5), hold, and release. The display will automatically be programmed for 5959, and all you have to do is press START-STOP (S5) to begin the countdown. That shortcut might be useful in an application where several time periods are required. **SP**

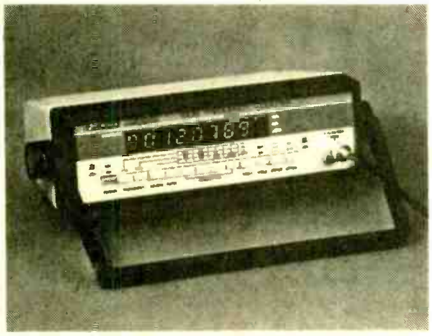


HERE'S THE ASSEMBLED unit as wired by the author. As suggested earlier, you may want to incorporate the Programma V Timer with some other project.

NEW PRODUCTS

MULTIFUNCTION COUNTER model *1805*, measures frequencies from 5 Hz to 80 MHz. Resolution may be selected from .1 Hz for frequencies below 10 MHz to 1 Hz resolution for frequencies to 80 MHz.

The period mode can be used to measure low frequencies from 5 Hz to 2 MHz accurately. The totalize mode counts individual events from 0 to 99,999,999 plus overflow LED. That mode is helpful in applications where a specific number of cycles occurs, such as gated tone bursts.



CIRCLE 311 ON FREE INFORMATION CARD

For lessened susceptibility to noise and undesirable high-frequency components, a front-panel switchable 100-kHz lowpass filter is incorporated in the counter. All operating modes, resolution ranges, and functions are front-panel selectable. The model *1805* incorporates a switchable ×10 attenuator, HOLD switch to freeze the display at the present reading, and a RESET switch to clear the display and initiate new measurement.

The model *1805* has a suggested price of $290.00.—**BK Precision, Dynascan Corporation,** 6460 West Cortland Ave., Chicago, IL 60635.

CAR AMPLIFIERS, model *HPA-51* and model *HPA-71* (shown) are high-power, low-distortion car-stereo amplifiers, designed to be trouble-free. Both models feature self-protection circuits such as a speaker transient-protection relay, output short-circuit protection, and output thermal-overload protection. Both have provision for low-level or high-level inputs.

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The model *HPA-51* produces 100 watts total (50 watts per channel) at 0.5% THD or less from 20-20,000 Hz into a 4-ohm load. Its suggested retail price is under $200.00.

The model *HPA-71*, designed to appeal to the higher-power performance enthusiast, produces 140 watts total (70 watts per channel) at 0.5% THD or less from 20-20,000 Hz. Its suggested retail price is under $270.00.—**Concord Electronics,** 6025 Yolanda Avenue, Tarzana, CA 91356.

MICROPHONE, the model *SP19*, is designed to provide a high level of performance and is suitable for a wide variety of applications, especially home reel-to-reel and cassette recording. It is also useful for general-purpose use in schools, hospitals, churches and other public-address applications, musical groups, etc.

The model *SP19* also features a pop-resistant, multi-stage steel-mesh grille assembly, an on-off switch, a 15-foot permanently attached cable, and a professional accessory swivel adaptor. It is built to withstand rough treatment.

The model *SP19* is available in two versions: *SP19H-C* (high impedance, with a ¼-inch phone plug at the cable's equipment end) and *SP19L-CN* (low impedance, with a

CIRCLE 314 ON FREE INFORMATION CARD

professional 3-pin connector at the cable's equipment end). The suggested retail price is $48.00 for each model.—**Shure Brothers, Inc.,** 222 Hartrey Avenue, Evanston, IL 60204. **R-E**

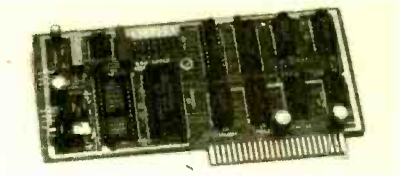
TEMPERATURE PROBE, model *15*, offers fast response time, Fahrenheit or Centigrade temperature measurements with ±2°C nominal accuracy. Portable and plug-in adaptable to any analog or digital multimeter

CIRCLE 315 ON FREE INFORMATION CARD

with 10 megohms or more input impedance, the battery-operated model *15* is suited for many industrial-, commercial-, or service-oriented temperature-measurement applications.

The fast-responding silicon sensor provides temperature measurements ranging from −58°F to 302°F, −50°C to 150°C with ±2°C accuracy over 0°C to 100°C. Output voltage is 1 millivolt DC per degree, F or C. The model *15* has a life of approximately 3500 hrs when powered by two 1½-volt "AA" alkaline batteries. There is a battery-check function that lets the user know the status of the battery instantaneously. A single switch provides °C, °F, or battery-check/OFF functions. The model *15* is priced at $75.00.—**Triplett Corporation,** Bluffton, OH 45817.

SPEECH SYNTHESIZER, the *SSB-APPLE*, is a plug-in board that gives *Apple II* users an easy and economical way to add speech capabilities to their systems.



CIRCLE 313 ON FREE INFORMATION CARD

The board can be used for language instruction, speech therapy, video games, experiments in speech synthesis, and many other applications. Its 1200-word vacabulary is the largest one presently available for the *Apple II*.

The 2.75 × 6-inch board is based on Texas Instruments' model *TMS52220* high-performance speech-synthesis device; it plugs into any spare slot of the *Apple II*.

The *SSB-APPLE* has an on-board audio amplifier, which provides 325 mW to drive either the built-in *Apple II* speaker or any external 8-ohm speaker. A socket is also available to expand the unit's voice-synthesis memory by adding a TI TMS6100 chip. Included with the board are a 5¼-inch floppy diskette containing the 1200-word dictionary (in digitized form), a complete instruction manual, and a stand-alone high-quality speaker.

The *SSB-APPLE* is priced at $195.00.—**Multitech Electronics, Inc.,** 195 W. El Camino Real, Sunnyvale, CA 94086.

TURNTABLE, model *8000A*, has an advanced linear motor which contributes to its high signal-to-noise ratio, elimination of tracking error, low wow and flutter, and neutral skating force.

The model *8000A* also features a polymer graphite tangential-tracking tone arm with a direct-induction linear motor for improved tracking ability. An opto-electronic detector cell senses tracking error and corrects the tone-arm position. The stable hanging rotor eliminates "platter wobble" and the quartz-

CIRCLE 318 ON FREE INFORMATION CARD

PLL (*P*hase-*L*ocked-*L*oop) system, combined with frequency-generator reference, helps maintain accurate motor speed. A double isolation suspension system minimizes acoustic feedback and susceptibility to vibration. The tone arm can be operated by push-button control even when the dust cover is closed.

(Continued on page 98)

DISPLAY CONTROLLER with Frequency

POSSIBLY EVERY AUDIO ENTHUSIAST HAS WANTED A FREQUENCY counter. For tasks such as aligning a tape deck or tuning speakers, it is crucial to know the frequency of the test signal with greater accuracy than that provided by the typical signal-generator dial. But, of course, commercial meters can cost hundreds of dollars. The counter presented here offers the builder an interesting alternative. It is crystal-referenced for stability, and the normal gate time of one second gives ± 1 Hz resolution, from 1 to 999,999 Hz. It can be built from a good junkbox for about $40. But besides being a handy tool, the project can form the basis for a microcomputer-oriented counter/display system, because it is based on National's 74C912 decimal display controller integrated circuit. By gaining familiarity with that chip, you'll be able to easily add a six-digit display to any microcomputer (μC) without having to bother with complicated LED driver subroutines or designing a video interface.

The basic idea

At a general level, it is best to distinguish the frequency-counter and display functions. Figure 1 shows the block diagram. There are no surprises in the frequency-counter section, except perhaps for the fact that the digit latch outputs are bused. Either the internal sinewave oscillator or an external input is applied to the comparator, which converts that input signal into suitable pulses. The gate logic combines the input with the time base to produce three signals. First, it enables one-second or one-tenth-second bursts of the input frequency to advance the binary-coded decimal (BCD) counters. Second, the *latch* signal stores the resulting BCD count from the counters in the digit latches, And third, the *reset* signal clears the counters in preparation for the next gated input burst.

