

Hobby  
Electronics

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Radio-Electronics

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# Hands-on Electronics

48784

#5

THE MAGAZINE FOR THE ELECTRONICS ACTIVIST!

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The original guessing game that yields to logical thought! →



## Automotive Electronics

Computers make travel safer

## Tune in the Space Shuttle

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A  
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PUBLICATION

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How their circuits operate

## Electrical Shock

How to avoid it!  
How to save a life!



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 1-800-527-2262

## FEATURES

- 25 **Shuttle Communications**—Hear voices of astronauts and Earthbound support personnel
- 42 **Electrical Shock**—The killers that lurks in your home shop
- 65 **The Drive to Computerize your Car**—What the future will bring
- 97 **Shure Celebrates 60th Anniversary**

## THEORY AND CIRCUITS

- 58 **Digital Fundamentals**—Getting into digital circuits
- 71 **Oscilloscopes**—Discover the circuits that bring signals to shape

## PROJECTS YOU CAN BUILD

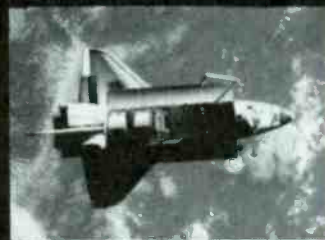
- 33 **Wireless Home Burglar Alarm System**—Build and assemble your very own
- 48 **How to Add Constant Memory to a Calculator**—Save batteries and programs
- 51 **The Plasma Machine**—Direct the flow of plasma and harness the unknown
- 74 **Put Your Telephone on Hold**—An add-on feature that costs only pennies
- 76 **Tormentor**—This troublesome gadget will turn the tables on your tormentors
- 79 **Add a Digital Dial**—Know for sure the frequency of the tuned signal
- 83 **Mind Master**—An absorbing game that will challenge your senses

## SPECIAL COLUMNS

- 18 **Saxon on Scanners**—Listen to the news media before it's news
- 23 **Friedman on Computers**—Computer Aided Design (CAD) programs are available for  $\mu$ P's
- 92 **Testbench Tips**—Clever ideas that clever readers submit
- 93 **Calling All Hams**—Getting covered by a multi-band umbrella dipole antenna

## DEPARTMENTS

- 2 **Editorial**—Good news from the Chief of our Circulation Department
- 3 **Letter Box**—Communications that inspire information
- 8 **New Product Showcase**—A peak at the coming consumer-electronics marketplace
- 39 **Reader Service Card**—Get more information at no cost



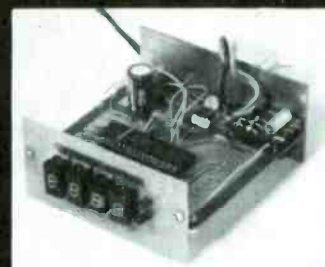
Hear the action in space—Page 25



Are you clever enough?—Page 83



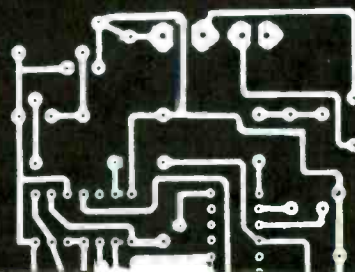
Fill her up with chips—Page 65



Analog to digital dial—Page 79



Phone feature project—Page 74



### *Getting more issues to you each year!*

We're happy to tell you that HANDS-ON ELECTRONICS will be published every other month. That means that you'll get even more of the latest, best, and most-interesting projects that you've come to know and expect from your favorite magazine!

When? Right now! It begins with the very issue you're holding in your hands. We think that this is exciting news, and couldn't wait to tell you about it. But there are some things you ought to know.

Until now, our subscribers have been paying ten dollars for four issues each year. That was the same as the newsstand price. With the change to six issues per year, our subscribers will be getting six issues for only \$14 - a saving of one dollar over the newsstand cost—and you don't have to go out to get it. It is delivered right to your door.

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Jacqueline P. Weaver  
Circulation Director

P.S. You'll find subscription order-forms in this issue. Fill one out and send it in now, while you think of it, along with your check. We'll simply extend your existing subscription. If you're a new subscriber, we'll start you off with issue #6.

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# LETTER BOX

## LNA—What Is It?

I've just read an article that talked about LNA's, which I figured out are amplifiers, but (believe it or not) no where in the article did it say what an LNA is! What does LNA stand for? All the article talked about was degrees! Can you give me some info?

I.K., Commack, NY

*The LNA, which stands for Low-Noise Amplifier, is a substantial part of the home-TVRO (television-receive only) system. Since that unit must separate the very weak satellite signals from surrounding noise, its low-noise characteristic design means that the price is somewhere between \$1000 and \$1500 a pop! At least that was the case until a year ago.*

*But now you can look forward to big price breakthroughs. A couple of hundred dollars should do it for an LNA that*

*is considerably better than last year's model. The lower the unit's degree rating, the better the LNA can separate the signal from the noise.*

*You can also expect to see specs like 30–55 dB gain with noise temperatures from 120 degrees down to 60 degrees. I suggest you pick up a good book on satellite receiving systems at the local library.*

## All the Same

In project after project, your magazine has continued to provide regulated power supplies for DC voltages of 5, 6, 9, 12, 18, etc. Be honest—they are all the same! Why are you wasting the space? F.V., Kalamazoo, MI

*Admittedly, we could leave out the power supply, but we include it because we want to provide a complete project. Besides, what will we tell our readers when they see a large power stepdown*

*transformer in a photograph and we don't give the specs. Also, think of the neophyte who's undertaking his first project, or the person who wants a complete project.*

*Considering all the different people out there that read this magazine, we must be considerate to one and all. For those who do not need the information we are indeed sorry that that bit of page space is used.*

## Carbon Pile

I was told that to accurately test the battery of my automobile, I should connect a carbon pile across it. What is a carbon pile?

T.G., Santa Rosa, CA

*A carbon pile is a device that offers a low resistance at a very high current. The reason it is called a carbon pile is that many versions of the device consist*

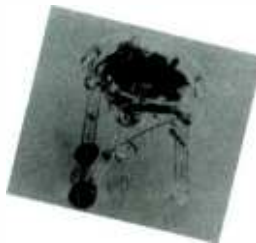
*(Continued on page 16)*



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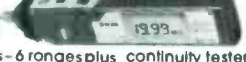
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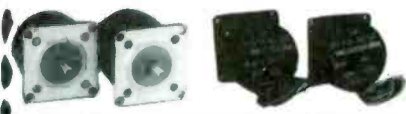
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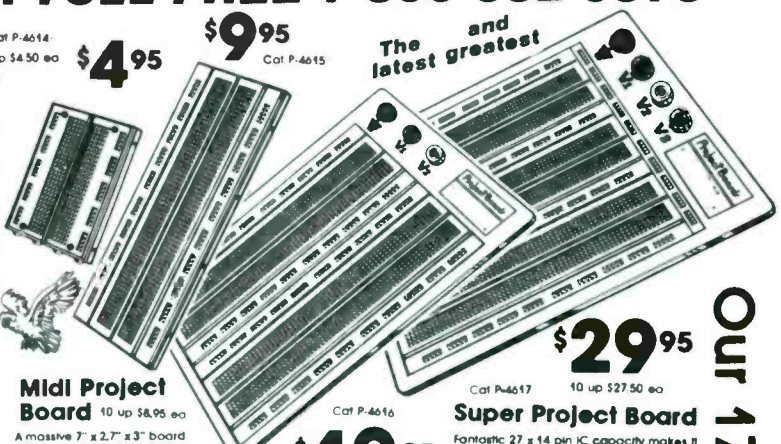
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# NEW PRODUCTS SHOWCASE

## IBM-COMPATIBLE MATRIX PRINTER

Canon has showcased its latest advance in NLQ Printers. The company's new A-40 impact matrix printer provides maximum support for IBM PC application programs. It's printing speed is a fast 140 characters-per-second in draft mode (11 × 9 dot matrix, Pica). In NLQ mode, the simple press of a button produces a sharp 23 × 8 matrix at the speed of 27 characters-per-second.



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Its linefeeding speed is 8 lines-per-second, with selectable linefeeding of 1/6, 1/8, and 7/72 of an inch, and programmable. The A-40 is equipped with IBM graphics printer character Set 2, and features escape codes that are fully compatible with IBM's graphics printer.

The machine has quiet operation—less than 60 dB—and will be welcome in any office environment. It can handle fanfold, single sheet and multipart plain paper. Weighing less than 17 pounds, the A-40 can be moved from one office to another with little effort. For further information, write to: Printer Division, Canon USA, One Canon Plaza, Lake Success, NY 11042; Tel: 516/488-6700.

## 14-BAND GRAPHIC EQUALIZER

For the ultimate in equalizing convenience, Sansui has introduced its new SE-88 computer-controlled, 14-band graphic equalizer with uniquely detachable hand-held remote that controls all equalization functions. One of the major problems in setting equalization is that one's favorite listening spot in a room is usually more than an arm's length away from the control panel. That usually means a lot of walking back and forth

before equalization is set to one's liking. And if you decide to move to a different spot in the room, the whole process must be repeated.

The Sansui SE-88, however, solves those problems by letting the user set equalizations from his or her favorite listening positions using the remote control. That equalization can be stored in memory for instant recall. In fact, the SE-88 can remember and instantly recall five different equalization settings so the user can equalize not only for position, but also for type of music. Other functions that can be remotely controlled include: line, tape, 1/2 EQ, EQ reverse, EQ curve, EQ flat, spectrum and channel mode.

The model SE-88 has center frequencies of 25, 50, 100, 160, 250, 400, 630 Hz, 1K, 1.6K, 2.5K, 4K, 6.3K, 10K and 20K Hz with a control range of ± 10 dB.

The basic component itself features full control both at the front panel and remotely, and incorporates a spectrum analyzer to aid in adjusting system response to the desired equalization. It also has bi-directional, tape-dubbing facilities for two decks. The key specifications of the SE-88 include: frequency response of 10–100,000 Hz; a signal-to-noise ratio of 100dB, and THD of less than 0.02%. Its



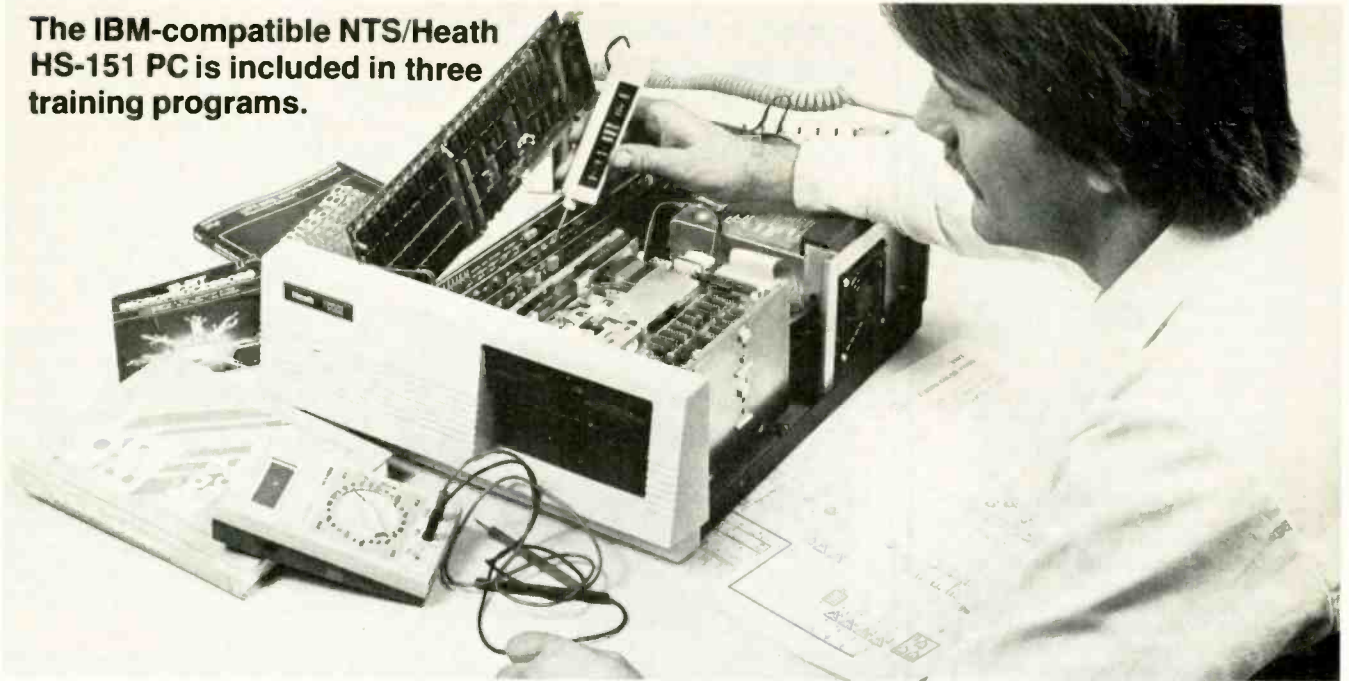
CIRCLE 566 ON FREE INFORMATION CARD

suggested retail price is \$400, and like all other Sansui components, the SE-88 is available in black.

The new unit joins Sansui's line of audio-graphic equalizers, which include the SE-9 Compu-equalizer (\$700, suggested retail), and the SE-77 12-band graphic equalizer at \$280. For more information on Sansui equalizers and other fine audio and video components and systems, please contact: Sansui Electronics Corp., 1250 Valley Brook Ave., Lyndhurst, NJ 07071; Tel: 201/460-9710.

(Continued on page 12)

The IBM-compatible NTS/Heath HS-151 PC is included in three training programs.



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By Mark Saxon

# SAXON ON SCANNERS

OFTEN OVERLOOKED AS A POTENTIAL source of monitoring excitement are the frequencies used by the news media: newspapers, radio, and TV stations. Those organizations go to great lengths to put into the field crews of reporters in roving cars, vans, and even helicopters. Often the reporters spot accidents or other newsworthy events before police or fire authorities are summoned to the scene. That is why it's so unusual to note that they haven't been heralded as the greatest discovery since the invention of Twinkies.

One of the things I like about what's being heard on those frequencies is that when they call in their stories they go into lots of detail. The accounts are much better than what you get on the police and fire frequencies where it's strictly a matter of, "Just the facts, ma'am."

In the case of the broadcast media you may hear actual live on-the-air "feeds" taking place on those channels, and that is especially true in the case of traffic helicopters. In some instances, however, you'll find that what the broadcast audience is led to believe is a "live" broadcast from a traffic chopper is actually a taped rendition which is put on the air as much as five minutes after it was sent "live."

### Up in the Smog

Where I live there are traffic helicopters from several local radio stations. The pilots all know one another and they usually chat with one another and swap small talk on the VHF aero band (122.85 and 122.9 MHz are favorite frequencies) between traffic reports. Moreover, the pilots like to kid around with the air personalities at their broadcast stations before and just after their traffic reports. That takes place on the channel used for the traffic report.

In addition to direct remote location feeds, those frequencies are also used for dispatching staff personnel. In once instance I know of, most of the station personnel have two-way equipment in their cars (and boats) and use those frequencies to place and receive telephone calls through the radio station switchboard. It's interesting to hear the station manager's

reaction when they disturb him while he's fishing to say that the afternoon DJ can't go on the air because he had one-too-many martinis with (or for) lunch!

### Where to Listen

The frequencies used by the various media are shown in Tables 1 and 2. You'll find that even in areas away from large cities you should be able to pinpoint activity on one or more channels. Put your scanner into the *search* mode to see which channels are active in your area.

Reader Sallye Reynolds of Illinois asks us to remind readers that sometimes you have to root around on the scanner bands to locate what you're seeking. In her area, for instance, there was reputed to be an "unlisted" police frequency used for special tactical purposes. After rigorously scanning every possible frequency allocated to the Police Radio Service and drawing a complete blank, she was beginning to think that the rumors were without substance. That was until she stumbled across the mystery frequency by accident. It wasn't on a regular frequency where it was "supposed" to be.

Well, it was regular frequency, but not one set aside for exclusive police uses. It was on a frequency allocated to the so-called Local Government Radio Service. That radio service is usually used by miscellaneous municipal, county, and state agencies such as parks/recreation, social services, civil defense, sewer repair, etc. There is no restriction against the use of Local Government Radio Service by governmental services such as police and fire departments. And Sallye has also discovered that in one state, the State Police have their communications on an Interstate Highway Emergency Radio Service where you'd never think of looking for them.

### Or would you?

Local Government Radio Service frequencies are gently sprinkled amongst various other services' frequencies in the following bands: 37.10 to 37.26, 39.06 to 39.98, 45.08 to 46.58, 153.74 to 158.955, and 453.025 to 453.975 MHz.

(Continued on page 22)

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## SAXON ON SCANNERS

(Continued from page 18)

Check 'em out!

In our mailbag for this issue we find an inquiry from Sam Carrone of Baltimore, MD. Sam wants to know if there are national scanner clubs he can join. Sam, you may be just a little late for the only such group with national aspirations. The California-headquartered group looks to have entered a declining cycle in its popularity and some folks don't seem to think it will ever re-gain the status and member value it once had. Your best bet would be to try to seek out some of the local or regional groups which have been coming into existence of late. Ask around at communication shops selling scanners.

Andy Collins of Toronto asks if we can pass along a few frequencies in his area since they seem hard to obtain by asking around at communications shops. The Royal Canadian Mounted Police use 41.28 and 49.12 MHz, and you can listen for the Ontario Provincial Police dispatchers on 41.96, 41.98, 42.06, 42.20 and 42.72 MHz. On 42.10 Mhz you can hear emergency service agency communications. Forestry conservation communications are on 48.16 MHz. And if you're a fire-communications enthusiast, be sure to listen on 46.70 and 46.74 MHz. Prisons in Ontario are using 41.86 MHz.

Robert Cosgrove of Texas notes that "nobody" ever gives out information on frequencies used for inter-company communications by telephone companies. Bob says that they've got repair crews and all sorts of other personnel out on the road around the clock. He'd like to see some data on their frequencies published, and he's sure that others would also like to have that information, too! Could be! All you need do is ask!