The display section consists of the 74C912 display controller (U1) and the digit address on a 4-bit data bus and write logic. The controller, U1, only accepts one BCD number at a time over the data bus. So the *address* inputs (K1-K3) are needed to tell the controller for which of the six display digits the current BCD number is intended. While incrementing and providing the controller with digit register addresses, the address logic simultaneously decodes digit select strobes which enable the frequency-counter digit latches corresponding to the addressed registers to sequentially place their data on the bus. Then, a *write* pulse latches the data into the controller register for that digit. The controller takes care of the rest. It contains all the circuitry for multiplexing a six-digit, eight-segment LED display. The eighth segment is the decimal point, which isn't used here.

Display circuit

Turning now to the actual schematic diagram (Fig. 2C), let's look first at the heart of the circuit, the 74C912 display controller, U1. That CMOS device is intended for +5V operation and all inputs are TTL-compatible. The controller sends numbers to the display by circulating them out of its internal registers and multiplexing them through a 4-bit to 7-segment decoder. To drive the display, it has seven outputs for LED segments *a-g*. Each segment output is wired to all seven corresponding LED segments through current-limiting resistors, R1-R7. Since up to 100 mA is available from each segment output, it may be necessary to increase resistance to protect other common-cathode displays than those specified.

As the controller, U1, segment outputs change, the digit transistor drive outputs D1-D6 (Fig. 2C) go high sequentially, turning on Q1-Q6 in turn, thus grounding each common cathode of the displays and lighting a digit. For example, to display the number 000,031 the controller first raises segment outputs b and c, then briefly turns on Q1, to flash the "1." After displaying the "1" it raises segments a, b, c, d, and g, then turns on Q2 to flash the "3." To display the zeroes, all segments except g are raised, then Q3-Q6 are "strobed." That sequence occurs at about 50 Hz, so the eye sees a continuous numerical display without flicker.

Pin 8 of U1 (Fig. 2C), *oscillator scan enable* (-OSE), must be low (tied to ground) to enable the display to constantly refresh itself. Pin 16, *segment output enable* (-SOE), must also be low to enable the display. If -SOE goes high, the segment outputs go into a tri-state (high-impedance) condition, which will save power. The 74C912 data sheet suggests driving -SOE with a variable pulse-width oscillator, to obtain a brightness control. Pin 1, *-chip enable*, must be low, or no data can be written into the U1 controller's registers.

Now we have to see how numbers get into the controller registers so it can display them. The BCD data is set up on inputs A-D, with A being the least significant bit (LSB). "BCD data" just means that the four bits at most represent the number 9 (1001) rather than 15 (1111, in Hexadecimal).

The 74C912 chip (U1) is designed to be easy to address

This 6-digit frequency and event counter offers excellent performance and a bus-oriented design for easy interface with microcomputers!

Counter

STANLEY JUNGLEIB, WA6LVC

and write to. Each digit register can be written to randomly; but conveniently, it turns out that the sequence required to increment digit addresses and write into the internal registers is simply the four-bit sequence, 0000, 0001, 0010, 0011, ... through 1011. The three most significant bits (MSB's) provide the address inputs to K1, K2, and K3 while the least significant bit (LSB) toggles to produce the necessary *-write* pulses.

Looking at the addressing circuitry in more detail as show in Fig. 2B, U2 is a CMOS 555-type timer, U2 set up to oscillate at about 1500 Hz. It clocks U3, a 4516 synchronous binary counter. A *synchronous* counter is required so that all four outputs change state simultaneously (rather than in "ripple" fashion). Tying pin 10 high programs that counter, U3, to increment, rather than decrement. Assuming that the binary counter ouput on Q1-Q4 is 0000, the -WE pin (U1, pin 2 of Fig. 2C), is low, so that data can be written into the digit register corresponding to address 000, which is Digit 1. When U3 receives the next clock pulse from U2, (Fig. 2B), the counter state increments to 0001. That causes the -WE pin to go from a low to high state, latching whatever data is present on the A-D inputs into the internal register for Digit 1. Then the counter increments to 0010, preparing Digit 2. Again, when the LSB goes to 1, at count 0011, data is latched into the Digit 2 register, and so on. After the counter reaches 1011, which writes data to Digit 6, the controller ignores the unneeded sequence numbers 1100-1111, which means that you don't have to bother resetting the counter.

U4 Digit latch Decoder (see Fig. 2B) arranges for the desired data to be placed onto the data bus at the right time. In this project the data is from the frequency counter, but it could as easily be from any other set of latches. The three counter address lines also drive the decoder inputs, while the LSB line strobes the decoder Inhibit (I) input (U4, pin 6), to synchronize the decoder to the counter. When I is low, the decoder transfers the low on its input, pin 3, to one of its

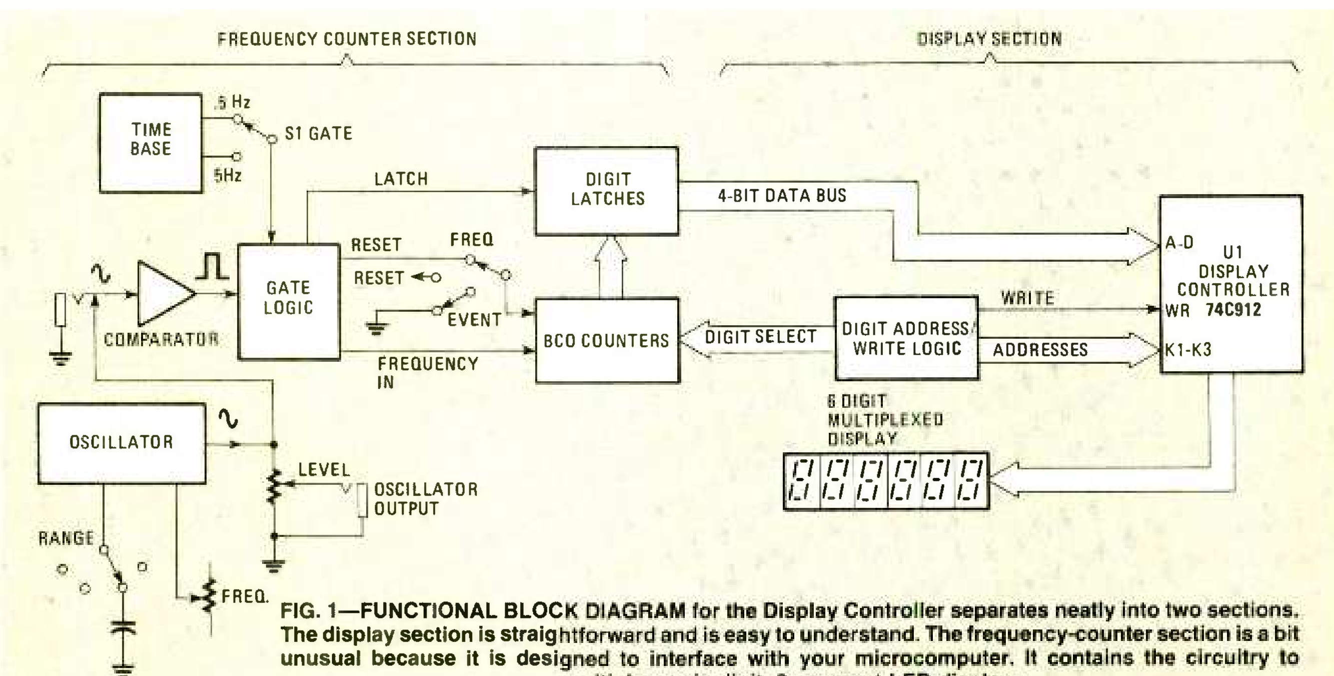


FIG. 1—FUNCTIONAL BLOCK DIAGRAM for the Display Controller separates neatly into two sections. The display section is straightforward and is easy to understand. The frequency-counter section is a bit unusual because it is designed to interface with your microcomputer. It contains the circuitry to multiplex a six-digit, 8-segment LED display.