Some companies use 35.16 or 151.985 MHz for base/mobile communications, with additional frequencies for mobile units and hand-held's on 43.16 and 158.34 MHz. There are also UHF frequencies available and those frequencies are in especially heavy use by telephone companies in larger metropolitan areas. Those are all in the 451.175 to 451.6875 MHz band.

From San Diego comes a postcard from "C.L.G." who wants to know "what's with" 56.75 MHz. He says that its supposed to be VHF marine channel 15 but he's never heard so much as "peep" on it.

That frequency is intended for use by coast stations in a way roughly similar to the NOAA weather transmissions on 162.55 MHz (and similar frequencies). The idea is for coast stations to furnish mariners with weather, sea conditions, time signals, hazards to navigation, and other notices. Basically it was a good idea but coast stations have not shown much interest in becoming involved. Maybe it is a matter of economics (since the service would not produce any revenues) or it's because they fear lawsuits from mariners who have problems after using the broadcasts.

TABLE 1—FREQUENCIES (MHz)  
USED BY NEWSPAPER REPORTERS

173.225	173.275	452.975
173.275	173.375	453.00

TABLE 2  
FREQUENCIES (MHz) USED BY RADIO/TV STATIONS

161.64	450.0875	450.2875	450.4875	450.70
161.67	450.1125	450.3125	450.5125	450.80
161.70	450.15	450.35	450.55	450.85
161.73	450.1875	450.3875	450.5875	450.90
161.76	450.2125	450.4125	450.6125	450.925
450.05	450.25	450.45	450.65	

Note: Additional radio/TV station frequencies are situated exactly 5 MHz higher than the 450 MHz frequencies shown above (i.e. 455.05, 455.0875, 455.1125 MHz, etc.)

By Herb Friedman

# ON COMPUTERS



# FRIEDMAN

## Computer Aided Design (CAD) programs are available for $\mu$ P's

□IT'S MORE THAN LIKELY THAT IN A FEW more years templates, ruling pens, and other drafting tools will be antiques, to be seen in display cases along with other *objects d'art* because just about everyone—including hobbyists—will be creating drawings and schematic diagrams by computer.

Even though computerized artwork often takes longer to prepare than conventional drawings, in the long run they are more convenient because, among other things, they are easy to modify. One can make additions and deletions without having to scrub away with an eraser, or paste tiny scraps of paper over the drawing in order to show changes.

Although most of you are familiar with the expensive and somewhat tedious-to-learn CAD (Computer Aided Design) software used by architects to design buildings, few electronics technicians and hobbyists need computing power that can show an entire building or an entire room, or which can zoom in and fill the screen with a sink drain. As a general rule, anything that powerful costs *big bucks* because it needs a maxi-computer—a mainframe.

The typical electronics technician and hobbyist doesn't need all that much computer power. More often than not CAD is used to simply prepare a flow chart or the schematic diagram for some particular equipment, either of which can be easily done by a desktop computer. Your home and family personal computer is capable of handling such tasks.

### Looking at Bucks

There are basically two kinds of moderately-priced CAD programs intended for

the personal computer. The more common kind, the type generally used in schools from high school up, costs several hundred to over a thousand dollars and is generally intended for drawings that use lines, rectangles, and circles. Much of their strength lies in the ability to easily replicate some kind of structure in any desired physical relationship. For example, if the user draws the symbol for a single *op-amp*, the program allows the user to replicate as many similar *op-amps*—either larger or smaller—anywhere on the screen. For a few hundred dollars more, plus the cost of a digitizing pad, the program usually comes with a *library* of stock shapes and symbols. A sheet of paper imprinted with the symbols is placed on the digitizing pad. To insert a symbol into the drawing, the user places the tip of an electronic pointer on the

symbol, presses a button on the pointer, moves the pointer to the screen where the symbol is needed. When the button is again depressed, the symbol appears on the screen.

While that kind of software and the hardware that can run it is relatively expensive, much of the cost represents features not needed by the average electronics hobbyist and technician. In fact, a very fine low-cost (\$49.95) electronic drafting system known as *Schematic Drafting Processor* from Spectrum Projects (Box 21272, Woodhaven, NY 11421) is presently available for a Radio Shack Color Computer equipped with a single floppy disk.

Unlike most other drafting programs, which are universal in the sense that they are intended for any conventional drafting  
(Continued on page 94)

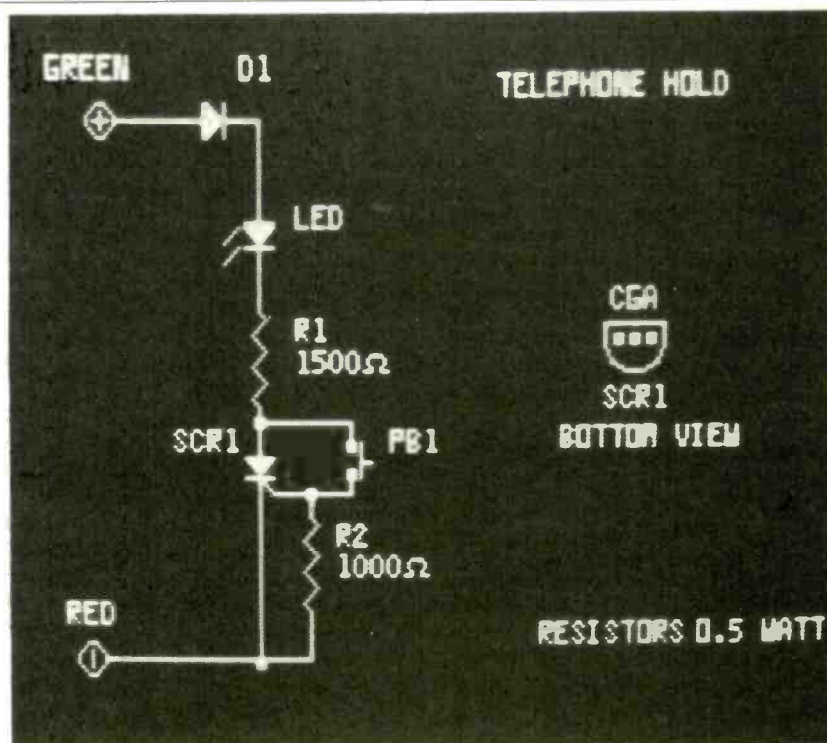


Fig. 1—This is how the schematic diagram of the *Telephone Hold* appears on the screen of a Color Computer. The type is actually graphics generated by the program's text mode. The construction project for the Telephone Holder appears in this issue. You may want to compare a draftsman's version against the monitor's view.



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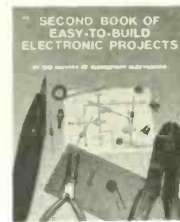
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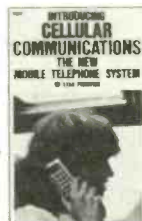
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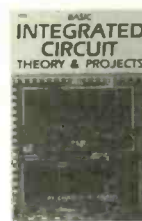
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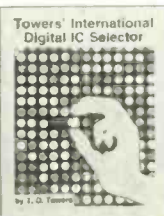
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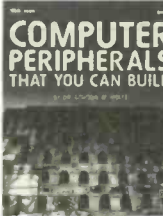
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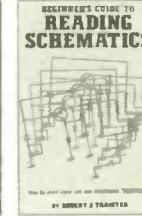
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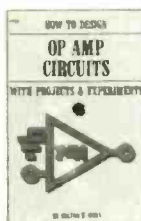
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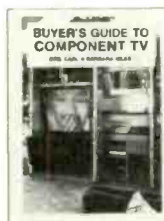
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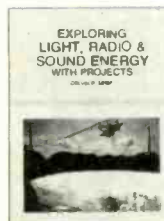
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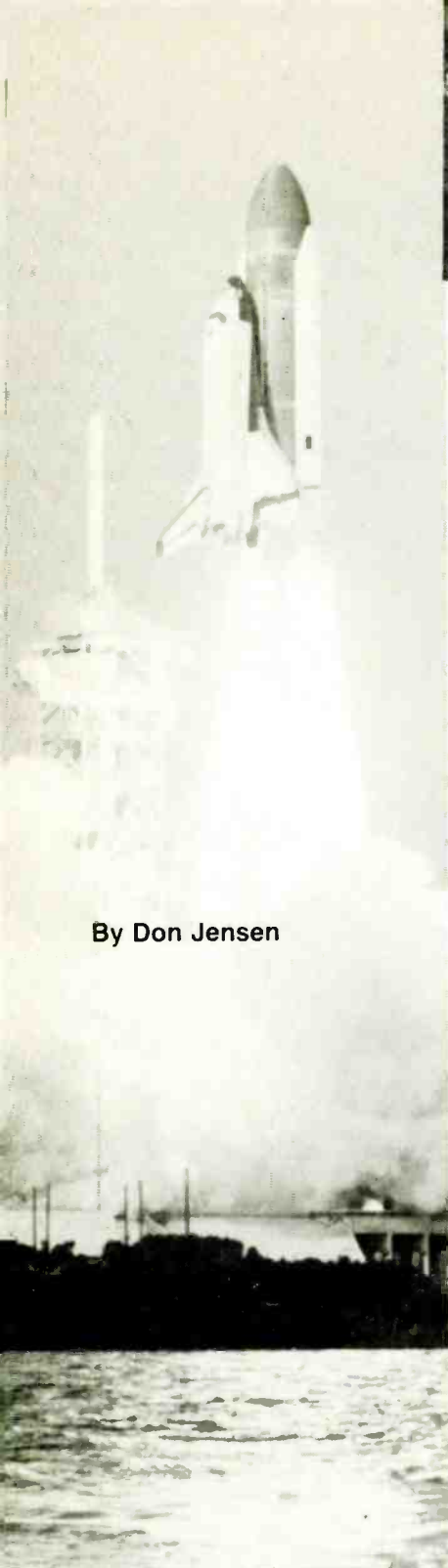
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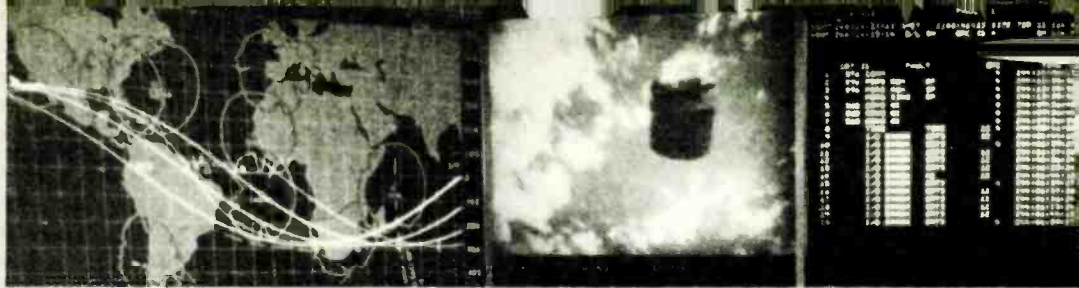
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RESP-885





By Don Jensen



Tuning-in on...

# Shuttle Communications

**Hear voices of astronauts and earthbound support personnel!**

**I**n the nearly quarter century since man first broke free from global fetters, we've come far in our quest to conquer space.

From a single cosmonaut, tentatively circling the planet, we are now regularly launching reusable space shuttles with shirtsleeve crews of men and women, scientist and payload specialist, a school teacher, and even a U.S. Senator!

In just over four years, the shuttle orbiters—*Columbia*, *Challenger*, *Discovery*, and, in 1985, *Atlantis*, too—will have logged over 3,000 hours and millions of miles out beyond Earth's atmosphere.

The shuttles function as freight carriers, delivering and launching satellites in space and bringing some back in the shuttles' payload bays. They also serve as traveling repair shops for orbiting satellites that are ailing, science laboratories for space experiments and observations, and factories for manufacturing products in zero gravity.

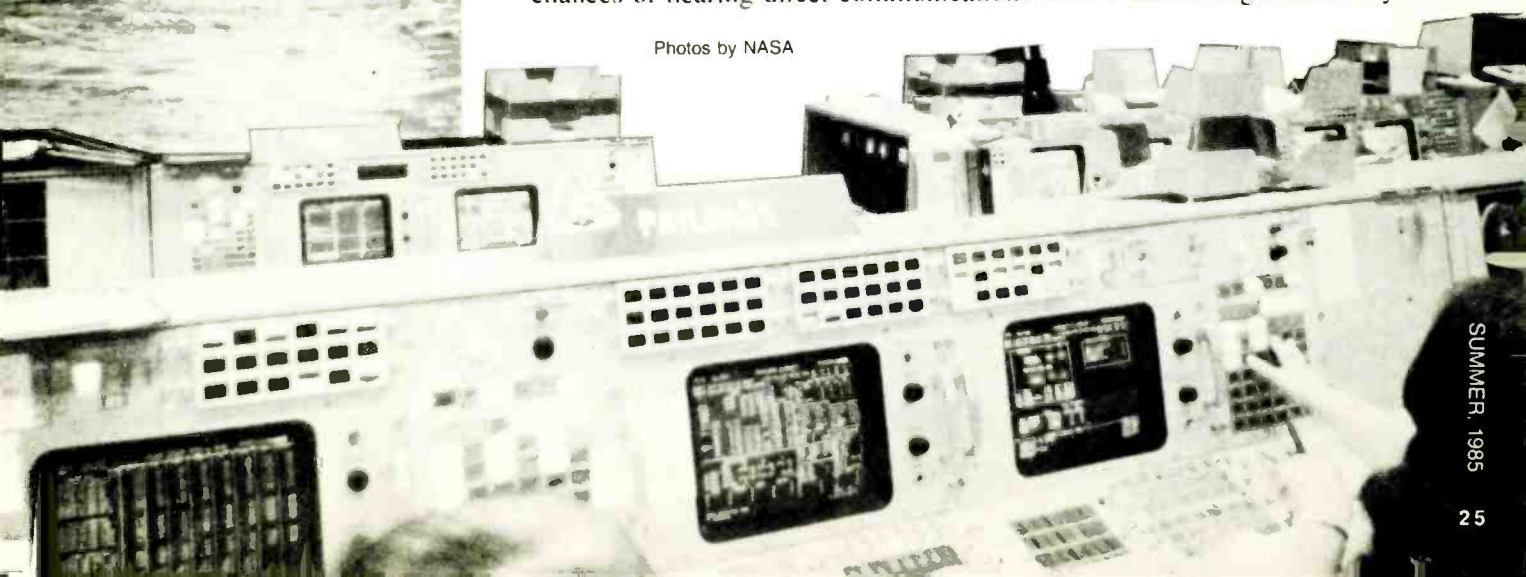
With those space trucks some 170 miles out for days or weeks at a time, an elaborate communications system is a must. As a National Aeronautics and Space Administration (NASA) spokesman said recently, "Communications? Everything relies on communications!"

The ability to put human beings and multimillion dollar packages of high-tech cargo into space means nothing if NASA can't find and talk to the technicians and instruments.

Finding the shuttle orbiter means space-tracking systems. Keeping in touch means complex telemetry operations and both voice and video communications.

For the guy at home with a shortwave receiver or a scanner, regrettably, the chances of hearing direct communications from a shuttle flight these days are

Photos by NASA





## SHUTTLE MISSION FREQUENCIES

Shortwave Frequencies (kHz)			
2622	6693	9042	13277
2678	6708	9132	13600
3850	7461	10780	14397
3860	7675	11205	14896
5180	7910	11407	20166
5190	8972	12160	20197
5350	8981	12277	20198
5810	7765	13170	20390

Aeronautical VHF/UHF (MHz)			
KCS	Patrick AFB	Edwards AFB	
117.8	118.4	116.4	
121.7	121.7	120.7	
126.3	125.1	121.8	
126.2	126.2	126.1	
284.0	128.7	127.8	
	273.5	236.6	
	335.8	269.9	
	340.9	290.3	
	348.4	318.1	
	358.3	390.1	

KSC Ground Support VHF (MHz)			
148.48	163.51	170.35	
149.17	163.56	171.15	
162.61	165.19	171.26	
163.46	170.15	173.56	
163.48	170.17	173.58	

S-Band Microwave (MHz)			
Shuttle-to-Ground	2205.0	2217.5	
	2250.0	2287.5	
Ground-to-Shuttle	2041.9	2201.4	

## Closing the Communications Gap

A revolutionary new way of tracking the orbiters began with the launching of the first Tracking and Data Relay Satellite by the Shuttle *Challenger* in April 1983. It was the first step in closing the communications gaps that existed in the systems since the earliest days of space flight. Before TDRS, the shuttle could remain in contact with one of the ground tracking stations around the globe only about 20 percent of the time during a typical mission.

With the TDRS system, nearly constant (85 to 100 percent) global coverage is possible. The high geosynchronous orbit TDRS's serve as tracking stations in the sky, relaying orbiter's S-band signals via higher powered K $\mu$  band, from orbiter to ground. Eventually the satellite system will replace more than half of the existing ground-tracking stations, with greater efficiency and reduced costs.

TDRS, designed jointly by NASA and Western Union, can handle up to 300-million bits of data per second—the equivalent of processing 300 14-volume sets of encyclopedias each second!

The orbiter vehicles have two sets of antennas. The S-band (2,000 MHz) antennas are located on the outside surface of the shuttle. K $\mu$ -band communications use a steerable dish antenna mounted in the cargo bay and deployed once the bay doors are opened in space. The K $\mu$  band is used for the greater flows of digital information required by television signals, high-rate telemetry, and the orbiter's text-and-graphics system—a kind of teleprinter on which the astronaut crews can receive copies of printed material transmitted up to them during a mission.