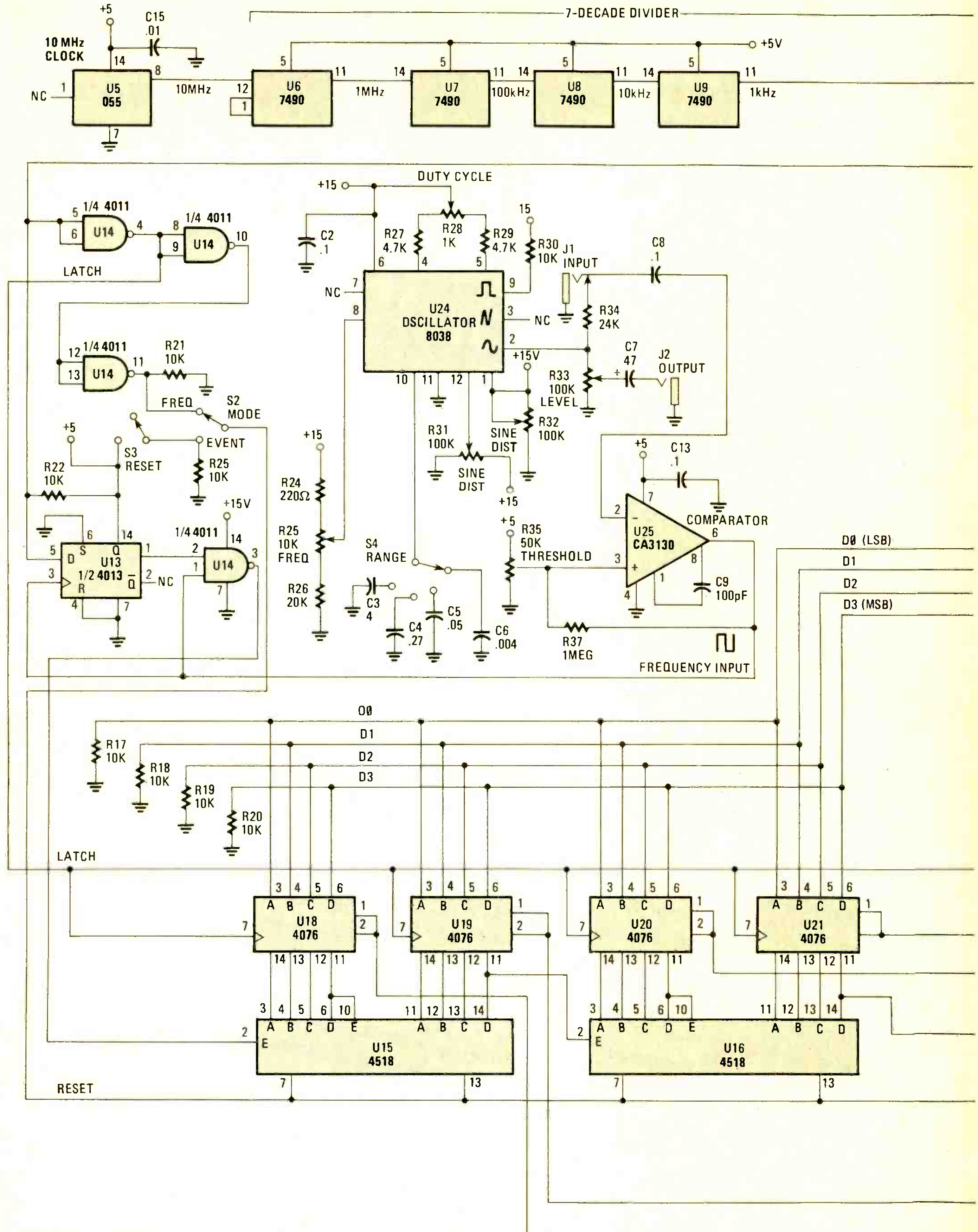


FIG. 2A—THE SCHEMATIC DIAGRAM for the Display Controller appears on three consecutive pages of this article. It is not that complex, but rather, the diagram was stretched out for rapid scanning and understanding. The layout of the functional sections of this schematic in no way suggests physical layout on the circuit board.

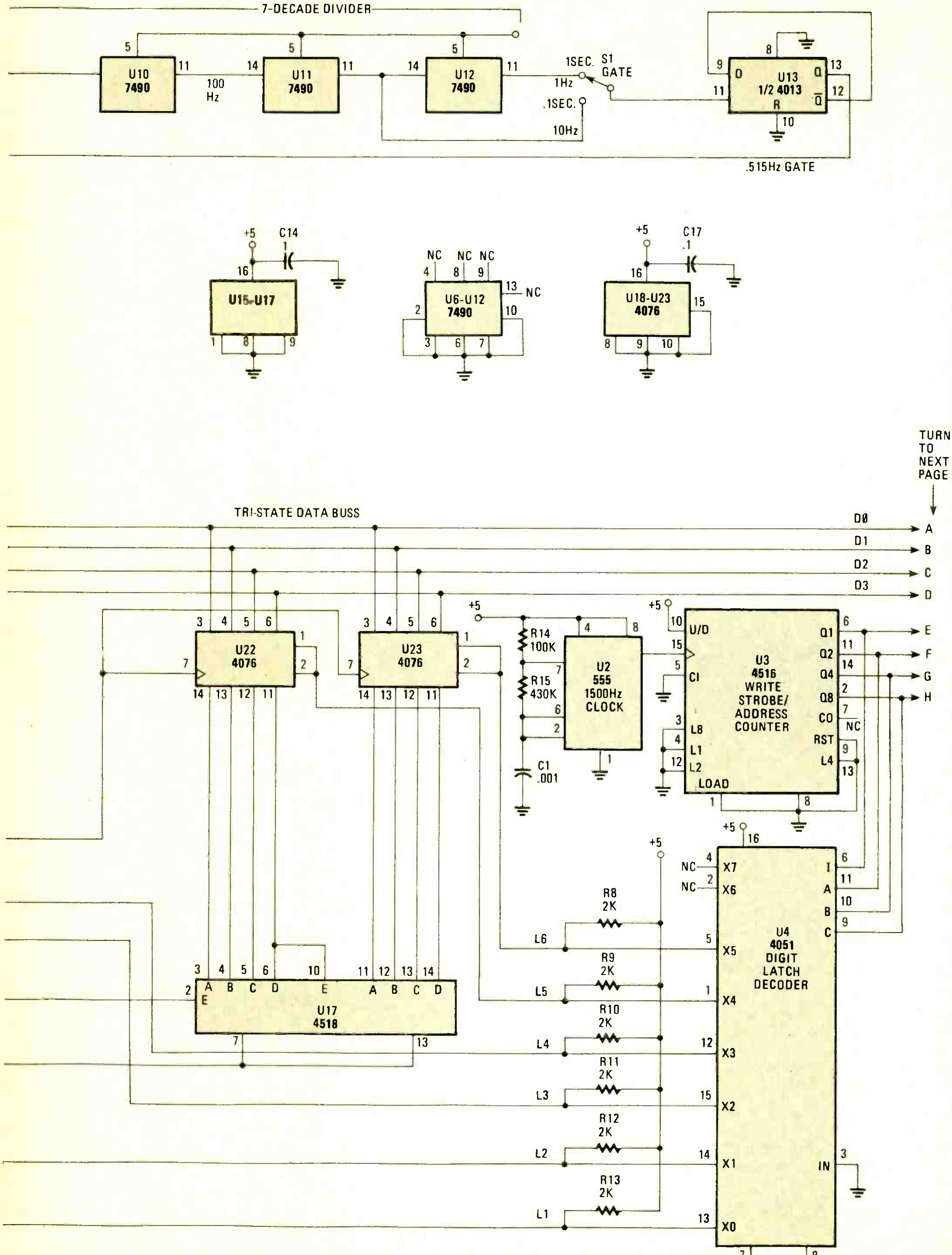


FIG. 2B—SCHEMATIC DIAGRAM for Display Controller (Continued)