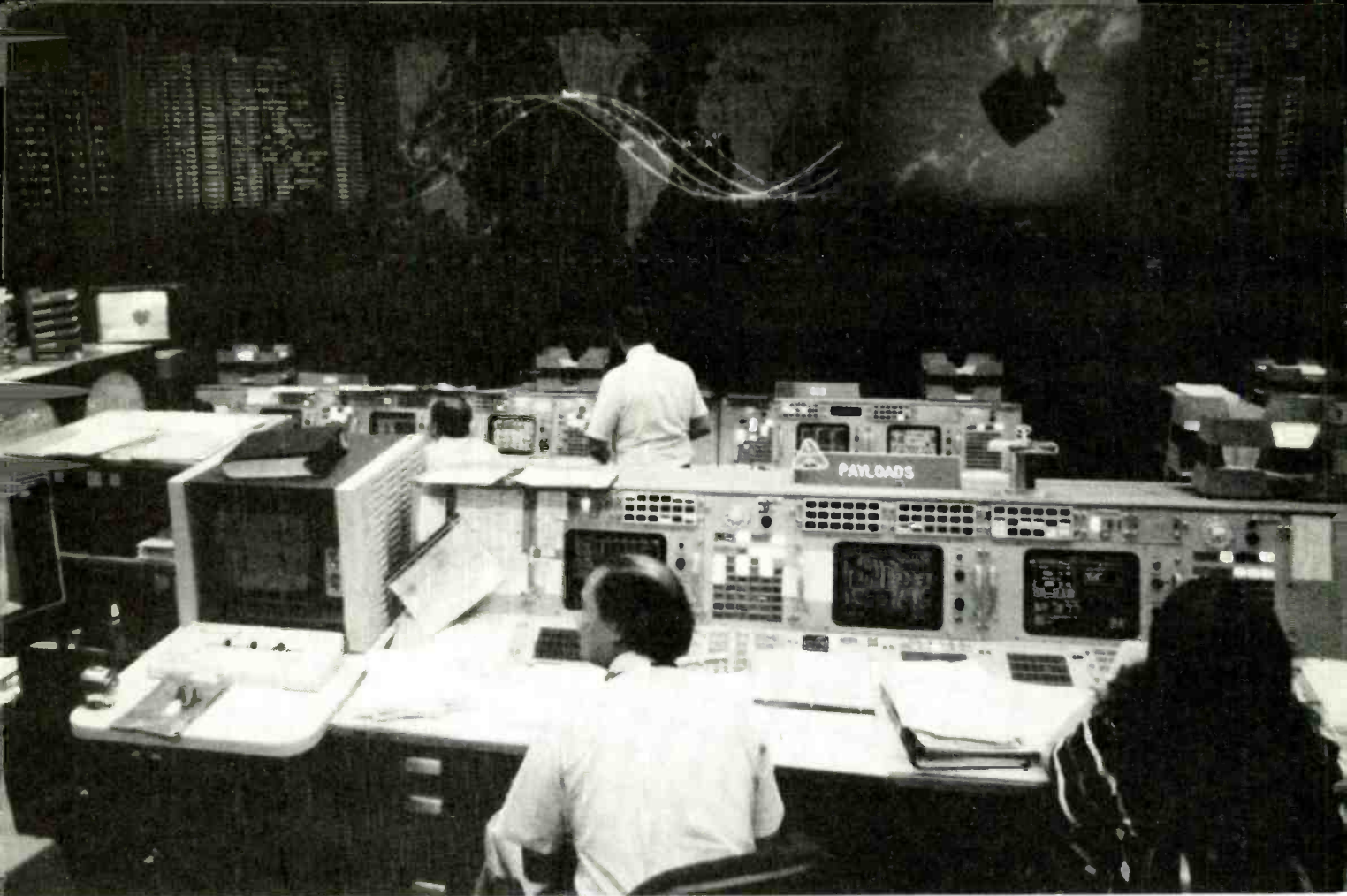
The shuttle voice communications with the ground use the S-band 10-watt (2205.0 and 2250.0 MHz) and 100-watt (2217.5 and 2287.5 MHz) transmitters. There are dual voice channels, one for contacting Mission Control Center.

Mission Control at Houston is the central control point for the shuttle flights. Its communications flexibility is great, combining voice, teletype, video, and facsimile. The data,

Photo by NASA



Shuttle flights are becoming more frequent and more successful. Here space shuttle *Columbia* main wheels touch Runway 17 at Edwards AFB to successfully complete a mission of 10 days, 7 hours, 47 minutes and 23 seconds. It was the shuttle's sixth and longest trip into space.



A triumphant moment in space is monitored on Earth by ground controllers in the flight control room (FCR-1) of the Johnson Space Center's mission control center. Two flight controllers (foreground) man the payloads console during the deployment of a Syncom payload. Communications between the shuttle and ground pick up during this period.



Photos by NASA

real time and delayed, comes to and from Houston via the various ground stations. The interface systems use computers to format, compress, and route outgoing information; and to reformat, decode, and forward incoming data.

Scientific telemetry data are transmitted in real time or by delayed playback on the orbiter's K $\mu$ -band system via the Tracking and Data Relay Satellite or directly by the S-band frequency-modulated system to the ground-tracking network. Television is available from the orbiter cockpit camera or from one of four payload-bay TV cameras.

There also are a number of other communications systems connected with NASAs during space shuttle flights. They include the facilities at the primary launch and landing site at the Kennedy Space Center at Cape Canaveral, FL, and the secondary return location at Edwards AFB, CA.

The Defense Department—with Army, Air Force, Navy, and Coast Guard personnel, aircraft, ships and communications equipment—provides logistical, special studies and search-and-rescue support.

#### Listen at Home

The shortwave listener with a receiver capable of tuning in single-sideband (SSB) radio signals—and most modern sets

*(Continued on page 32)*

Astronaut Sally Ride communicates with ground controllers from the mid-deck of the Earth-orbiting Space Shuttle Challenger. She is reporting on continuous-flow electrophoresis system at the photo's left.



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RP-31

(Continued from page 28)

can—may find a good number of tuning targets among those transmissions.

Begin checking the various NASA and military frequencies about 24 hours before the scheduled shuttle launch. Action will begin to pick up as the liftoff nears. During the pre-launch hours, the support facilities gear up for the mission. NASA's own communications facilities, in particular, the down-range tracker on isolated Ascension Island in the South Atlantic, will check in. Tracking vessels, booster recovery, and search-and-rescue ships will be heard. Radio communications will be noted between U.S. Air Force ground controllers and EC135 tracking aircraft, T-38 chase jets, rescue medical and evacuation helicopters, and photo and surveillance planes.

### The Language They Use

You may hear key ground-communications stations such as AFE71, called Cape Radio, at Patrick AFB, FL, near the Kennedy Space Center. Other call signs include AFE83—Ascension Island, AFE86—Antigua in the West Indies, and AGD—Vandenberg AFB, CA.

More common, perhaps, are the many strange-sounding tactical call identifiers used by the military-support units. Calls such as AGAR and ARIA, followed by several digits, identify USAF tracking planes. Other fixed wing and helicopter designators noted during recent space flights included Gull, Jolly, Peapod, Variety, and Bloodhound. Eyesight seemed to be a Navy aircraft tactical call.

Some aircraft use a phonetic-alphanumeric identifier, such as Victor-3-Charlie, Bravo-Hotel-8, or India-6-Hotel.

Navy tracking and booster recovery ships have been heard with radio calls: Liberty, Freedom, Picopay, and Dishpan.

Those *identifiers* may baffle you at first. Who is saying what to whom? But with careful listening to the message traffic, often you can figure out the probable identities of the stations, their locations, and just what they're doing to aid the shuttle mission.

Probably the single best shortwave frequency to try during space-orbiter flights is 10,780 kHz, Cape Radio's primary upper-sideband (USB) channel. A secondary frequency of 20,390 kHz also is a good bet, as are frequencies from 20,186 to 20,198 kHz, which have been especially active recently.

Other suggested channels, depending on propagational factors and the time of day, include 5,350, 5,180, 7,675, 7,910, 9,132, and 11,205 kHz.

Scanner fans living within VHF range of Florida's Patrick AFB or California's Edwards AFB may want to watch frequencies including 138.30, 138.45, 149.925, and 162.612 MHz for various ground-operations communications before, during and after shuttle flights.

### Amateur Radio

The VHF aeronautical band, particularly frequencies such as 117.8, 121.5, 121.8, and 126.3 MHz also may be worth checking.

Nearly two years ago, for the first time ever, amateur radio operators around the world had the opportunity to work a ham, W5LFL, astronaut Dr. Owen Garriott from the flight deck of the Space Shuttle *Columbia*.

With his 5-watt, hand-held, 2-meter ham transceiver, Garriott transmitted on 145.55 MHz, while receiving signals from earthbound hams on some 10 to 20 frequencies between

## SPACE TALK ALPHABET SOUP

<b>ACN</b>	Ascension Island
<b>AFB</b>	Air Force Base
<b>AGAR</b>	(usually AGARxxx with several numbers following) Air Force shuttle tracking plane
<b>AGO</b>	Santiago, Chile
<b>ARIA</b>	Air Force Advanced Range Instrumentation Aircraft
<b>AGD</b>	Vandenberg AFB call sign
<b>AMSAT</b>	Amateur Radio Satellite Corporation
<b>ARRL</b>	American Radio Relay League—amateur radio society
<b>BDA</b>	Bermuda
<b>CYI</b>	Canary Islands
<b>DOMSAT</b>	Domestic satellite
<b>DSN</b>	Deep Space Network
<b>GDS</b>	Goldstone
<b>GSFC</b>	Goddard Space Flight Center
<b>GWN</b>	Guam
<b>HAW</b>	Hawaii
<b>IUS</b>	Inertial Space Stage
<b>JPL</b>	Jet Propulsion Laboratory
<b>JSC</b>	Johnson Space Center
<b>KSC</b>	Kennedy Space Center (also known as Cape Canaveral, Cape Kennedy)
<b>MAD</b>	Madrid, Spain
<b>MCC</b>	Mission Control Center
<b>MIL</b>	Meritt Island
<b>NASA</b>	National Aeronautics and Space Administration
<b>POCC</b>	Payload Operations Control Center
<b>QSL</b>	Usually a colorful postcard verifying a reported communication (could be in letter form)
<b>QUI</b>	Quito, Ecuador
<b>SSB</b>	Single side-band
<b>STDN</b>	Space Tracking and Dating Network
<b>STS</b>	(Usually STS-x with number following) Shuttle identification
<b>TDRS(S)</b>	Tracking and Data Relay Satellite (System)
<b>ULA</b>	Fairbanks, Alaska
<b>USB</b>	Upper side-band

144.910 and 145.770 MHz. The Federal Communications Commission also authorized NASA space centers to retransmit those ham communications. At Cape Canaveral, for instance, it was possible to hear them via the Spacecraft Amateur Radio Club's 2-Meter repeater on 146.94 MHz.

Hams making contacts with W5LFL (as well as non-amateur monitors who heard the signals from space) received special QSL's, thanks to the American Radio Relay League (ARRL), which, with the Amateur Radio Satellite Corp. (AMSAT), sponsored the project. Unfortunately, so far, there has been no repeat of the ham-in-space experience.

But beyond a doubt, the best listening involves radio communications between the orbiter crews and Houston Control for this, the 20,191-kHz shortwave frequency, is a good spot to try. Remember, those are shortwave relays between earth stations not direct-from-space signals; but the behind-the-scenes peek at space-shuttle operations can be fascinating.

Overhead during an earlier space mission, for instance, was a slightly exasperated ground controller who spelled out in detail just what he wanted his spaceman to do:

"Move the control back down to the first black scribe mark below the little red one!"

Amid all that high-tech gee whiz gadgetry, it's comforting to be reminded, now and then, that astronauts are only human, too. ■

# WIRELESS HOME BURGLAR ALARM SYSTEM

*BUILD AND ASSEMBLE  
YOUR VERY OWN!*



The antenna design is also a major consideration. For most transmitters sold, a balun-coil antenna is used, which works well; but it is very directional, and incorrect placement of the transmitter may prevent the signal from reaching your receiver. Also, battery life expectancy is minimal because the transmitters operate continuously when the door or window is left open.

This article discusses a new method of RF remote sensing that basically eliminates all of those difficulties.

The alarm system incorporates analog, digital, and RF technology. There is only one critical layout circuit, involving L101 of the transmitter, which is discussed later. All parts used are easily obtainable and inexpensive. Complete assembly of a one-zone alarm can be built in one evening.

An entire one-zone system is shown in Fig. 1. Each transmitter is placed at doors and windows, and even on expensive appliances. When the magnetic switch is activated, the transmitter transmits for 5 to 10 seconds and then shuts itself off to save battery power. That allows you to leave a door or window open while the rest of the perimeter is armed. All transmitters operate under 100 mW of power and transmit an RF signal, variable between 88 MHz and 108 MHz, that meets all FCC requirements. The receiver is simply any portable FM radio with an earphone jack, which provides the demodulated tone for the decoder.

The decoder is complete with entrance/exit delay and external siren, limited only by external battery power. Trickle-charge circuit is included to provide charge current for battery backup. After assembly, a one-time adjustment is required to tune all transmitters to the proper frequency and tone. Then just arm or disarm the system with one switch.

By Desi D. Stelling

OF ALL THE WIRELESS ALARM SYSTEMS AVAILABLE TODAY, the RF remote transmitter type is the most reliable. Remote sensing is achieved by a switch detecting a door or window opening. The switch activates an RF Transmitter that transmits data or a code to a receiver. The receiver decodes the signal and determines whether an alarm is made, or not.

The problem with most RF systems currently on the market is that the transmitter's RF carrier is not tunable. If you wish to install additional transmitters, you will find that they operate on a slightly different RF carrier frequency. Therefore, the receiver is unable to detect and decode alarm signals transmitted to it.

Also, some installations at locations such as metal doors or window frames may interfere with the signal by attenuating the RF carrier.

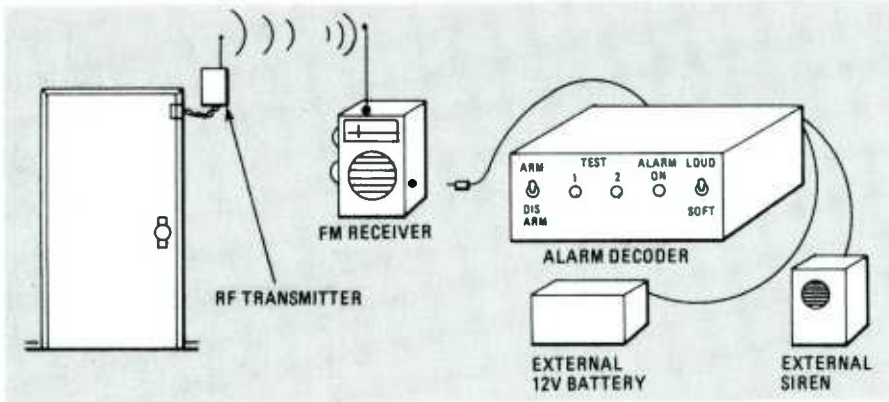


Fig. 1—Entire one-zone alarm system, incorporating analog, digital, and RF technologies. The receiver can be any portable FM radio with earphone.

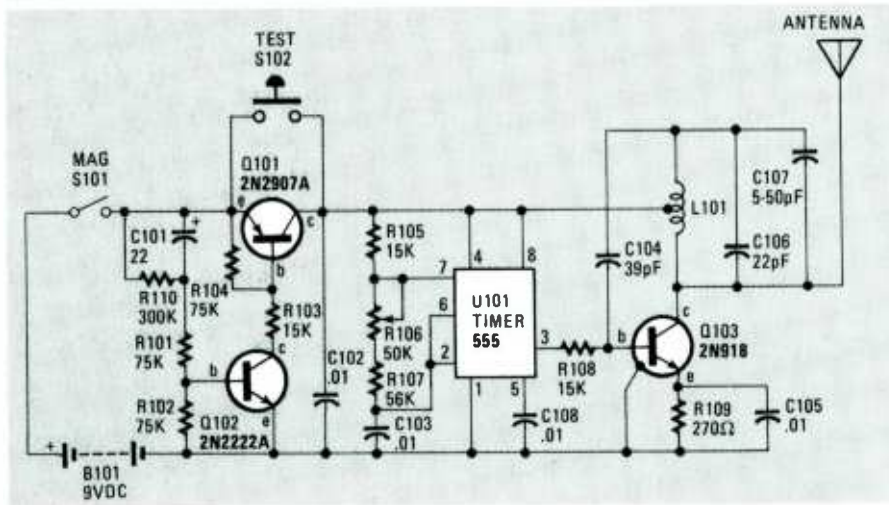


Fig. 2—RF transmitter schematic. Note that coil L101 is part of the printed-circuit board. Also, note that a magnetic reed switch is used to detect when a window or door is opened.

### Inside the RF Transmitter

Refer to Fig. 2 for the schematic diagram of the RF Transmitter. The circuit elements illustrated in the schematic diagram are in the 100 series (R103, C105, U101, etc.) so that you would not be confused with the decoder circuit elements (R3, C5, U1, etc.).

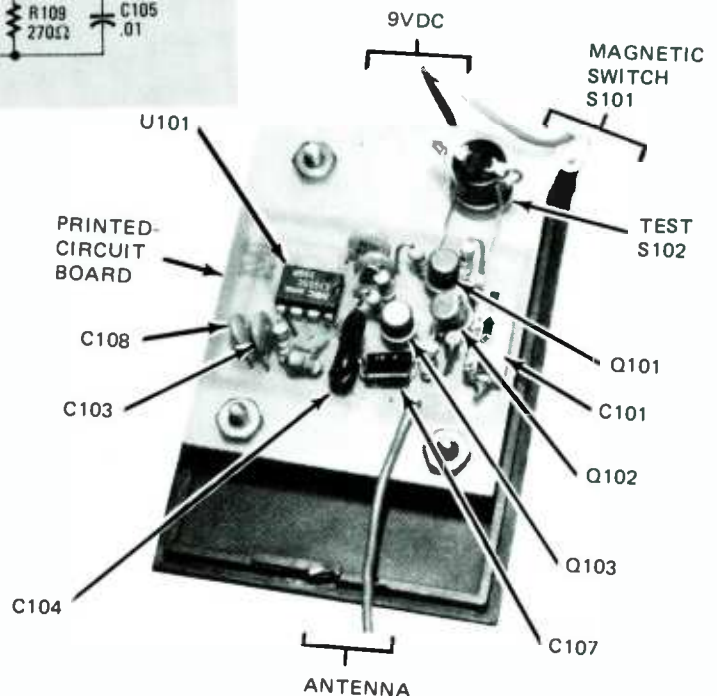
The RF Transmitter operates under 100 mW into the final stage (Q103) at a tunable frequency between 88 MHz and 108 MHz. The RF signal is gated on and off at a 1000-Hz rate by U101, a precision 555 timer integrated circuit. An auto shut-off circuit activates the transmitter for a short time to save battery power. Referring to Fig. 2, note that magnetic-reed switch S101 is used to detect the opening of a door or window. The switch is held in the open position by a magnet when the door is closed. When the door opens, the magnet is transported away from S101 and the switch contacts close.