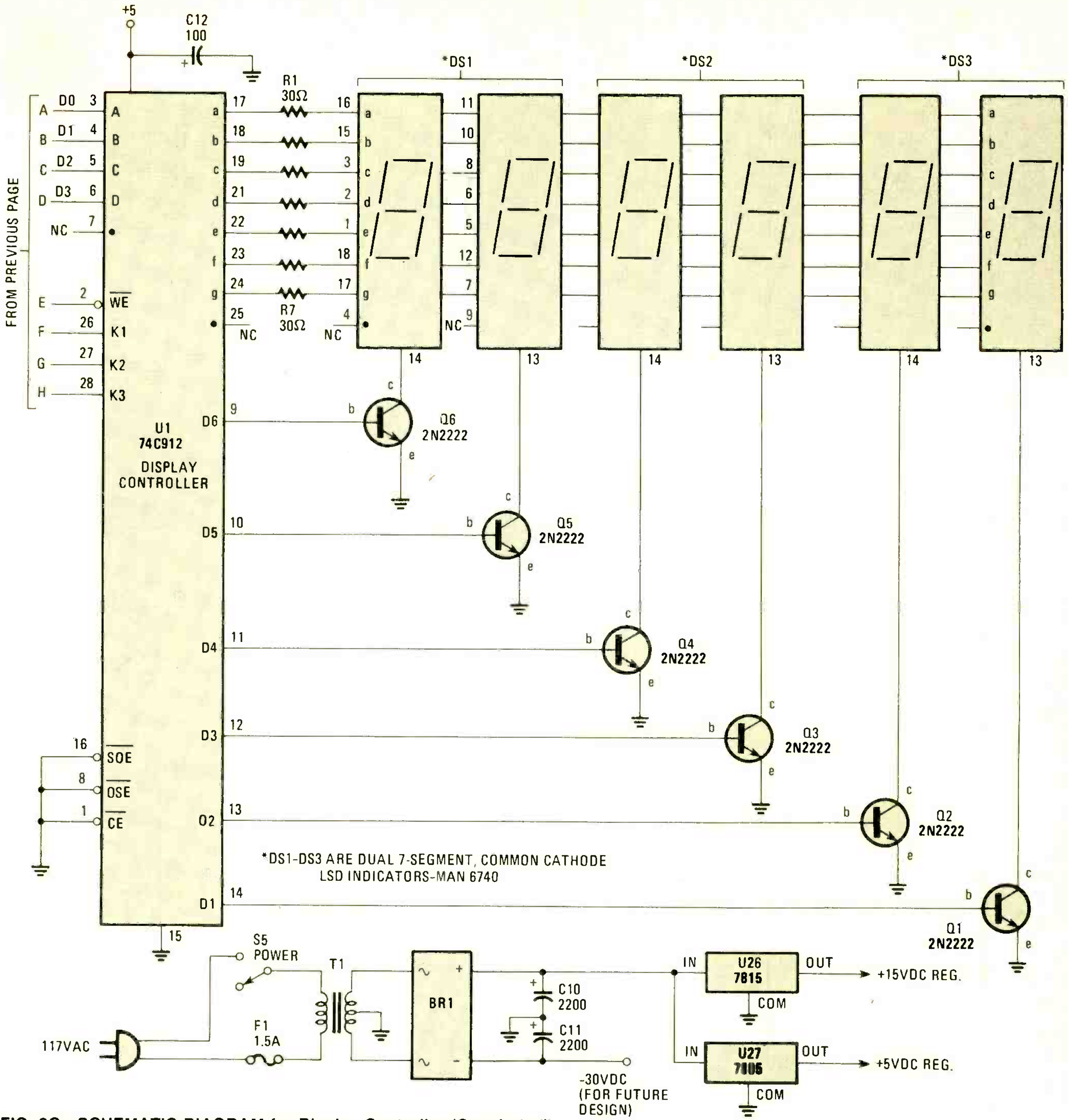


FIG. 2C—SCHEMATIC DIAGRAM for Display Controller (Concluded)

outputs, XO-X7, as determined by the address provided to inputs A-C (U4, pins 11, 10 and 9). Assuming again that the output of counter U3 is 0000, the I line is low, so decoder output XO is forced low from its normally high state. That negative-going pulse, L1, causes latch U18 in the frequency counter section (see Fig. 2A) to place its data for Digit 1 on to the data bus. When the counter increments to 0001, the data is latched, as mentioned above. The decoder I input is now high, so the XO output is inhibited and returns high. When the counter increments to 0010, of course, the sequence is repeated for decoder output X1, pulse L2, and U19, then again for the remaining latches.

Frequency counter circuit

For accuracy and stability, the frequency counter is referenced to U5 (see Fig. 2A), a 10-MHz crystal-based TTL oscillator. 7490's were used for U5 thru U12 for the seven-decade divider chain, because the author had them in his junkbox. Due to the high speed of operation, U6 *must* be an LS or standard TTL counter. U7-U12 can be CMOS (74C90) for lower power consumption if you add a 10-K pull-up to +5V at U6, pin 11.

Switch S1 selects the 1- or 10-Hz time base applied to one section of U13 (see Fig. 2B), which is configured as a "T" flip-flop. The T flip-flop has the handy property of dividing its input exactly by two, so its output is a perfect squarewave at .5 or 5 Hz. Those frequencies are chosen for gating the frequency counter because they are high (or low) for exactly one or one-tenth second.

The rest of U13, and part of U14 (see Fig. 2A and 2B) form the gate-synchronizer circuit, which prevents the LSD from jittering between two values. When the gate goes high on the

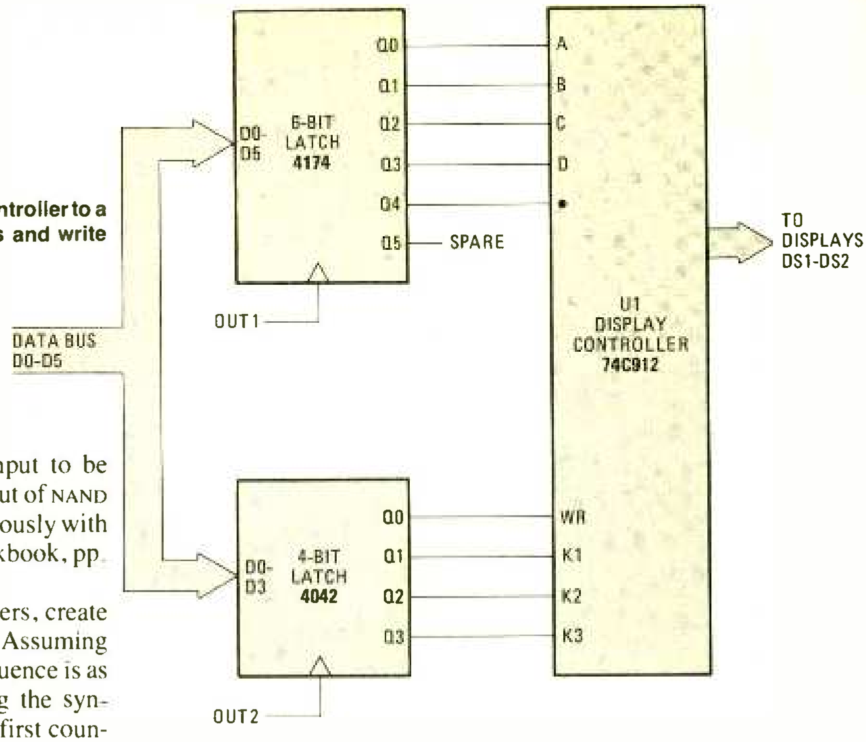


FIG. 3—HERE IS ONE WAY to interface the Display Controller to a microcomputer. This circuit provides the addresses and write strobes from a latch.

D input, the Q output remains low until the input to be counted on U13-pin 3 goes positive. Thus the output of NAND gate U14-pin 3 goes low and returns high synchronously with complete input cycles (see *Lancaster*, CMOS Cookbook, pp 283-5).