Once switch S101 closes, 9-volts DC is applied to C101 and instantly the base of Q102 is at approximately 4.5-volts DC, which allows power to be applied to 555 timer U101 and the oscillator/driver circuitry. Due to the long time-constant of C101 and R101-R102 combination, the voltage at the base of Q102 will start to discharge. When that voltage discharges to approximately .6-volt DC, transistor Q102 will turn off causing Q101's base to pull high via R104, removing power from U101 and the oscillator section.

The shutoff circuit is bypassed by using TEST switch S102 for calibrating the RF and modulation tone discussed in the calibration procedure.

The time constant of C101 and R101-R102 should be set to approximately 10 seconds, to make sure that the receiver gets at least three seconds of transmission. Also, discharge resistor R110 is needed to bleed off the voltage on C101 to allow

Transmitter circuit with several board components called out.



the transmitter to be reactivated when switch S101 is open. Otherwise C101 will stay charged, preventing the transmitter from operating after the door has been opened and then closed.

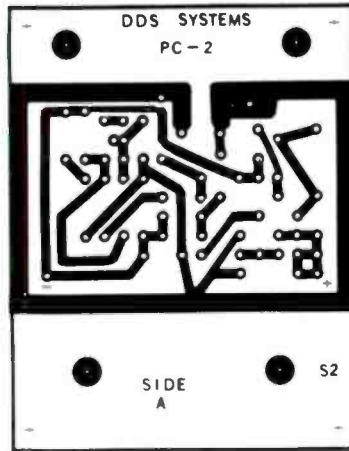
The 555 timer chip is used for U101 because of low output impedance and low cost. Also, the 555 provides precision timing using only four external parts: R105, R106, R107, and C103.

The oscillator/driver circuit using transistor Q103 is an electron-coupled oscillator (ECO) that is very reliable and precise. It uses minimum parts to achieve oscillation and ensures that plenty of power will be emitted from the antenna.





Fig. 4—Full-scale foil pattern for the RF transmitter's printed-circuit board. Though the circuit is simple enough to be built on perboard, a printed circuit is used to reduce the chances of wiring errors. Its size is such that it can be placed almost anywhere without detection.



PHONE jack J1. That signal is sent to tone-decoder integrated circuit U1 via current-limiting resistor R6. Chip U1 is an audio-tone decoder whose output goes low each time the proper tone is present on input pin 3. A two diode clamp, (D6 and D7) is used to protect the input of U1 by limiting it to  $\pm .6$  volt. That also helps prevent the tone decoder from detecting harmonics of a tone by not overdriving the chip's input circuit. Capacitor C103 is a DC blocking capacitor so that internal biasing of U1 is not changed. The center frequency of the internal voltage-controlled oscillator is determined by R8, R9, and C6. Tone decoder U1 bandwidth is determined by the value of C4 and C5. The circuit in Fig. 3 is scaled to operate at approximately 1 kHz with a frequency bandwidth of approximately 100 Hz. When the output (U1, pin 8) goes low, light-emitting diode LED1 is turned on. That provides a visual test for calibrating each transmitter's tone modulation.

Chip U2 is a CMOS 14-stage ripple counter with its own internal oscillator. The internal oscillator's frequency is set by the values of R11, R12, and C7. The frequency is approximately 24 Hz. When the enable input signal (U2, pin 2) goes low, U1 starts counting. If the input stays low for approximately 3 seconds, output from U2, pin 4 will go high, which clocks a low into the first D flip-flop in U3 at pin 3. That signifies a true alarm and LED2 will turn on. If U2, pin 12 goes back to a high during the 3-second time interval, it resets the counter back to zero, and the D flip-flop U3 will not get clocked. Therefore, all transmitters must transmit for at least 3 seconds each time they are activated, otherwise an alarm may never be detected.

A diode (D8) is used to clamp the enable input (U2, pin 2) low when a true alarm is made to keep the counter running after U1, pin 8 goes back high. After U2 has counted an

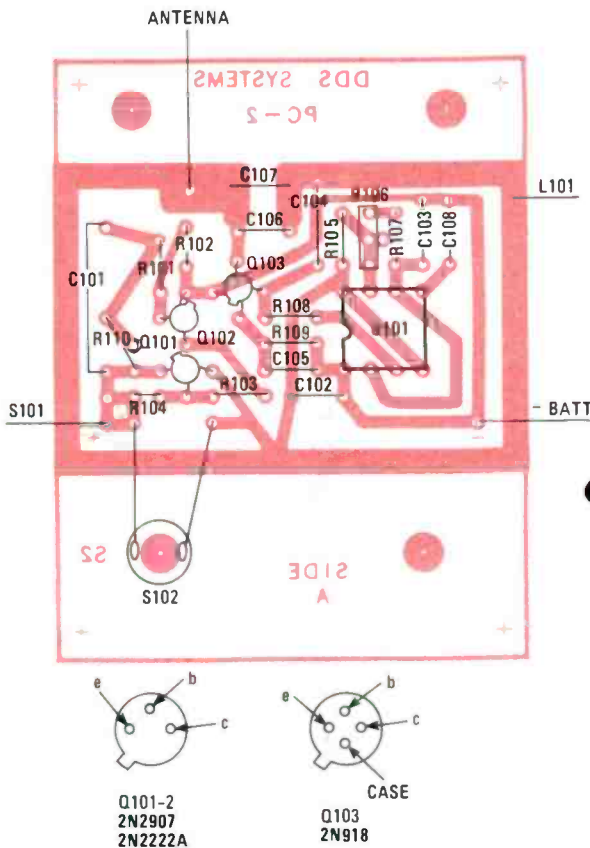


Fig. 5—Parts placement diagram for the alarm system's RF transmitter board. Be sure that all semiconductors are inserted in the proper place and correctly oriented. Package outlines are shown to aid in the placement of the transistors.

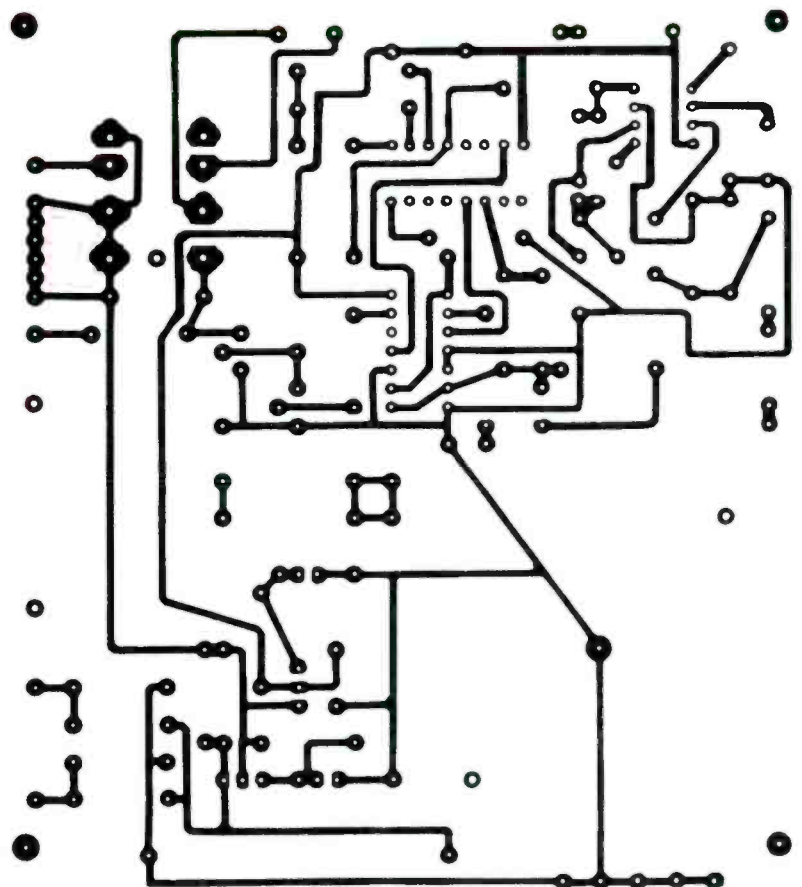


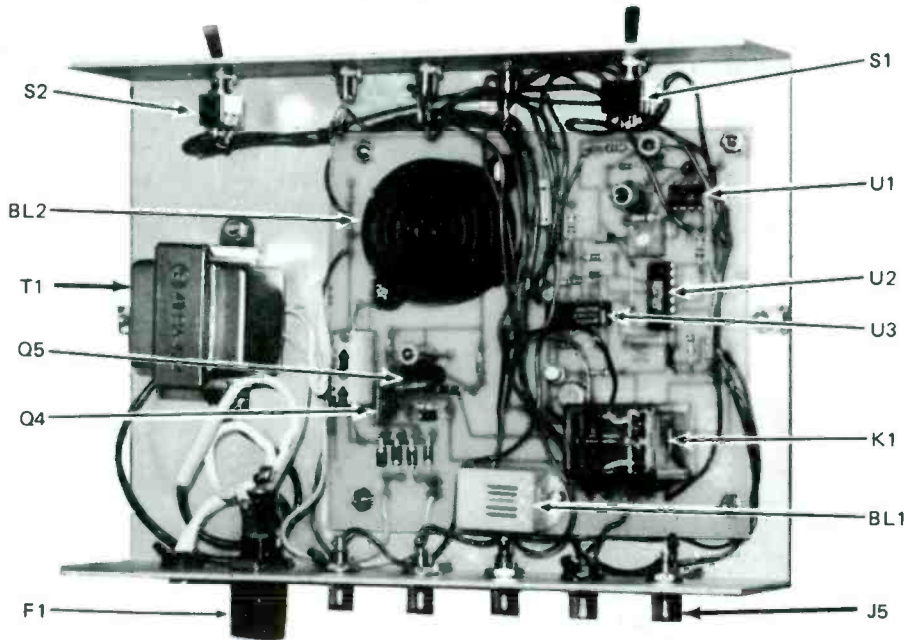
Fig. 6—Life-size, printed-circuit board, foil pattern for the decoder is shown here. The pattern may be lifted directly from the page with contact transfer film and the board can be etched from that film using a positive, photosensitive printed-circuit blank.

additional 30 seconds, output U2, pin 15 will clock a second D flip-flop (U3, pin 11). That 30-second period is considered a normal entrance delay. If more time is needed for entrance delay, simply select the next higher count—which would be approximately one minute.

When the second D flip-flop (U3) is clocked by the 30-second entrance delay count, its output U3, pin 12 will go low causing transistor Q3 to turn off, pulling up the base voltage

of transistor Q4 via resistor R18. A high on the base of Q4 will cause it to turn on, lighting LED3, enabling the relay (K1).

The relay provides power to the internal and external sirens (the latter via SIREN DDS ONLY jack J1) and also a normally-open switched output (N.O. SWITCH jack J4) for external use. The ripple counter will continue to count for approximately seven minutes before its output U2-15 will reset and rearm the alarm.



Top view of the decoder circuit board mounted in its aluminum enclosure. Notice the placement of the printed-circuit board in relation to chassis-mounted components.

## PARTS LIST FOR THE ALARM DECODER

### SEMICONDUCTORS

D1, D2, D3, D4, D5, D10—1N4001 difused-junction silicon rectifier diode  
 D6, D7, D8, D9—1N4148 silicon signal diode  
 LED1-LED3—Light-emitting diode, 20 mA  
 Q1—2N2222A NPN silicon transistor  
 Q2—2N2219A NPN silicon transistor  
 U1—LM567 tone decoder integrated circuit  
 U2—CD4060 14-stage ripple counter integrated circuit  
 U3—CD4013 dual D-flip flop integrated circuit  
 U4, Q5—LM317T 3-terminal voltage regulator chip

### RESISTORS

(All fixed resistors are 1/4-watt, 5% units)

R1—390-ohm  
 R2, R4—220-ohm  
 R3—2400-ohm  
 R5—1300-ohm  
 R6—1000-ohm  
 R7, R13, R14, R17—2000-ohm  
 R8—91,000-ohm  
 R9—20,000-ohm, 10-turn trimmer potentiometer  
 R10—100,000-ohm  
 R11, R12—220,000-ohm  
 R18, R16—10,000-ohm  
 R15—3-Megohm

### CAPACITORS

C1—250- $\mu$ F, 50-WVDC, electrolytic  
 C2-C4—1- $\mu$ F, 15-WVDC, electrolytic  
 C5—2.2- $\mu$ F, 15-WVDC, electrolytic  
 C6—.01- $\mu$ F, 15-WVDC, disc  
 C7—.1- $\mu$ F, 15-WVDC, disc  
 C8—10- $\mu$ F, 15-WVDC, electrolytic

### ADDITIONAL PARTS AND MATERIALS

T1—Line step-down power transformer: 12.6-volt, 300-mA secondary winding (Radio Shack #273-1385 or equivalent)  
 K1—DPST, 3-A, 12-15-volt DC relay (Radio Shack #275-206 or equivalent)  
 BL1—12-volt DC piezoelectric buzzer (Radio Shack #273-055 or equivalent)  
 BL2—12-volt DC siren (Radio Shack #273-060 or equivalent)  
 J1-J6—1/4-in. dia. panel-mount RCA phono jack  
 S1—DPDT, miniature, toggle switch  
 S1—SPDT, miniature, toggle switch  
 Aluminum enclosure (8-1/8" W  $\times$  1-3/4" H  $\times$  6-in. D), 3AG fuse holder, 2-conductor line cord with molded plug, plastic line-cord strain relief, rubber feet, lettering decals, mounting hardware, printed-circuit materials, wire, solder, etc.

The following are available from DDS Systems, P.O. Box 5715, Glendale, AZ 85312.

Printed-circuit board—\$9.95  
 Kit of parts less enclosure and hardware—\$69.95  
 2 decals for front and rear panels—\$5.50  
 Backup battery—\$29.95  
 External siren—\$14.95

Please add \$3.50 per kit for First Class postage and handling in USA, Canada, and Mexico. Minimum \$3.50 for any order. Foreign orders add \$6.00 for shipping and handling. Remit via cashier's check or International Money order drawn on a U.S. bank. Allow 6 to 8 weeks for delivery for all orders. Arizona residents add 6% sales tax.

Switch S2 is a DPDT switch which arms or disarms the alarm. When S2 is switched to the arm mode, 9-volts DC is applied to C8 and U3, pin 6, which sets the first D flip-flop (U2) preventing it from detecting a true alarm. That provides a simple exit delay. The exit-delay time period can be changed by altering the value of either C8 or R15. Diode D9 is a blocking diode to prevent the output from U2, pin 3 from being back driven by the charge of C8. After approximately one minute U3, pin 6 will be discharged enough to remove the set input voltage allowing the first D flip-flop to function normally. The second half of S2 simply opens or closes the circuit to the sirens. That is important in the event that the relay switch freezes in the closed position, which is a common failure among alarm systems.

Switch S2 allows you to switch between loud and soft sirens so you can install the receiver/decoder at your bedside and be awakened in the event of an alarm without alerting the intruder. That provides you with a warning to escape without the intruder's knowing that an alarm has been made. If you decide to expand your alarm into a number of zones, you will also know from which entrance an alarm was activated. That is discussed later.

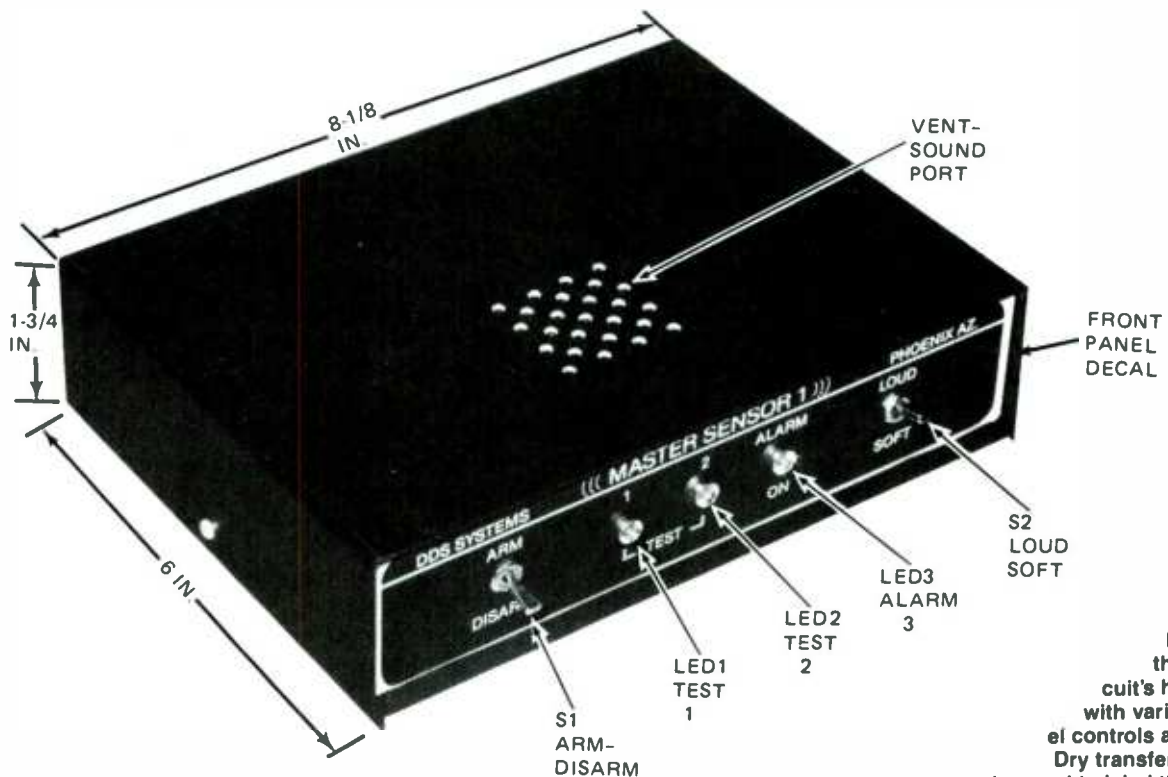
### Where the DC Comes From

The power supply in the Alarm Decoder consists of an AC step-down transformer, T1, (refer to Fig. 3) with a full-wave rectifier (D1-D4) and two adjustable, 3-terminal regulators (U4 and U5) along with filtering capacitors (C1 and C2). Transistor U4 is scaled to regulate at approximately +13.5-volts DC which is directly connected to the external battery (via EXT. BATT. +VDC jack J5) and U5 voltage regulator input terminal.

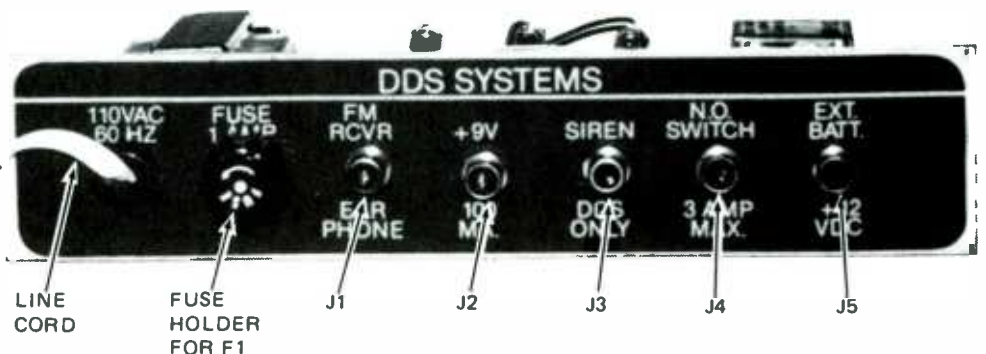
Diode D5 is used to protect U4 from being damaged by any external voltage transients. Resistor R1 provides extra current from the rectifier circuit in the event the external battery prevents U4 from regulating at the proper voltage. That helps ensure that Q2 has enough voltage on its input to regulate the voltage at a +9-volts DC output. The +9v 100mA jack J2 provides power for the FM receiver.

### Zoning

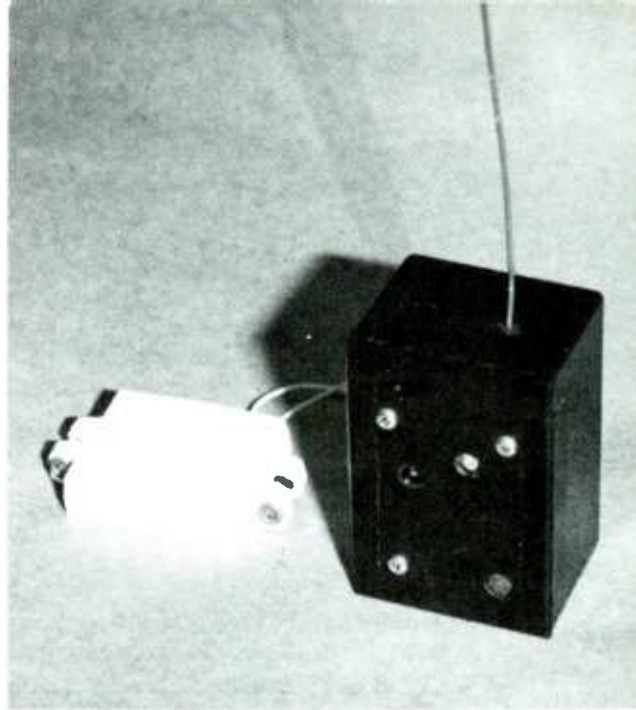
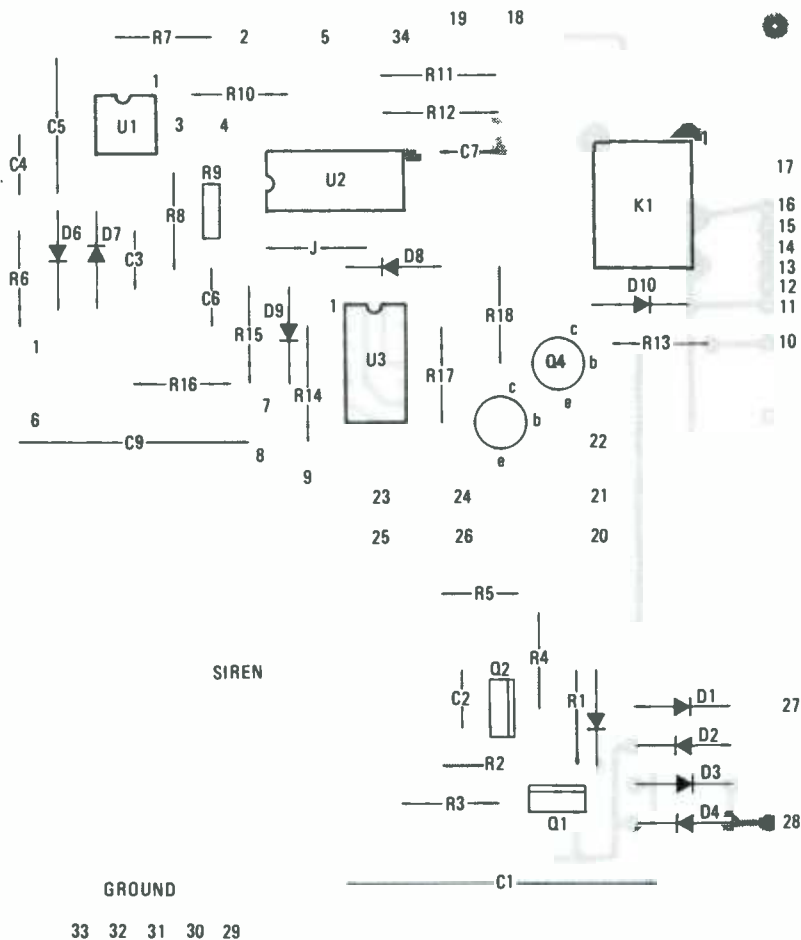
Zoning is a technique for assigning a separate channel for each transmitter or a group of transmitters. That allows you to know immediately which entrance or zone is being activated. By simply cascading a number of tone decoders with all



Dimensions of the decoder circuit's housing, along with various front panel controls and indicators. Dry transfer lettering may be used to label the front panel.



Rear panel with several input and output jacks shown. Note: Labeling the jacks in this manner makes for easier installation. Also note that the line cord (left) is mounted with strain relief next to the fuse holder.



A magnetic contact switch (the sensory device) is connected to the transmitter through a length of wire.

Fig. 7—Decoder circuit parts-placement diagram. Strict attention must be paid to the orientation of polarized devices and IC's.

outputs OR'ed together to replace U1, and a latch light-emitting diode driver to store the alarm zone, any number of zones may be used. The latch is triggered by U3, pin 2, which goes high each time an alarm is made.

### Calibration

When calibrating your Wireless Alarm System, remember that the FM receiver should be centrally located in the home to ensure that all transmitters will be detected. Tune your FM receiver near the low end of the FM band (88–95 MHz) at an unused spot on the dial. That allows the transmitters to perform in peak power, limited by oscillator speed. Reception from adjacent stations should be avoided to prevent false alarms from occurring.

Once you have done that, begin locating your transmitters where you want them. Make sure that the receiver can detect the audible tone by pressing the test switch on the transmitter and adjusting C7 to the frequency to which your receiver is tuned. Install all transmitters and adjust their output frequencies before you adjust the tone, R6. When the transmitters are in place, connect the decoder to the earphone jack of the receiver and begin tuning each transmitter's tone via R6, until Test 1 light-emitting diode (LED1) goes on. Now you have completed all adjustments required and the alarm system is ready to use. Every 2 to 3 months each transmitter should be tested to ensure that the battery is good. Marking the batteries with the date when installing them will keep a record of life expectancy.

You should also be aware that many FM receivers tend to drift with time, and the better quality receiver you use to support this circuit, the more reliable it will prove to be.

### Construction

Printed-circuit boards are used to make construction simpler and reduce the likelihood of making a wiring error. Figs. 4 and 6 are life-size drawings of the printed-circuit foils for the transmitter and alarm decoder, respectively. Figs. 5 and 7 are the parts-location diagrams for both circuits. The numbered circuit points in the schematic diagram for the alarm decoder (Fig. 3) correspond to the numbered solder pads in Fig. 7. Between those two diagrams you should have no trouble interconnecting the circuit elements mounted on the front and rear panels of the unit.

If you make your own printed-circuit boards, it is acceptable to introduce variations in the alarm decoder. Do not make any modifications or size changes in the transmitter's printed-circuit board. Here you will be fooling with RC circuits that may de-tune the output frequency beyond the reception range of the FM receiver. Maybe the transmitter circuit will fail to radiate energy at any band, or radiate energy in the RF spectrum where it should not be.

By mounting S102 directly on the transmitter's printed-circuit board, its shaft can be used to mount the assembly in a small plastic box. No metal enclosure should be used. The two wires from magnetic switch S101 should be at least 18-inches long so as to allow proper placement of the transmitters. The antenna can be longer if more signal strength is needed.

The alarm decoder can be constructed in any type of enclosure. No special layout and assembly is needed, because only audio-frequency and slow-speed counting signals are used. Make sure not to overload the power supply with external sirens.

I CAUTIONED MY SON TO KEEP HIS HANDS OFF A PIECE OF equipment in my workshop; I told him he might get a shock. He asked, "What's a shock?"

After years of playing with and taking apart transistor radios, intercoms, and other equipment, my son had never gotten an electrical shock! I remembered being knocked across the room by electrical equipment when I was in grade school. After being shocked, I spoke to some TV repairmen who taught me what not to touch when "experimenting" with electronics. Nothing was transistorized back then: most equipment had high voltages everywhere. Not everyone who received a shock was as lucky as I.

Even today, a lot of electronics equipment contains dangerous voltages and currents. A great many steps can be taken to make working with electricity safe. The safety measures described in this article can be applied to your work or hobby.

### **Making Your Workshop Safe**

Home workshops of any complexity should be inspected at least once by a licensed electrician. The electrician can make sure that home insurance is not invalidated by the violation of local electrical codes. He may also find unsafe wiring and fixtures; and the electrician will know about items such as what size and type of wire can be run in certain areas and what types of outlets are acceptable for certain loads. He may not have to do anything but look, so the cost may not be excessive.

I used to think of fuses as nuisances. They blew periodically for no apparent reason, as when an electric heater and a vacuum cleaner were plugged in near each other. It was bothersome to replace fuses. Then one day I accidentally connected the two sides of the AC power line together in a radio. When the radio was turned on, its frayed line cord literally exploded, but the 30-ampere house fuse did not blow. Since then I have preferred 5- or 10-ampere fuses on my workbench. They blow at the slightest provocation, but do not leave me in darkness because the house fuse is still intact (usually).

Any active workshop is going to have wires strung all over. There seems to be no way to avoid that, but what you can avoid is having it all tumble down on you. Mount what outlet boxes and junction points you can. This will prevent the problems which arise when cords pull outlet boxes down onto other pieces of equipment. Also, computers and other equipment can be harmed by power surges or outages. Just jiggling a computer's power cord can create transients which erase disks and do other nasty things.

### **SAFETY IN THE WORKSHOP**

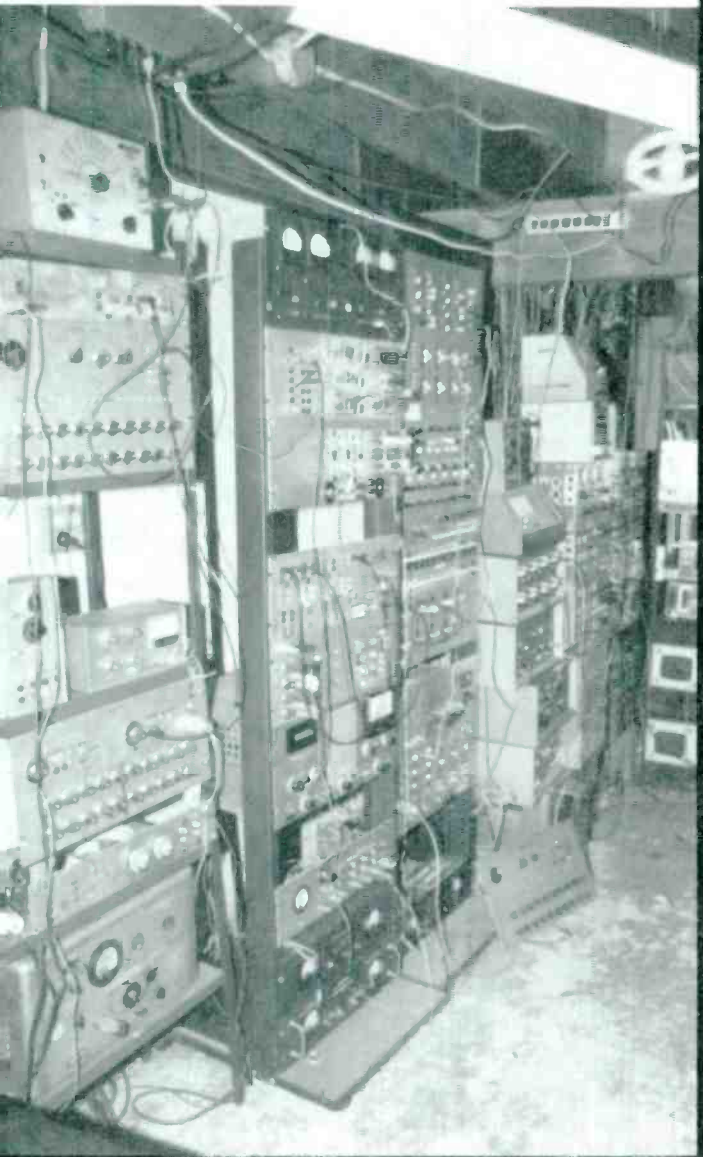
1. Have an approved AC power source.
2. Have separate fuses for lighting.
3. Securely mount electrical outlets and power wires.
4. Have a master equipment power switch.
5. Have adequate security.
6. Have a fire alarm.
7. Protect against water damage.
8. Watch visitors.
9. Have lightning protection.
10. Be wary of power tools.
11. Have proper grounding.
12. Have adequate wire power-ratings.
13. Phase power outlets.
14. Provide safe surroundings for hot instruments.

# *THE KILLER THAT LURKS IN YOUR HOME SHOP....*

By Ray Fish, Ph.D., M.D.



# Electrical Shock!

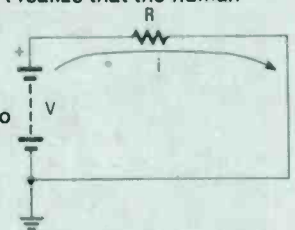


When leaving a work area, it sometimes seems to be impossible to remember to turn everything off. One main switch will give you peace of mind; when that switch is off, there is no worry about soldering irons or unproven equipment being left on, or children getting shocked on the equipment.

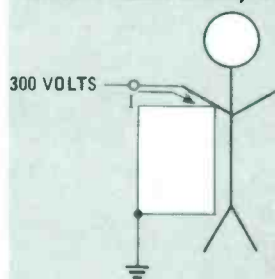
While buying switches and outlets, consider buying a few "extra" items. Additional power switches and fuses on each workbench are useful if you receive a shock or if equipment starts to burn. While you are at the hardware store, think of your work area's security and safety. Locks on doors and windows should be adequate to keep children and burglars out; but access for trusted adults is important because of the possibility of fire. Fire-alarm systems are available which automatically phone a local alarm company; less elaborate fire alarms cost as little as \$10. Lightning protection bypasses for antennas, and surge protectors for power lines, can be obtained at hardware stores or electronics supply houses. Such devices are now more available because transient-sensitive computers are so popular.

Water can cause problems, especially if your workshop is in the basement. A wet floor can damage your equipment, cause rust to form, and bring electrical shock when you touch relatively low-voltage sources. In a basement, a sump pump is a worthwhile investment. Water-powered pumps are difficult to find, but are useful during storms which cause the

**FIG. 1—**Ohm's Law is no mystery to the readers of Hands-on Electronics; however, a few don't realize that the human body obeys the same law, often with disastrous results. The current is shown as a "small"  $I$ , because the resistance of the body varies between any two contact points, the degree of pressure at the contact points, and the skin's conductivity.



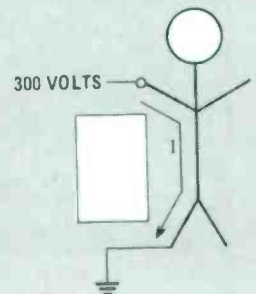
**Fig. 2—**Pardon our stick figure for a person in this drawing. The person's hand is touching 300-volts (AC or DC—it doesn't matter which) and the elbow is touching a metal cabinet. All other parts of the victim's body are reasonably isolated from electrical ground.



Assuming a resistance path of 10,000 ohms, the current in the victim's arm will be 30 mA; it will produce a very painful shock. Since the current does not flow through the victim's head or chest area, the shock experience will not directly affect the heart or breathing.

**Fig. 3—**In this illustration the person's hand is touching 300 volts and grounded through one leg. The current path is passing through the chest area.

Assuming a 300,000-ohm resistance path, a current of 1 mA will flow. The person may experience anything from no sensation to a tingling sensation. The heart will not be affected; however, should the resistive path be lowered to 3000 ohms (which is possible and probable) a killing 100-mA current will most likely stop the heart.



electricity to go out if only for a short period of time.