The other three sections of U14, wired as inverters, create the control signals for the counters and latches. Assuming that S2 is set for FREQUENCY mode, the control sequence is as follows. The *gate* on U13-5 goes high, enabling the synchronizer, thus U14-pin 3 goes low, clocking the first counter in U15. The more significant digits ripple down the counter chain to the sixth digit. After one-tenth or one second, *gate* goes low, inhibiting the synchronizer. The A-D outputs of each counter hold a valid BCD count. As the *gate* goes low, the output of the first inverter U14-pin 4, *latch*, goes high, causing U18 through U23 to latch the data from each counter. Owing to the propagation delay of the series inverters U14-10 and U14-11, the *reset* signal goes high just after the *latch* signal. *Reset* clears the counters in preparation for the next measurement period.

Switching S2 to EVENT mode pulls down the *reset* line through R23, so that the counters can be reset by momentarily closing S3.

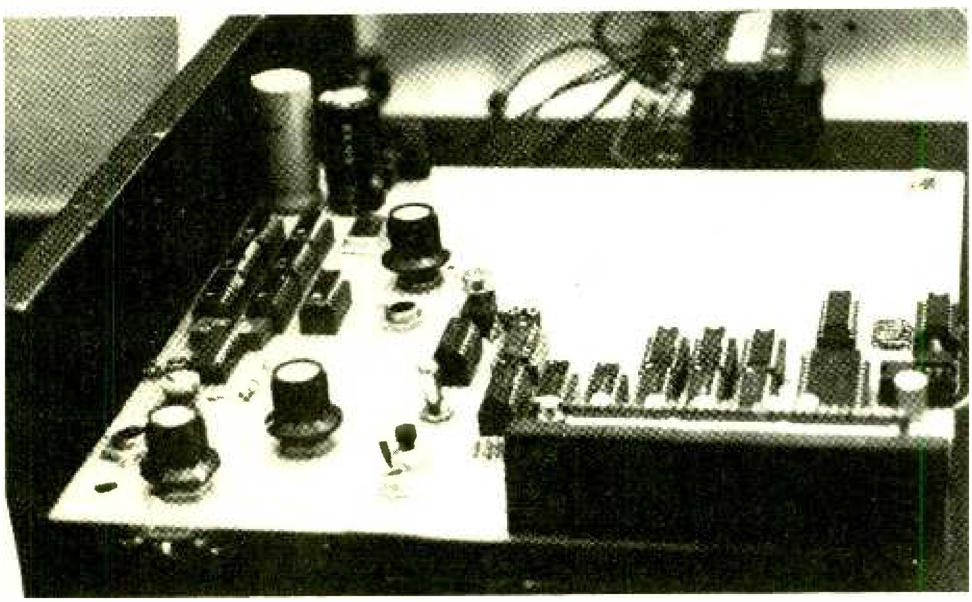
Oscillator and comparator circuit

The internal oscillator U24, is a simple 8038 circuit with four overlapping frequency bands. The capacitor values shown give a 1 to 24,000-Hz range, but that is easily changed for your uses. Up to 1 VRMS is available through LEVEL pot R33 and DC-blocking capacitor C7. You may want to tap the other waveforms, or increase drive capability by adding an amplifier or buffer.

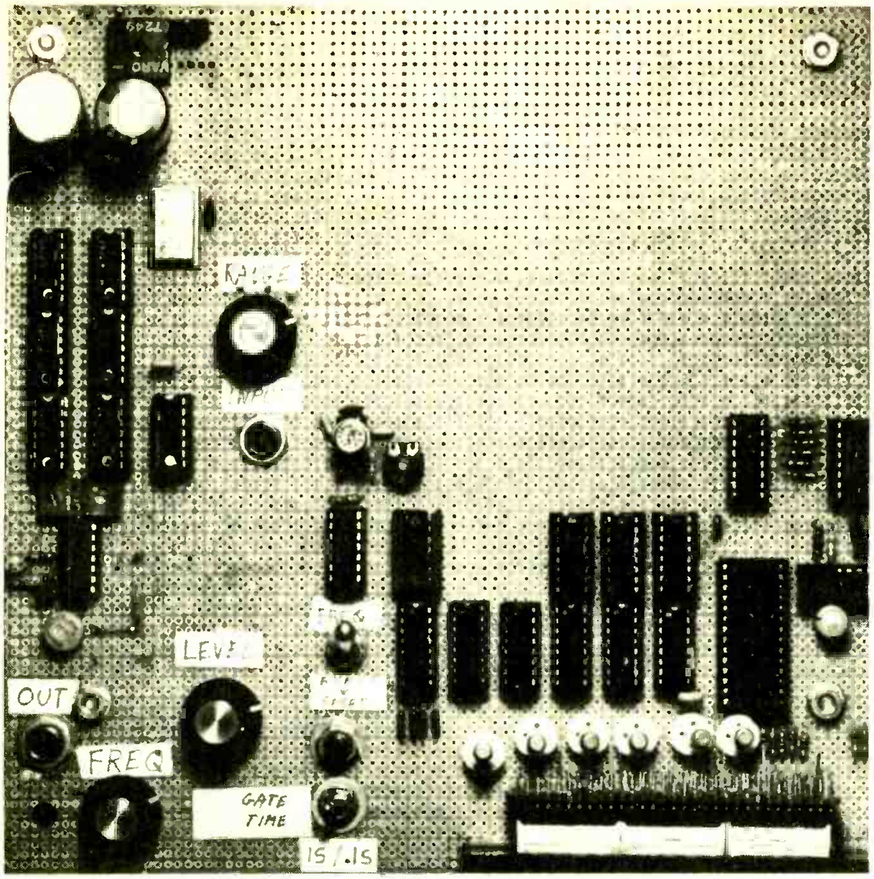
Comparator U25 uses a CMOS 3130 op amp in a popular circuit, which squares up the oscillator output or other external input through J1. It is important not to overdrive the comparator; otherwise it glitches and doubles the count. R34 was chosen to provide an optimum 0.9 VRMS. To control high-level inputs, you may want to add an input potentiometer.

Construction

Try to keep the high-frequency leads in the time-base section as short as possible. The remaining circuitry is not sensitive. The prototype was easily built with wire-wrap. Regarding that technique, two points of advice can be offered: First, wire power ground first to each socket, and verify every ground and power pin. Second, to save time, use a "just-wrap" pencil for wiring power, ground, and the buses; but also turn a minimum of ten wraps and verify every connection with an ohmeter, because those tools do not



THE AUTHOR was not looking for design awards when he laid out the Display Controller perfboard. Just as well, because there's plenty of room leftover for the addition of other circuit elements that may be added by those who find the project suitable. Computer buffs, in particular, will find the computer-bus tie-in a fantastic feature.



The CIRCUIT BOARD appears so simple, and it can be when an orderly layout of chip sockets is made. Wire-wrapping is hidden under the board. It is suggested that different colored wires be used, so that wire chasing during troubleshooting procedures will be relatively simple.

completely strip the wire, sometimes causing problems.

Any power supply can be used that provides +15V for the oscillator, and +5V for everything else. With all digits set to "8," the prototype draws 470 mA from +5V, so use at least a 1A regulator and plenty of heat-sinking. Provisions were made in the bridge rectifier circuit for negative regulated supplies should future design additions require them.

Testing and trims

Basically, you'll need a scope to trace the digital stages out, and to check comparator output. Generally, use the one-tenth second gate-time setting when checking for the *gate, latch,* and *reset* signals.

In the oscillator section, R28 is trimmed for a symmetrical sinewave output, then R31 and R32 alternately adjusted to trim-up the sine shape. In the absence of a scope, those trimmers can be adjusted surprisingly well by ear, by listening for the least amount of harmonics—in other words, the dullest tone. After the oscillator is trimmed, adjust comparator threshold R35. That is not critical; the voltage on U25-pin 3 should read from +0.5 to +1.1V.

Use

Operation is simple. With S2 set to FREQ and S1 set to 1s, the counter measures and refreshes the display every second. External inputs to be measured must be held steady throughout the measurement period.

When adjusting the oscillator, a 1-sec update can be frustrating when 1-Hz resolution isn't needed. So switch S1 to .1s and multiply the reading x10.

To total, switch S2 to EVENT and initially hold S3 RESET until the display reads all O's. Switching gate time between 1 second or .1 second won't affect the total, just the display-refresh rate.