Even after you are safe in your workshop, others will still be at risk. Do not assume that friends, relatives, and other visitors know about electricity. Many people do *not* know that it is dangerous to touch equipment in an enclosure or randomly connect patch cords to panels. Tell visitors not to touch anything, and then watch them.

Power tools give electrical shocks when insulation wears off motor windings, or insulation becomes brittle because of heat or long use. Tools may cut insulation when a moving part brushes against a wire. Power tools are dangerous mechanically as well as electrically: They can cut people and can throw shavings into one's eyes. Know the specific dangers of each of your power tools. Use electrical safety features or locked power switches which prevent children (and unauthorized adults) from using the tools.

One day after a heavy rain I found myself receiving a shock whenever I touched *any* equipment in my workshop. At that time, there was an old rug on the floor which had become damp. I grounded one side of a voltmeter to the center screw on an electrical outlet box, then put a wire in series with the other lead so that I could measure the voltages on the cases of each piece of equipment. The voltage between ground and each chassis measured between 5- and 100-volts AC. Placing the voltmeter probe on the rug in various places brought readings as high as 80-volts AC! (A "standing wave" voltage?) That actually made sense because some metal chassis were sitting on the damp rug.

Since that shocking experience, I have provided chassis and cabinet grounds for most of my equipment. Three-wire line cords, which include a ground wire, are usually used. When I buy a used piece of equipment I check the need for grounding by measuring the voltage to ground present on the cabinet of the equipment. That is done with the two-wire line cord plugged in both ways.

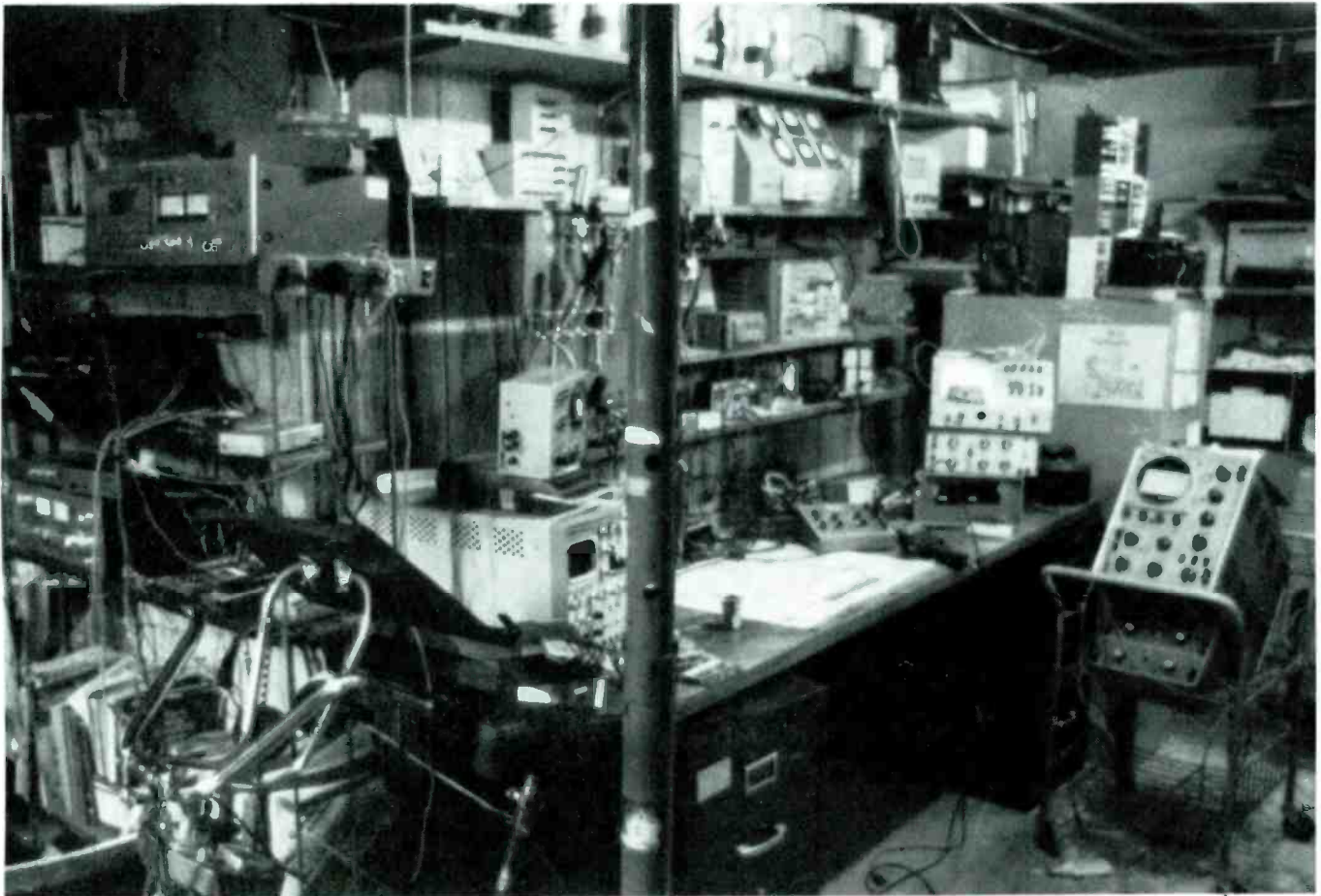
If you have lived in older homes, you may have noticed that the wiring gets hot at times; that is really scary in some old wooden houses. Use wiring and outlets (but not fuses) rated for much more power than you will use. Resistance in the wires will lower the voltage that your equipment gets and may cause heating of wires.

In addition to checking power ratings, check phase. (Is each power wire connected to the proper prong?) Phase can be checked with small devices that are available in hardware stores. They cost under \$5 and have pretty lights: some can be left plugged in permanently (if they do not heat up). Once phase is right, make sure that power switches cut off the hot wire (or both wires).

Old electrical wiring is not the only thing that can start fires. Soldering irons are *very* hot; they should have adequate holders. Papers, spray cans, and chemicals should not be near soldering irons and other heat sources.

### Personal Safety While Working

"Use one hand at a time." "Work with one hand in your pocket." I have read those suggestions many times over the



A view of the workshop used by the author. On the wall near the center of the picture can be seen an equipment power box with built-in switch. Separate switches and fuses are provided for lights and test equipment. Equipment on shelves and racks are securely mounted so that they can not be pulled off by their test leads.



last 30 years. They sound good, but just try working with one hand! It is more realistic to remember that you are at greater risk when you touch two things at once...you may become part of a circuit. Current goes from one point to another—and one point may be a damp floor or an equipment cabinet. Try not to touch two things at the same time. Wear shoes when working and have a rubber mat under your feet and chair.

Many people like to see their own heartbeat. It is tempting to try to measure electrocardiograms and other signals on yourself and others. But unless you have special training and equipment, that can be dangerous.

It saves time to yank wires from the wall. However, it is easier on the equipment to pull wires from sockets by the strong connector housing, not the wire at a distance. Unseen breaks in ground wires lead to shock hazards.

Isolation transformers can give an added measure of safety. Those 1:1 transformers provide 117-volts AC, which does not have a common ground with wall outlet power. Such transformers are especially useful in working on equipment that has one side of the powerline connected to the chassis. Remember that high voltages will still be present within the chassis, though they will be isolated from ground. Actually, the isolation is not perfect: There is capacitive and inductive coupling between the primary and secondary sides of the transformer.

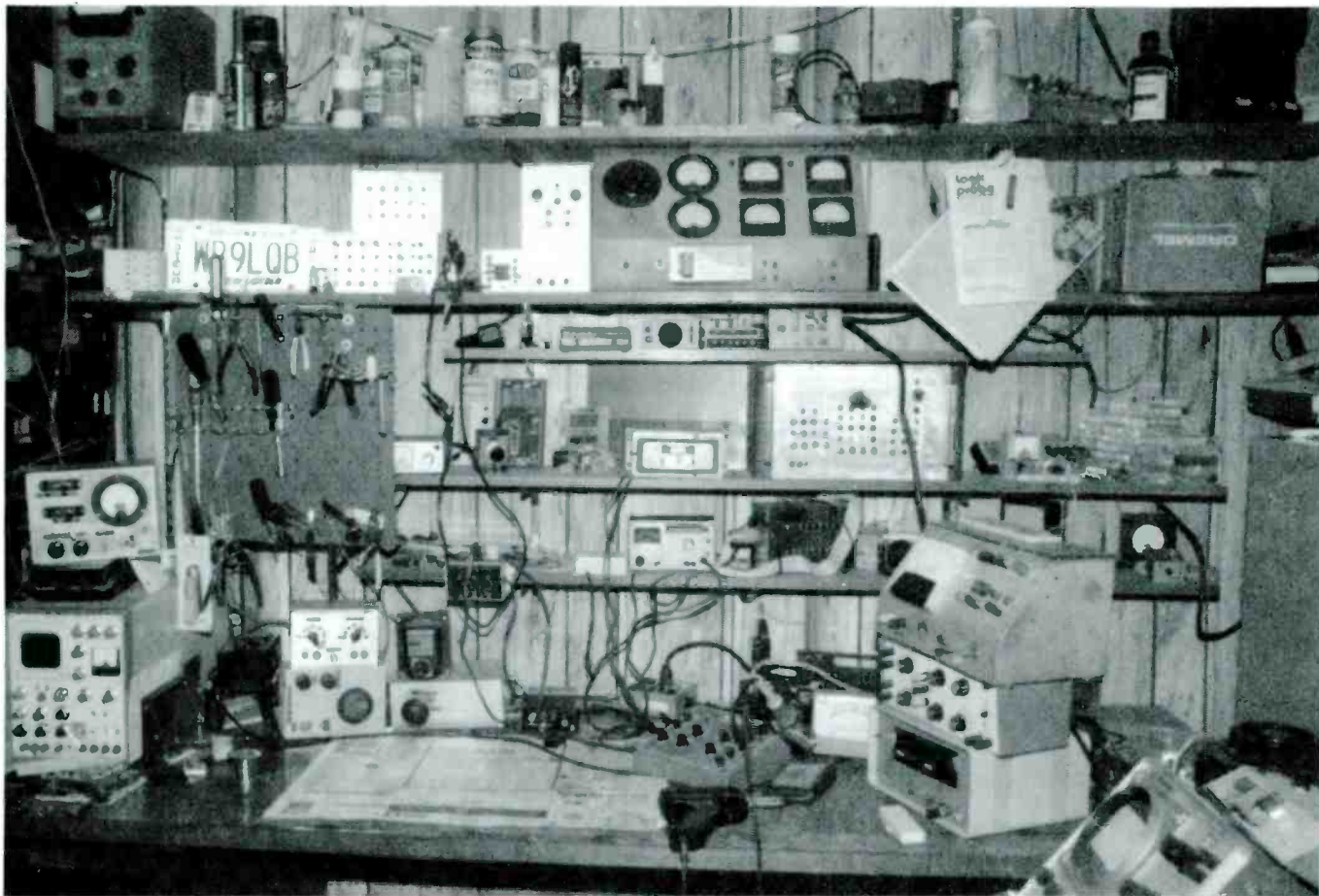
Other devices that can provide additional safety are power interlocks and power-supply discharge devices. Those devices shut off equipment and sometimes also discharge stor-

## PERSONAL SAFETY WHEN WORKING ON ELECTRICAL EQUIPMENT

1. Use one hand at a time.
2. Do not connect people to your circuits.
3. Handle wires and connectors gently.
4. Use isolation transformers.
5. Be wary of high voltages.
6. Use and respect power interlocks.
7. Discharge storage capacitors.
8. Do not reach into the dark.
9. Defeat remotely controlled power sources.
10. Replace safety covers.
11. Avoid metal on the hands.
12. Do not work when wet.
13. Work with others.
14. Know environmental limitations of equipment.
15. Do not work when tired or drinking alcohol.

age capacitors inside the equipment. An interlock may become defective, so always unplug the equipment and make sure that storage devices really are discharged.

I remember the first time that I measured the 20,000 volts on a television picture tube. The meter registered when the high-voltage probe was still half an inch from the point being measured. If working with very high voltages, know the strange properties of the voltage range involved. High voltages can arc certain distances; materials which are insulators can act as conductors with extremely high voltages, and safety gloves may be ineffective if they have tiny holes.



The author's workbench is well organized. Several power switches and isolation transformers provide power for equipment being tested. Chemicals are kept on the top shelf, away from soldering irons. The tabletop does not conduct electricity.

Before working on equipment, discharge storage capacitors and cathode ray tubes through a suitable resistance. Measure the voltages on storage devices using an insulated probe and meter that can handle the voltage which might be present.

Things can be dangerous even if you do not see or know about them. Do not reach into cabinets or areas where you cannot see; loose wires can swing around, carrying dangerous voltages. Do not work on equipment that can be turned on without your knowing it. It should not be possible that a person in another room, or a timer, would apply power to the device you are working on.

High-voltage terminals and power supplies often have safety cages or covers. They may be removed when the power is off, and capacitors are discharged, but replace them each time you turn the power back on.

Take off watches, rings, and other metal objects when working around high voltages or inductive fields. If you are wet or sweaty, or if the floor is wet, do not work on equipment.

Work with others. If help is needed, it will be there. Like many other suggestions, that one cannot always be followed: We all work alone at times. If you do work alone, be extra careful.

Know the environmental limitations of equipment. Most electronics equipment cannot be used out of doors. Water will cause shorts and mechanical damage to most home power tools and electronic devices.

I often work until a project is finished. I worked 40 hours straight on a shortwave radio kit once. Fortunately, it did not explode when I plugged it in; still, it would have been better to have spread the work out. Some components were damaged because the work was not carefully done. You make mistakes when you are tired.

Depressant drugs and alcohol can also make accidents happen. A large percentage (well over half) of serious accidents of all kinds in this country are alcohol-related. You don't have to be dead drunk to have your judgment impaired.

### Equipment Design and Experiments

When designing equipment, you can avoid the traps which are built into so many pieces of equipment. It should be assumed that the case will be touched, so remember that any paint may be scratched off, leaving bare metal. Non-conductive cases and knobs are one solution to the problem. Conductive cases need to be grounded, because capacitive coupling from wires and circuit elements may give enough current to cause a problem. If rough handling or mobile operation is expected, the case and internal mountings should be mechanically adequate.

*Any terminals that can be touched will be.* Any potentially dangerous contacts should be difficult to touch: A wire with an alligator clip on the end of it coming from a hole in the chassis would be unacceptable. Coaxial connectors are ideal; they are used on some power supplies. Such connectors must

## SHOCK HITS THE ROAD



Common sense tells you that if electricity can kill you at home, it can kill you at work and on the streets. In the scene above a severe thunderstorm toppled trees in Cincinnati tearing down high-voltage wires. Should you happen upon such a scene do not leave your car—stay inside. If possible, make a U-turn or back out of the area. Should your car touch a high-voltage wire every point in the car will be at that high voltage, leaving the interior electrically safe.

be clearly marked, so that it is clear that they are power sources. Remember that connectors have voltage and current ratings which cannot be exceeded.

Wires running through a chassis should be protected by grommets or other devices.

*Insulate hot points.* Points having power-line or other high voltages inside an enclosure may be covered with electrical tape or an insulating compound. Dangerous voltages are those over 40 volts which can supply 5 milliamperes or more.

*Use warning lights.* High-voltage power supplies and transmitters should have a warning light. The light serves as a warning that high voltage is present and makes it difficult to forget to turn the device off when it is no longer needed. A lot of lights also make your equipment look nice.

Power-line surges are common. It is unfortunate and unnecessary that some equipment fails, or starts a fire, when powerline surges occur, or line voltage is not exactly right, or power is intermittently connected and disconnected. Surge suppressors designed for computers are readily available in a variety of power ratings.

Lightning surges are a difficult problem. *The ARRL Radio Amateur's Handbook* or other reference should be consulted about antennas and other outside installations.

Thermal burns of the skin, and fires can be caused by inadequate ventilation of equipment. Some expensive stereo equipment will go up in smoke if a book is laid on top of the case. Look for any equipment that depends on easily blocked ventilation holes. Mount rubber feet or other devices around the holes so they cannot be easily covered.

Whenever you start a new kind of project, new dangers show themselves. Know about the dangers of what you are working with: laser light, microwaves, heat, moving parts, radioactivity, acids, alkali, x-rays, or high-intensity sound.

Think of your equipment's environment. Mechanical, thermal, and moisture design considerations are entirely different for mobile or outdoor equipment. Equipment failure, fires, and electrical shocks may result when such considerations are ignored.

Many electrical and electronic components can handle only a fraction of their rated power at high environmental temperatures. To the extent that it is possible, do not make the situation worse by designing equipment which heats itself significantly above the environmental temperature.

### Treating Electrical Shock

Electrical shock can make a person unconscious or can paralyze the muscles. People nearby may be paralyzed by fear or may act ineffectively and dangerously.

When someone receives an electrical shock, it is first necessary to separate the person from the current source. That may be done by turning the main power off or unplugging the appliance involved. It is important to avoid coming into contact with electricity and getting shocked in the rescue attempt. Using dry cloth, a broom, or other non-conductive materials to move a person or wire is usually adequate, except with thousands of volts.

After removing a person from the source of electricity, the status of circulation and breathing must be checked. If the breathing muscles are paralyzed or the heart is not beating, the brain will die within minutes unless CPR (cardiopulmonary resuscitation) is done. It is necessary to take a CPR course and practice with mannequins to get the feel of proper CPR. When doing CPR, call an ambulance with as little interruption in the CPR as possible.

## DESIGN OF EQUIPMENT AND EXPERIMENTS

1. Have shockproof equipment cases.
2. Protect inputs and outputs.
3. Insulate hot points.
4. Use warning lights.
5. Provide surge protection.
6. Provide ventilation.
7. Think of special dangers.
8. Think of the equipment's environment.

## THE TREATMENT OF ELECTRICAL SHOCK

1. Separate the person from the power source.
2. Check heartbeat and breathing.
3. Call an ambulance.
4. Splint possible fractures.
5. Apply cold to thermal burns.
6. Obtain medical care immediately.