Microprocessor applications

Building the frequency counter and getting it working is a good lesson in CMOS hardware. But if you understand how that hardware works you are also most of the way to programming a μC to drive the Display Controller. You know, for example, that you only need to provide the digit address and the data, then the write strobe in sequence. Now with a small program your little μC can display big numbers, without tying up the family TV.

It should be mentioned that although this project uses the 74C912, it could as easily have used its compatible sibling, the 74C917, which can display hexadecimal digits. The '917 would be preferred, for example, if you wanted to adapt the display to indicate register contents of μCs.

There are two basic approaches to interfacing the Display Controller to the computer. In all cases, the data to be displayed is latched off of the μC's data bus. The difference between approaches is that it is possible either to: 1) also provide the addresses and write strobe from a latch, or 2) connect the controller address inputs to the μC's address bus, and use system-generated -WR and -CE signals. Each μC has its own quirks, so you'll have to decide which approach suits your system.

It may help you make the decision if you anticipate the basic difference in the programs required for each approach. See Fig. 3, which depicts a basic implementation with two latches, wired as Output Ports 0 and 1. Port 0 outputs the three address bits and write strobe. Five data bits are needed for the digit and decimal point data through Port 1. If the decimal point is never to be used, you could use a four-bit latch, or combine both functions into a single eight-bit latch. It is easy to see the similarity between that configuration and the hardware already discussed. On power-up, the program should clear the display by sending OH to all display registers. That is easily done by outputting OOH to both ports, then incrementing Port 0 from 0000 through 1011 or 1111. To display numbers, the program would have to move each digit from its register in the μC through Port 1, in between each 0 to 1 (even-to-odd) transition of the address/write count through Port 0.

Fig. 4—ANOTHER APPROACH connects the controller's address inputs to the microcomputer's address bus, and uses the computer's system generated write enable and chip/enable signals.

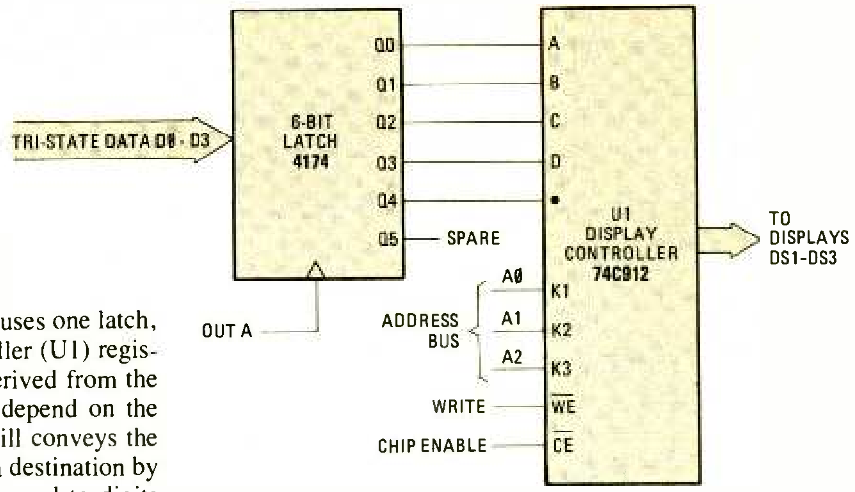


Fig. 4 shows the second approach, which uses one latch, uses the μC address bus to select the controller (U1) registers, and -WR or -CE lines which can be derived from the system I/O and *write* signals (which will depend on the specific processor). In this system Port A still conveys the data, while the program selects the digit data destination by specifying Output Ports 0 - 5 (which correspond to digits 1-6).

For simplicity those examples separate the frequency counter and controller. But the whole unit can also be interfaced to a μC, by replacing the digit decoder signals (from U4) to the digit latches U18-23, with *input* Port strobes from the μC. The microcomputerized counter would be able to conduct impressive feats. For example, after measuring and indicating the frequency from some voltage-controlled oscillators (VCOs), it could decide to correct or shift the VCO frequencies by changing a control voltage output through a digital-to-analog converter (DAC). This would be a way to automatically monitor, tune, and ultimately, program a modular music synthesizer. **SP**

PARTS LIST FOR DISPLAY CONTROLLER

SEMICONDUCTORS

BR1—Bridge rectifier module, 100-PIV, 2-A or better
DS1-DS3—MAN6740 dual 7-segment, common-cathode display
Q1-Q6—2N2222 NPN transistor
U1—74C912 Display controller integrated circuit (see text)
U2—CA555 CMOS timer integrated circuit
U3—4516 divide-by-16, binary, up-down counter (synchronous, presettable) integrated circuit
U4—4051 1-of-8 (multiplexer) switch integrated circuit
U5—10-MHz TTL clock module (Jameco OSC-10.000)
U6—7490 or 74LS90 divide-by-ten decade counter integrated circuit
U7-U12—7490 or 74LS90 or 74C80 divide-by-ten decade counter integrated circuit
U13—4013 dual D flip-flop integrated circuit
U14—4011 quad 2-input NAND gate integrated circuit
U15-U17—4518 dual synchronous divide-by-ten counter integrated circuit
U19-U23—4076 quad D register, tri-state integrated circuit
U24—8038 precision waveform generator integrated circuit
U25—CA3130 CMOS operational amplifier (comparator) integrated circuit
U26—7815 voltage regulator, + 15-volts integrated circuit
U27—7805K voltage regulator, +5-volts

RESISTORS

All fixed resistors are ¼-watt, 10% units unless otherwise noted.
R1-R7—30-ohm
R8-R13—2000-ohm
R14—100,000-ohm
R15—430,000-ohm
R16-R23, R30—10,000-ohm
R24—220-ohm
R25—10,000-ohm, linear potentiometer
R26—20,000-ohm
R27, R29—4700-ohm
R28—1000-ohm, trimmer potentiometer
R31, R32—100,000-ohm trimmer potentiometer
R33—100,000-ohm potentiometer
R34—24,000-ohm
R35—50,000-ohm trimmer potentiometer
R36, R37—1 Megohm

CAPACITORS

C1—.001-µF, disc
C2, C8, C13, C14, C16, C17—.1-µF disc
C3—4-µF (see text)
C4—.27-µF (see text)
C5—.05-µF (see text)
C6—.004-µF (see text)
C7—47-µF, 12-WVDC electrolytic
C9—100-pF disc
C10, C11—2200-µF, 35-50-WVDC electrolytic
C12—100-µF, 12-WVDC electrolytic
C15—.01-µF disc

SWITCHES

S1, S2—SPST toggle
S3—SPST, normally-open, momentary pushbutton
S4—SP4T rotary, make-before-break
S5—3-A, power, toggle

ADDITIONAL PARTS AND MATERIALS

F1—1-A, slow-blow type, fuse
J1—Single-circuit, shorting, phone jack
J2—Single-circuit, non-shorting, phone jack
P1—AC plug with power cable
T1—Power transformer: 117-VAC primary winding; 30-36-VAC, 2.5-3.0-A secondary winding
Metal cabinet, box or chassis, 8½ × 8½-in. perfboard, knobs, fuse holder, transistor sockets, IC sockets, standoffs (1¼-in. minimum), fleaclips, hardware, solder, wire, etc.

(Continued from page 89)

The model *8000A* has a suggested retail price of $650.00.—**Phase Linear,** 4136 North United Parkway, Schiller Park, IL 60176.

MOBILE TRANSCEIVERS, model *TR-7950* (shown) and model *TR-7930* are 2-meter mobile transceivers identical in features except for RF output. The output of the model *TR-7950* is 45 watts, while that of the model

CIRCLE 310 ON FREE INFORMATION CARD

TR-7930 is 25 watts. Both models offer a large, easy-to-read LCD display, 21 multi-function memories, automatic offset, programmable priority channel, memory and band scan, long-life lithium-battery memory backup (estimated 5-year life), and built-in 16-key autopatch. Accessories include an optional 3-frequency sub-tone unit, with keyboard-selectable subtones.

The suggested retail price of the model *TR-7950* is $300.95; for the model *TR-7930*, it's $359.95.—**Trio-Kenwood Communications, Inc.,** 1111 West Walnut St., Compton, CA 90220.

DYNAMIC RANGE EXPANDER, model *4BX,* offers 20 dB of noise reduction and three separate bands of expansion for high, mid, and low frequencies. A fourth band recaptures the stored, previously unreachable audio signals, the omission of which has

CIRCLE 312 ON FREE INFORMATION CARD

been responsible for the lack of presence or dullness common to much recorded music. It restores the transients that are clipped during the recording or broadcasting processes.

A hand-held, digital, wireless remote "Logi-control", which is supplied with the model *4BX,* allows the user to set volume and degrees of expansion, transition, and impact-restoration levels precisely from the listening position. The actual tracking of the music signal is displayed on four horizontal rows of program-dependent yellow and red LED's, which show the amount of expansion.

The model *4BX* is $3\frac{1}{2} \times 17\frac{15}{16} \times 12\frac{1}{4}$ inches, and comes with 19-inch standard rack-mount hardware for its faceplate. An optional wood side-kit will be available. The model *4BX* is priced at under $1000.00.—**dbx, Inc.,** 71 Chapel Street, Newton, MA 02195.

DMM, model *3500,* is a hand-held, 3½-digit, 22-range digital multimeter that uses CMOS LSI circuitry to provide autoranging, autopolarity, overrange, and low-battery indication in a compact tester that the user will find easy to operate.

The audible continuity tone and overrange buzzer-alarm offer additional convenience for laboratory, design, or field-service testing. A zero-adjustment memory button can be used to make different measurements. Overload protected (fused) up to 100-volts DC and 750-volts AC and up to 600-volts on the resistance and current ranges.

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Ranges are: DC volts: 0-1000 volts DC in five ranges; AC volts: 0-600 volts AC in four ranges; low-power ohms: 0-2 megohms in four ranges; high-power ohms: 0-2 megohms in five ranges; AC and DC current: 0-10 amps in three ranges. Frequency response is 40-500 Hz on all ranges. Basic DC accuracy is 0.25%.

The model *3500* is priced at $140.00.—**Triplett Corporation,** One Triplett Drive, Bluffton, OH 45817. **SP**

(Continued from page 16)
U4. These buffers could supply current drive for operating solid-state relays, switches, and sensitive electromechanical relays from the One-By-One Sequencer.

Other Timing Possibilities

Clock time periods can be changed by using a different RED circuit chips for U2 following the 60-Hz generator, U1. Other times can be established by changing the count of the RDD104 chip, U3, in the circuit. As a funciton of the logic applied to pins 1 and 2 of U3, the following clock intervals can be made available at pin 7:

Clock Counter U2 Out (Sec)	Time Multiplier U3 Program	Time Multiplier U3 Out (Sec)	Sequencer U3, Pin 12 (Sec)
6	10	60	600
6	100	600	6000
6	1000	6000	60000
6	10000	60000	600000

Time Delay Operation

The One-By-One Sequencer circuit can be used to generate one or more one-minute outputs that are delayed a specific amount from the zero output or any other output. The example of Fig. 5 demonstrates this technique. Suppose that you wish to establish an output condition with a turn-on period corresponding to 0 (zero) and another turn-on interval that is to start 3 minutes later. This can be accomplished by using output 0 and output 3 applying both outputs to a 2-input OR gate as shwon in Fig. 5. Input waveforms and the resultant output waveform are shown. Note the time spacings.The turn-on sequence will repeat itself as the integrated-circuit chip 4017 goes through each cycle.

Generating a Special Time Output

Special times and counts can be established by connecting one of the decoder outputs back to the reset input, using that particular output to reset the counter and return activities to t_0 condition. For example, if you wish to operate the 4017 as a 6-to-1 counter, pin 5 would be connected back to pin 15 on U4 as shown in Fig. 6. The 6-to-1 output would then be taken off at pin 3. Recall that each of the outputs is a positive pulse and its positive transition if connected as illustrated in Fig. 6 will reset the 4017. The basic circuit of Fig. 4 need only be modified slightly to set up the special count made available by the circuit of Fig. 6. You need only remove the light-emitting diode (LED9) at pin 5, U4 of the 4017. This prevents LED loading and insures that a positive transition is obtained for resetting the 4017. Install a second reset pushbutton switch, S2, specifically for the 4017 that you have the means of aligning the t_0 condition for all counters. Output activity can be observed with the light emitting diode, LED4, connected to pin 3.

Make the necessary connections. What will be the output time interval at pin 3 (0 output)? The pulse duration will remain at one minute. However, the total period will now be 6 minutes. Thus there will be a one minute output each six minutes as compared to a one-minute output each ten minutes that occurred before the circuit change. Similar pulses appear at outputs 1 through 5. You could set up a one-minute output each four minutes by joining pins 15 and 10. Check it out!

An output time period of exactly one hour can be obtained by setting the RDD104 (U3) for a time multiplication of 100 (pin 1 to ground and pin 2 to supply voltage). Now the multiplication will be:

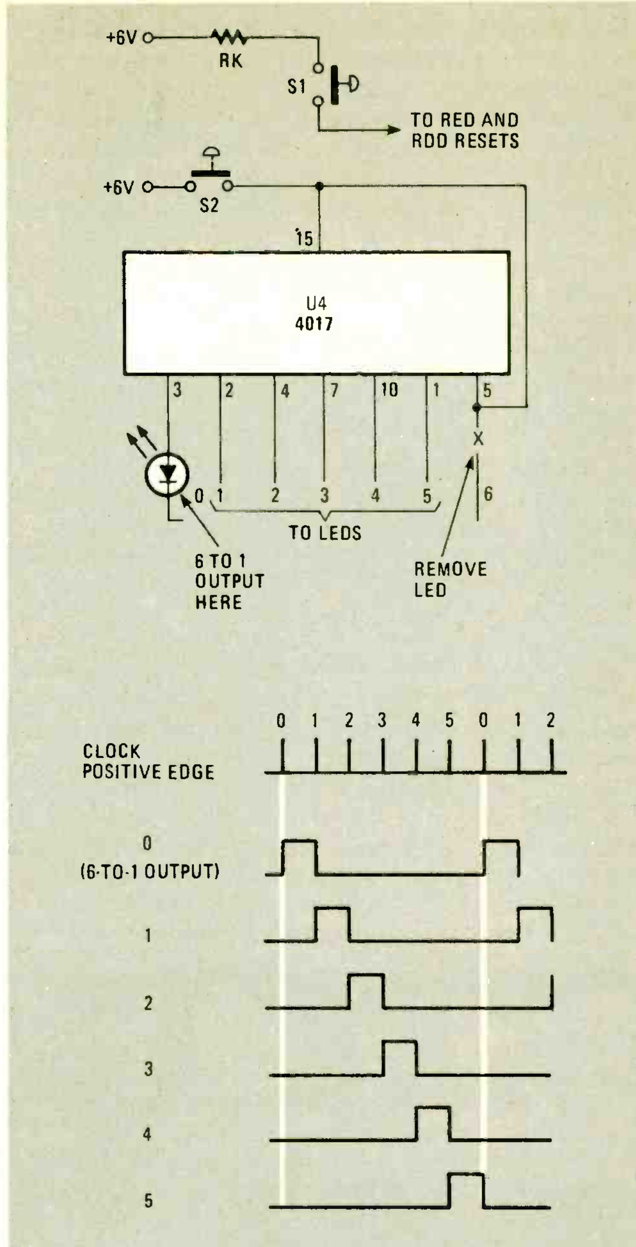

FIG. 6—PERIODS of other than subdivision units of ten are possible with slight circuit changes. Combining the modifications in the circuit in Fig. 5 with this figure will permit unlimited selection of timing pulses for special applications you may have in mind.

$$6 \text{ seconds} \times 100 \times 6 = 36 \text{ seconds.}$$

The number of seconds in an hour is 3600. Set up the circuit for this mode of operation by making the appropriate RDD104 (U3) changes.

If you wish to synchronize operation on the hour, first hold down pushbutton switch S1. Momentarily close pushbutton switch S2 to reset the 4017. Continue to hold down pushbutton 1. At the instant the second hand of your watch passes the on-the-hour moment release it. Sequencer is now locked in with real time. By observing the LED connected to output 0 you can measure its duration as ten minutes. It will now come on for a ten-minute period each hour.