If a person is to be moved, it is important to splint possible fractures, including the spine. Fractures are difficult to detect, but might be suspected if the person had a fall, contracted muscles strongly, or was violently thrown. To immobilize the spine, keep the person lying on the back. Keep the head in a neutral position with small pillows or the equivalent on each side of the head. Moving a person while maintaining spinal immobilization is a skill that ambulance personnel are trained in.

Even with mild shocks, it is important to apply cold to burns. Clean cloths soaked with ice water will decrease tissue damage and pain during the first half hour after a burn. Ice itself (especially "dry ice") may cause more damage by freezing tissue. Deep injury due to electrical current is probably not helped by applying cold soaks to the surface. Do not apply ointments, oils, or other medicine before seeing a physician.

In the Emergency Department, complex factors are considered. Significant electrical burns can release the chemical myoglobin from damaged muscles. Myoglobin can plug the kidneys, so intravenous fluids and drugs are sometimes given to wash it out.

People with electrical burns are often observed in the hospital because the true extent of damage deep under the skin is so difficult to estimate.

Burns from flames often cause breathing problems and body-fluid loss, both of which worsen over the first few hours. Inpatient hospital admission criteria include: a). significant skin burns; b). suspicion of deeper burns; c). cardiac arrhythmias (irregular heartbeat); d). neurological problems; and e). laboratory evidence of myoglobin in the urine.

### Summary

Electrical safety is a broad, complicated subject. Each topic covered in this article could be discussed in more detail, and some topics were not mentioned at all.

That means that you are on your own. Read about the special devices and voltage ranges you are working with, and think about what you are doing. Do not work with electricity when you are tired, or taking medication which impairs judgment (especially the drug called alcohol).

Learn CPR.

When working on electronics equipment, take the time to apply all the principles discussed in this article. Post the previous charts on the wall in your workshop. ■

# HOW TO ADD CONSTANT MEMORY TO A CALCULATOR

**Make your antiquated calculator function more like its modern counterparts by giving it a memory—then, it can remember formulas that you'd rather forget!**

By Jerry Bronson

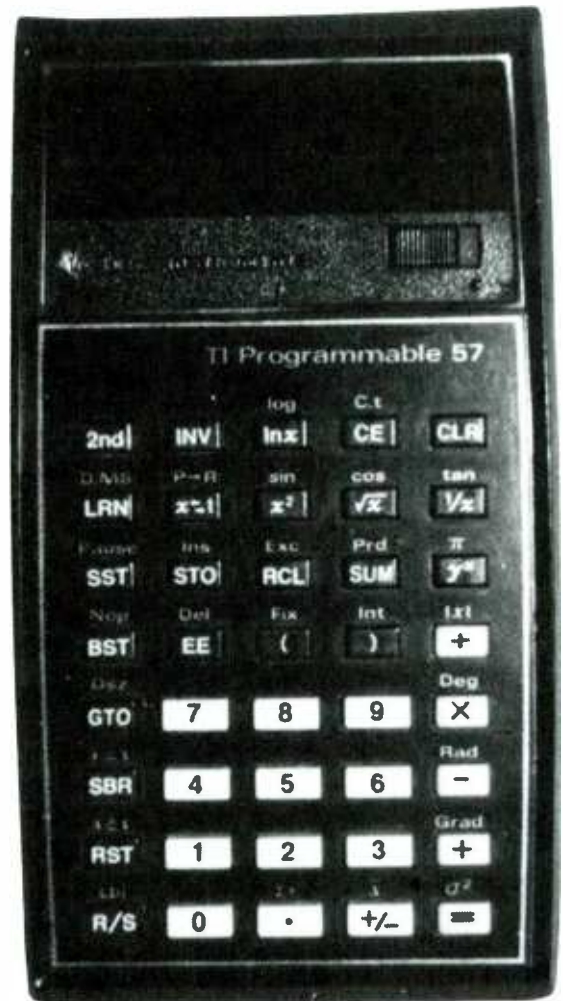
□RECALL THOSE EARLY CALCULATORS, THE ONES WITH THE LED displays? And before them were the gas-discharge and nixie-tube displays. You remember them, the ones with only four D-cell batteries that lasted almost a week. Of course, now everyone has the LCD readouts with constant memory (memory and program software is not erased when the calculator is turned off). Well, almost everyone.

There are still a few of the Jack Benny types around that have the old-fashioned archaic LED calculators, and there's no reason they don't deserve extended battery life and constant memory just like the better new ones, now is there?

Well, I'm one of those people. I have a TI-57 Programmable calculator. I love everything about it. Well, almost everything. To begin with, I find myself recharging it every Friday night. But, the most serious inconvenience is losing all my programs when I turn the calculator off. That means that I can't create a program at home and use it at school without *punching* it in again. The alternative is to leave the calculator turned on all the way to school.

On most older calculators, about 85 percent of the current is devoted to the display, so it's obvious that if the display were turned off whenever you're not reading it, battery life would be greatly extended.

Unfortunately, at least in that application, there is no one "common" wire to turn off the display. Each digit of the display has its own enable, or multiplex line. There are two possibilities in turning off the entire display. One is a switch technique (see Fig. 1A), and the other is a transistor technique (see Fig. 1B). Either each segment of the LED can be turned off, breaking eight connections (a seven segment character plus a decimal point), or each digit's multiplex line can be broken. (The author did the latter breaking 11 lines.) While the former has the advantage of breaking fewer lines, the latter gives the advantage of being able to leave on any chosen digit. Rather than adding some type of pilot light, I leave the left-most digit of the display on. When I turn off the display, I make the last result negative, leaving one segment of the display on.



Turning off the display involves breaking those connections. Turning the display back on would involve re-making the broken connections. One solution is a multi-pole, single-throw switch. While that is probably the simplest solution, it would be nice to make the state of the display software controllable. You might want to turn off the display while doing some long calculations and display the results every hundred loops. If we use transistors for the switch, we could control the display with a voltage from the calculator. It turns out that seven general purpose transistors are usually cheaper than an eight-pole switch (maybe larger) anyway. Figure 1B shows the schematic diagram of the eight-pole transistor switch used in the conversion.

## The Diode Test

The first step in the conversion of your calculator is to locate the common wires for each segment on the printed-circuit board. Usually, those lines are fairly easy to locate, as there is one line for each segment, going to consecutive pins on the driver (often one LSI IC includes the driver circuitry). The circuit board of the TI-57 programmable calculator used in that conversion is shown in Fig. 2.

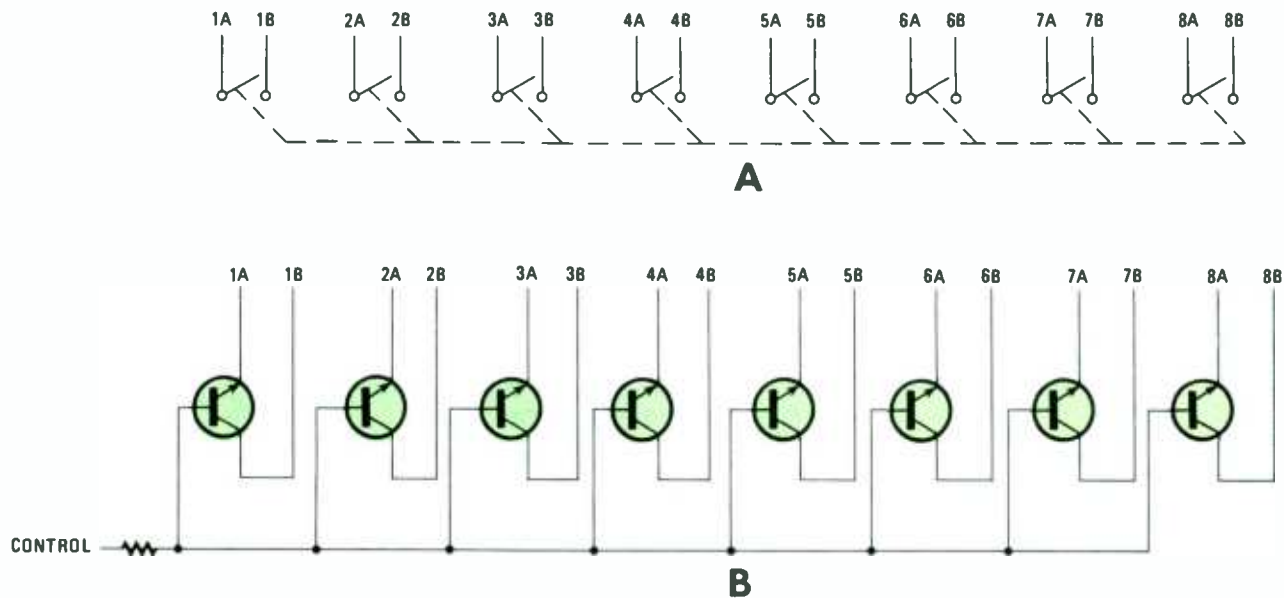


Fig. 1—Two ways you can turn on and off the LED display in your calculator. In A, an 8PST slide switch may be used. The switch would be difficult to find and install. In B, transistors are used, one transistor per switch section. Since transistors are polarized, the diode test (see text) is required.

After finding the lines, mark each one of them clearly, as shown in Fig. 3. After each line is clearly marked, carefully break one of the lines as shown in Fig. 4. When the calculator is turned on, that segment of the display will not be lit. Type in the number -88888888 E -88 to check that.

Now place across the cut foil line a test diode as shown in Fig. 5. If the digit does not light, reverse the polarity of the diode. While most displays are common-anode, there are some made common-cathode. The difference in the conversion is the polarity of the transistors (and test diodes).

The location of the diode's *anode* is the connection that the *collector* of the transistor will occupy. The diode's *cathode* connection will accommodate the *emitter* of the transistor. After the test for one of the digits is completed, carefully cut all the other lines that you marked. If you are not absolutely sure that those are the proper lines, cut them one at a time and perform the diode test on all of them.

The next step is to prepare the transistors for installation. That step will take a bit of time and *should not be rushed*. A job well done here will save hours of work later (not to mention the saving of your calculator). Take all the transistors and bend the base leads up as shown in Fig. 6. Now, carefully bend the emitter and collector leads of the first transistor so that it will fit well across the broken connection. Repeat for the rest of the transistors.

### Touch Each Base

The next step is to connect the base leads together. I chose to daisy-chain a piece of wire-wrap wire. Soldering will of course work equally well, but wire-wrapping is very well suited to that application. A drop of solder on each connection over the wrap will help insure a good, permanent connection. The bases will go to switch S1, so be sure to leave enough wire on here to reach the switch location.

After all the bases are tied, it is time to install the transistors. Begin with the left-most transistor (if you are left handed, make that the right-most). That will keep the previously installed transistors out of your way while you are working on the next one.

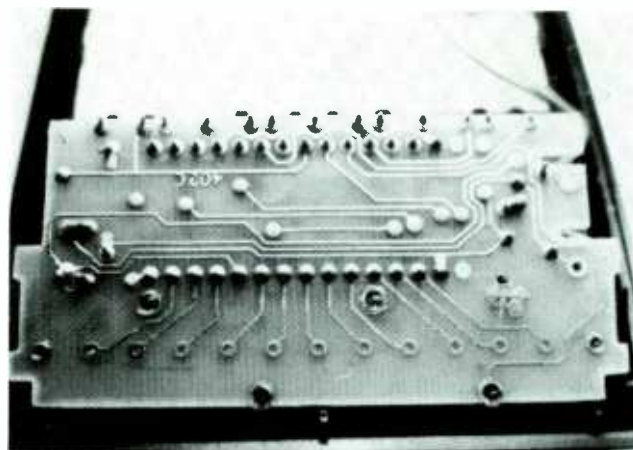


Fig. 2—This is the display-end view of the TI-57 circuit board. The lines at the bottom of the picture are going to the LED's. Those lines are usually heavier than others on the board because they carry relatively large currents.

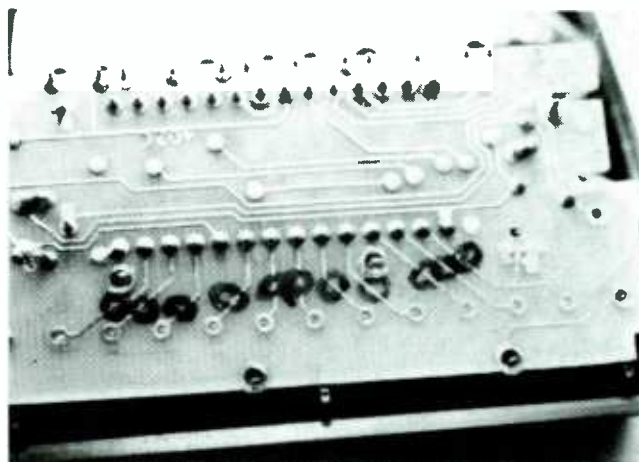


Fig. 3—The copper traces to be cut on the calculator's printed-board are circled in black with a marker pen.

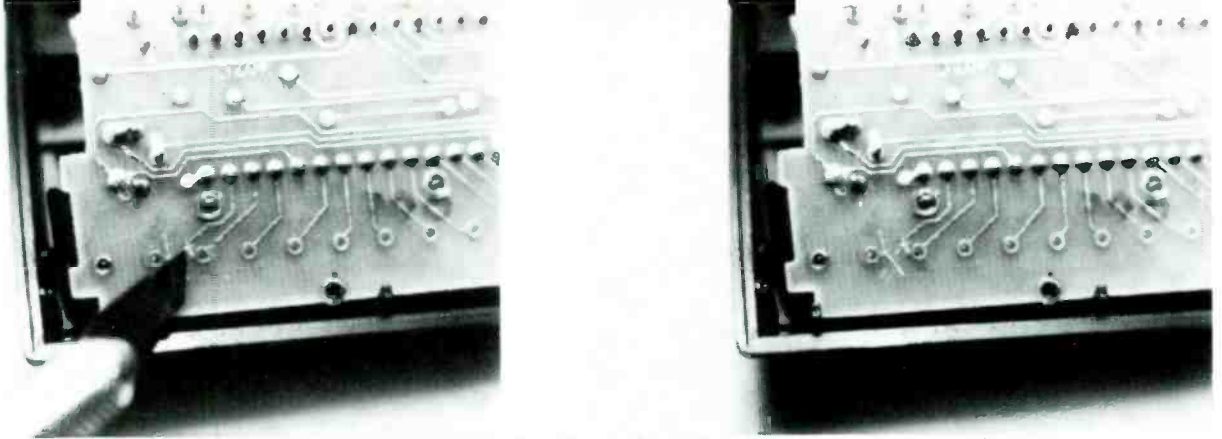


Fig. 4—Use a sharp knife, old biology scalpel, or Exacto blade to cut the copper traces on the printed-circuit board—do one trace at a time and perform the diode test. Refer to the text.

TABLE ONE—TROUBLESHOOTING GUIDE

Symptom	Cause and Remedy
One of the digits is always on.	Leaky or shorted transistor. Check for solder bridges and shorts. Replace transistor.
One of the digits is always off.	Bad or open transistor. Check connection to the base, emitter, and collector. Replace transistor.
One of the digits is dim.	See Symptom for <i>Always off</i> .
All of the digits are off.	Is calculator turned on? Is S1 in the proper position? Is battery charged? Defective resistor. Replace resistor. Poor wiring. Check for solder bridges, cold solder joints, broken wire, cracked PC board, etc.
All of the digits are on.	Switch S1 is shorted.

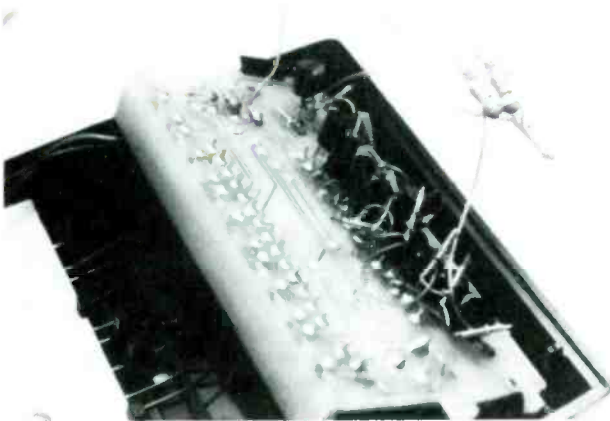
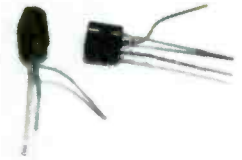


Fig. 5—The diode test is applied after the first trace is cut. That tells us that we cut the correct trace and where to place the transistor's collector and emitter. Refer to the text.

Fig. 6—Here are two transistors with their base leads bent upward so that they can be easily connected to other bases. Just about any switching PNP transistor, and most audio PNP transistors, will do the job.



Begin by heatsinking the transistor. The next step is to get the transistor in place and keep it there. A third hand comes in very handy here. Once in place, carefully solder the emitter and collector leads of the transistor in place. Connect the free lead of R1 to + VCC and turn the calculator on. The first digit of the display should go on. It is much easier to catch a mistake at that point than it will be after all the transistors are soldered in, so test it now. After the first digit is working properly, turn the calculator off and solder the next transistor in. Repeat until all the transistors are in place.

After all the transistors are in and the test proves good for all the digits, connect the free end of R1 to switch S1. The other tap of the switch goes to the + side of the battery pack.

There are many possibilities for controlling the display other than the simple switch here. If you use a momentary switch, you can push the switch whenever you need to check a result. If you connect the left-most digit's segment to the resistor, the display will turn on whenever the calculator comes up with a negative number. There are many other possibilities, and any combination of them is limited only by your imagination.

Your calculator should be re-assembled and tested. It should operate as it did before the modification. Should you run into a little difficulty, refer to the troubleshooting suggestions in Table 1. By the way, be careful not to make accidental entries into the calculator as you transport it from here to there, and back again.