There are almost unlimited timing possibilities for the combination for the 4017 and the clock frequency dividers. It can be made to meet many interesting timing and sequencing needs you could conger up. **SP**

LETTERS

Continued from page 6

sensing is not necessary. Ride the mechanical valve in front of the electric hot-water valve until you get the mix you want. Now all you do is set the time. Also, throw in a cutoff timer so that all your hot water will not go to waste should you get called to the phone. **SP**

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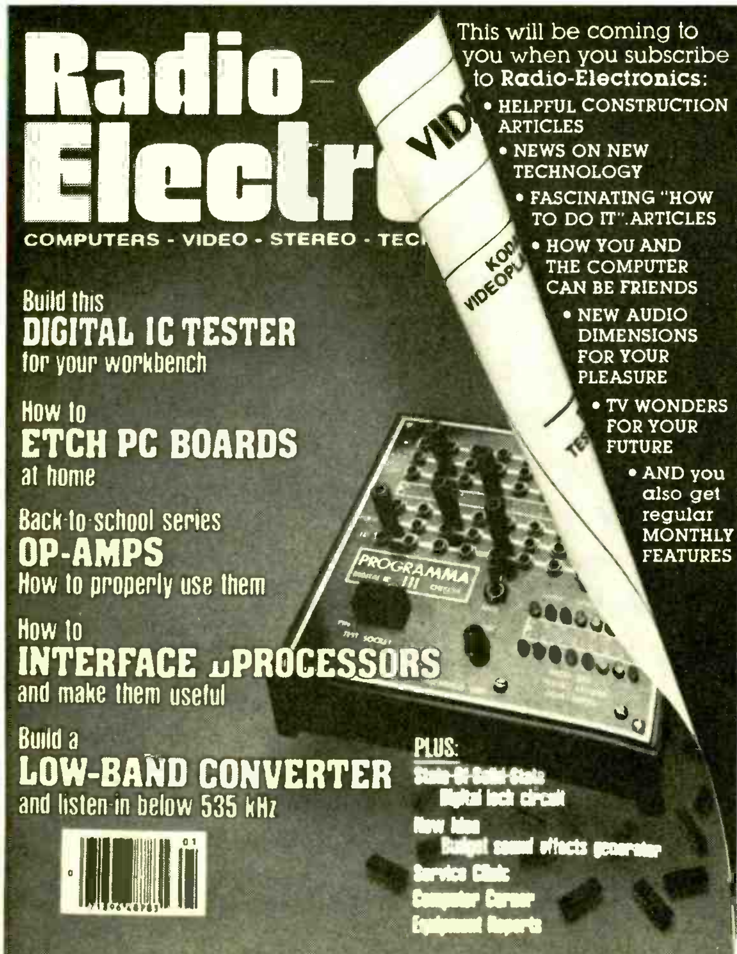

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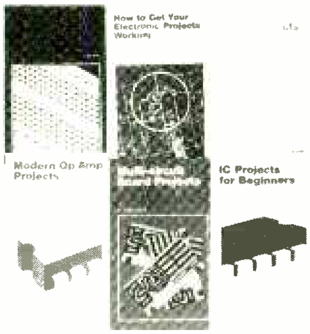

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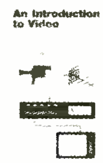

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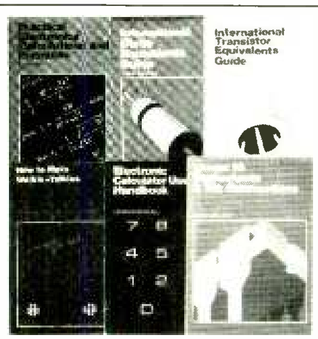

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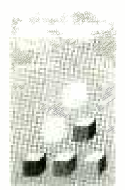

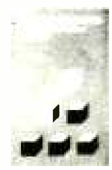

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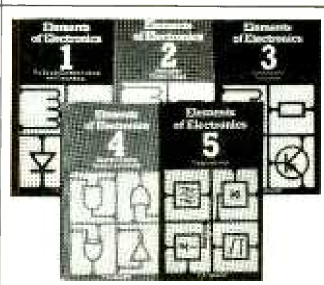

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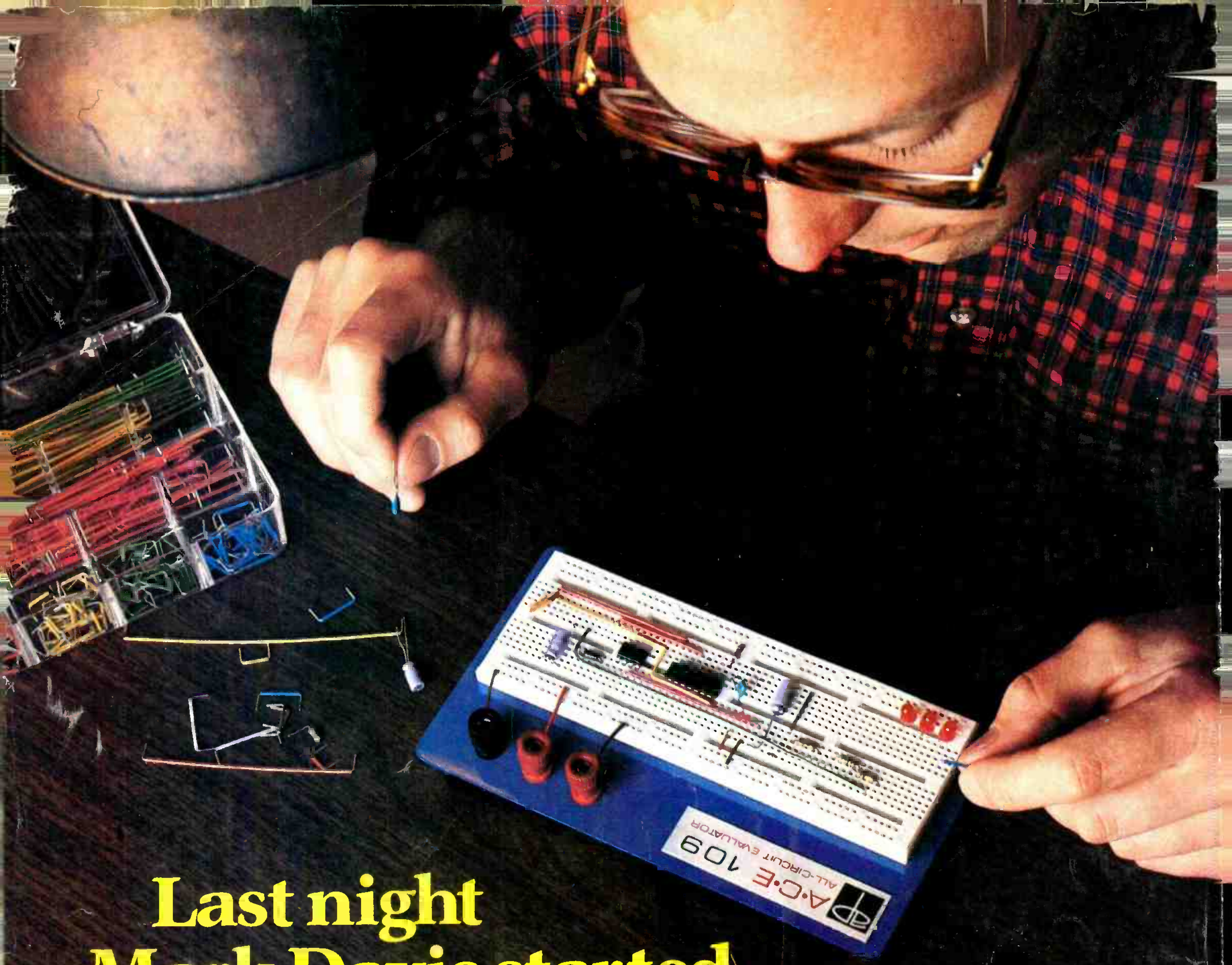

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