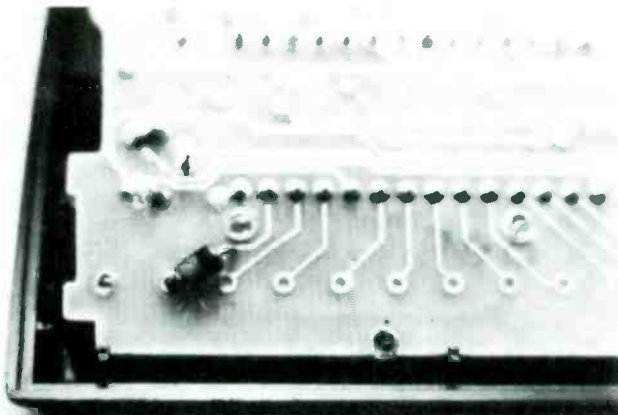


Fig. 7—Here's what the finished work will look like. Wire-wrap wire is used because it is insulated, very thin, and can be tucked away when the calculator case is closed.

# THE PLASMA MACHINE

**You can control the very basic forces of nature with your finger tip! Direct the flow of plasma and harness the unknown!**

By Robert Iannini

□ PLASMA IS OFTEN CONSIDERED TO BE THE FOURTH STATE of matter. It consists of atoms that are ionized and it demonstrates peculiar effects unlike the other three forms of matter—solid, liquid, and gas.

The Plasma Machine is a device that demonstrates the presence of a plasma produced by high-frequency, high-voltage, electrical discharge through a low-pressure gas. The plasma created produces a visible and bizarre lighting effect that is totally different than any other presently existing phenomenon. Columns of pinkish and purplish plasma are attracted to external influences, such as fingers and other objects, when placed on or near the display container. Those columns of plasma light span the entire length of the display container, dancing and writhing with a tornado type effect. Balls of plasma and *fingers* are created and controlled by simply touching the container. That effect cannot be effectively or justifiably described in words. The effect can only be appreciated when actually observed.

The Plasma Machine is intended for display purposes such as advertising, conversation piece, novelty decoration, special effects, etc. The device can also be an educational, science-fair project demonstrating plasma controlled by electrically and magnetically induced fields. Special materials treated by a controlled plasma beam can also be realized.

## What It Is

The Plasma Machine consists of a low-powered, high-frequency, high-voltage generator that is somewhat like the high-voltage circuit in a television receiver. The generator produces a voltage with the necessary parameters for obtaining the described plasma effect. The generator uses a circuit consisting of transistors that rapidly switch current through a winding on a ferrite core of a high-voltage, resonant transformer (similar to a TV flyback transformer). Power for the transistors is obtained from a step-down transformer and rectifier combination.

A clear, glass container or jar of suitable size is evacuated to a low gas pressure of less than 2 *torrs* and uses the metal cover as a convenient discharge element. The metal cover of this container also provides an excellent low-cost approach to constructing a home-made or laboratory model without expensive glass-blowing facilities. The display jar has provision for depressurizing and then being permanently sealed. Again, the metal cover of a pickle jar makes an excellent choice because a piece of copper capillary can be soldered directly to it, forming a good vacuum-tight seal and allowing pinching-off for sealing. Should the display container require the vacuum to be restored, the pinched capillary tubing is opened for connection to the vacuum system.

The display jar is mounted on a suitable stand that houses the high-voltage generator beneath it. The entire assembly resembles a water cooler. To some, it looks like a gumball machine. Refer to Fig. 1.

The following instructions show how to assemble the Plasma Machine that is capable of generating a plasma *tornado*. That phenomenon uses nature's fourth state of matter to produce the effect. While the Plasma Machine doesn't do anything really useful, with the exception of deodorizing putrid air, it does demonstrate an interesting display of that form of energy. Several local pubs in the area have purchased those units assembled and ready to use. They place them on the bar, or other appropriate location, and allow the customers to control the plasma tornado using their fingers, hands, pencil points, etc.

Science Fair buffs can look to the Plasma Machine as an exciting, visual display of electronics and plasma in action. It could be a sure winner if you are the first in your school to display it.

The plasma is inside a glass enclosure (the pickle jar) and

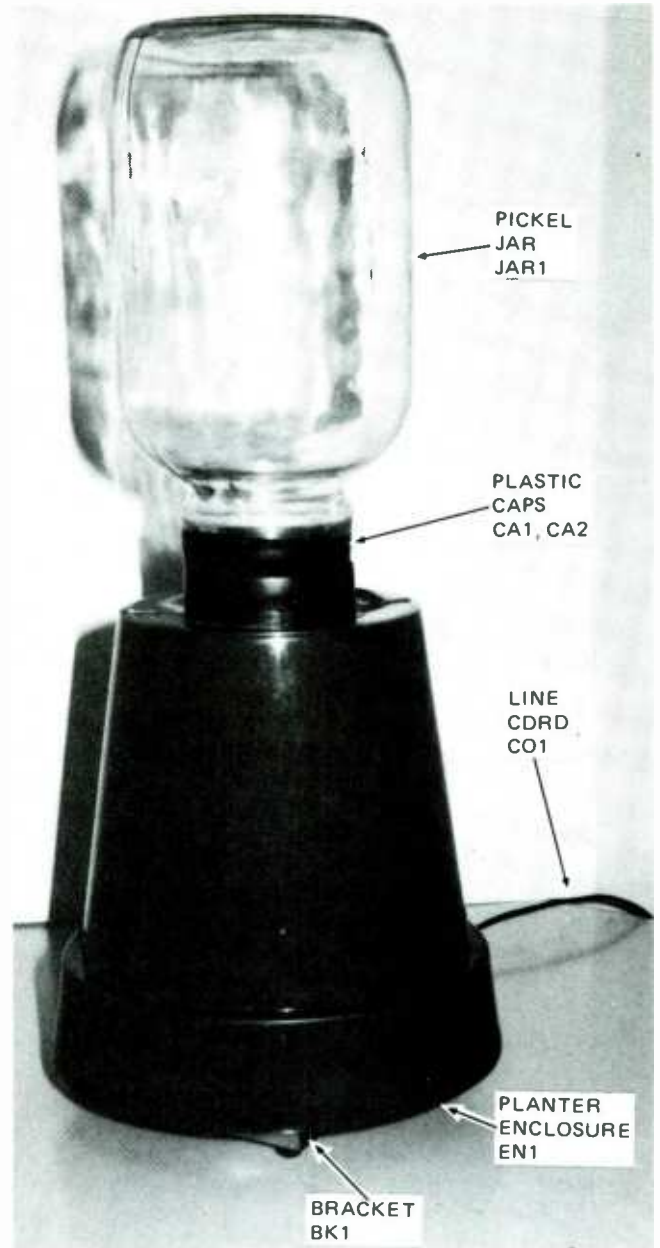


Fig. 1—The Plasma Machine is illustrated here with a few of its basic parts identified. Always keep in mind that the pickle jar (JAR1) contains a large evacuated volume so that it always should be handled with care.



The plastic enclosure fits neatly over the assembled bracket assembly. The enclosure is a No. 10 planter found in most variety stores. A hole is cut in the bottom to fit the PVC extender tube (EXT1) snugly. All of the electronics is safely covered so that observers can approach the Plasma Machine and touch the display jar without fear of a high-voltage shock.

resembles a tornado shape of glowing and swirling plasma. It dances and jumps to anything brought near it and is highly visible even in normal fluorescent lighting. That sensitivity to any external capacity creates many bizarre and seemingly striking effects. The plasma also can light up a fluorescent lamp when brought near the glass enclosure, without any wires or connections of any kind.

The Plasma Machine is an extremely interesting conversation piece and is unlike anything else that most people have yet seen. Its theory is very basic, but yet it still seems to amaze most people, who do not understand it.

### Theory of Operation

An evacuated, glass jar is sealed and pumped down to 1-3 torrs of pressure. A metal cap seals the jar and serves as an electrode for charging the remaining thin gas mixture. The



voltage applied to the cap is at a potential of 10- to 20-thousand volts of high-frequency AC at 15 to 30 kHz.

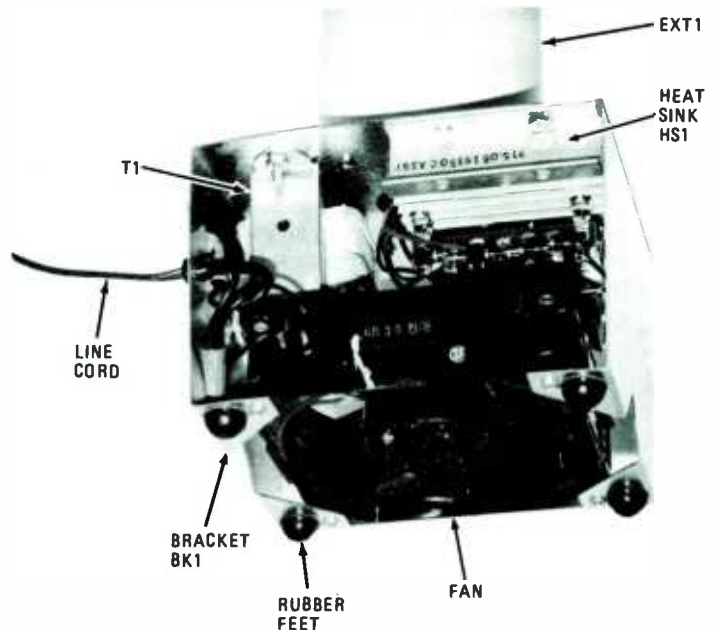
The ionization of the thin gas causes current to flow, creating the plasma discharges within the glass jar. One may visualize the device in the following manner: The conductive gas forms one plate of the capacitor inside the jar. The glass envelope of the jar is the insulating dielectric with the outer air serving as the other plate of the capacitor. Any conducting object brought near the jar now only enhances the conductivity of the outer plate and appears to draw the plasma flow to the point of contact. The vacuum will vary along with the physical parameters of the jar, and can be adjusted to enhance the type of discharge desired.

The evacuated pressure level, where the plasma discharges are best viewed, is critical. Increases in pressure above that level will create a broken wisp effect and a decrease will broaden the discharge path within the glass jar, making it less pronounced. Further variances from the above will eliminate the discharge completely.

The effect of where conduction of a gas peaks at a certain pressure is known as the Townsend Effect, and it becomes an important factor in the design of vacuum systems where medium-to-high voltages are encountered. The basic Plasma Machine does not require any gas other than the existing atmosphere rarefied by evacuation to obtain a decent display.

Other colors and effects are limitless when the builder chooses to charge the Plasma Machine with other gases or combinations of gases. For example: Evacuate the jar and then place a balloon filled with helium over the input port. Open the valve and let the helium in. Now, evacuate the jar and the bulk of the residual gas will be helium.

Another technique is to place a few ounces of dry ice in the jar. Allow the jar to exhaust into the atmosphere until all of



Looking up into the bottom of the assembled bracket you can see the fan installed. It blows upward providing a cooling stream of air against the heat sink immediately above it.

the ice sublimates. Do not permit internal pressure to build up in the jar. The carbon-dioxide gas that the dry ice emits will displace most of the nitrogen and oxygen in the jar. Again, evacuate the jar, leaving mostly carbon dioxide behind. Nitrogen gas is easy to obtain from tanks used by welders, hospitals, telephone company, etc.

Gas contained in tanks are at very high pressures. Take special care to allow the gas inserted into the glass jar to bleed out freely so that the internal pressure of the jar is only slightly above normal air pressure, and never higher. The best way to do that safely is to place a rubber or plastic hose inside the jar and let the nitrogen come in quickly with the cover off the jar. Then, as quickly as possible, remove the hose and clamp on the cover practically in one motion.

Do not use cooking gas, propane, pure oxygen, or other gases that support combustion. They can produce an ex-

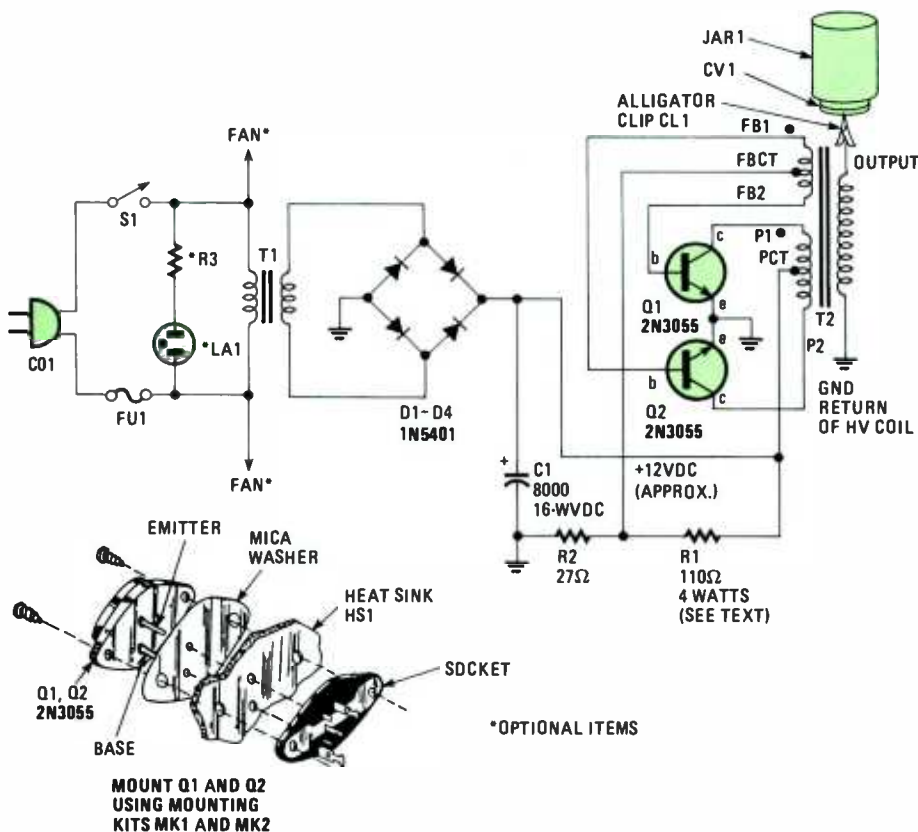
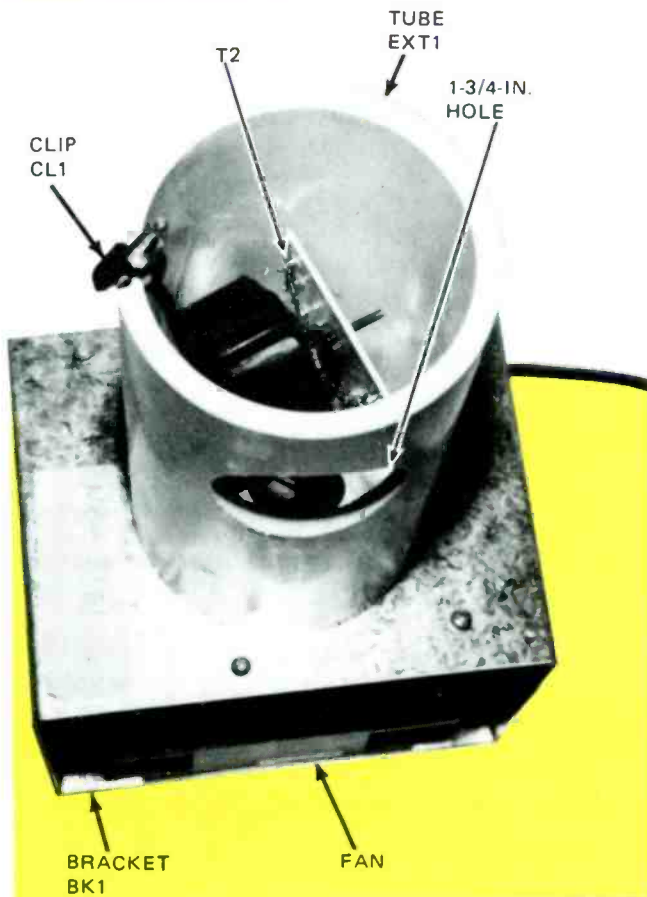


Fig. 2—Schematic diagram for the Plasma Machine indicates that the electronics of the device is limited to a fullwave rectifier and switching circuit which drives a resonant, high-voltage transformer. For portable and field demonstrations a car battery (12-volts DC) or other heavy-duty dry-cell battery types may be connected across electrolytic capacitor C1. Be sure to observe polarity. Transistors Q1 and Q2 are physically mounted on a heat sink (HS1 in Fig. 4). The transistors and other circuit elements are electrically isolated from the heat sink and mounting bracket (BK1 in Fig. 4) in order to reduce shock hazards. If you wish, an optional three-wire power cord (in place of CO1) may be used with the green lead connected to the metal mounting bracket (BK1).

## PARTS LIST FOR THE PLASMA MACHINE

Part No.	Quantity	Description	Part No.	Quantity	Description
†BK1	1	Mounting bracket made from #22 aluminum or #24 galvanized sheet metal (\$12.50)	MK1, MK2	2	Transistor mounting kits for TO3-case
BU1	1	Small knurled brass nut	†PV1	1	1/8-in. brass petcock and fitting
BU2	1	Strain-relief bushing for line cord	†Q1, Q2	2	2N3055 NPN power transistor
BU3	1	1/2-in. bushing for wires from T2	R1	2	Use two 220-ohm, 2-watt, 10% resistors in parallel to form one 110-ohm, 4-watt, 10% resistor
C1	1	8000-μF, 16-WVDC electrolytic capacitor	R2	1	27-ohm, 1/2-watt, 10% resistor
CA1, CA2	2	3 1/2-in. plastic caps	*R3	1	100,000-ohm, 1/4-watt, 10% resistor
CL1	1	Alligator clip	*S1	1	SPST toggle switch
CO1	1	2-wire power cord with molded plug	SW1, NU1	as req'd	6-32 screws and nuts, 1/4- to 1/2-in. lengths
COP1	1	1/8-in. copper capillary (tubing)	SW2	2	6-32 1-inch screws
CV1	1	Metal cover to 1-gallon display jar (JAR1)	SW3	3	#6 1/2-in. self-tapping screws
D1-D4	4	1N5401 3-A, power-rectifier diode	†T1	1	117-volt AC to 12-volt AC, 3-A power transformer
EN1	1	Large plastic enclosure made from #10 plastic planter	†T2	1	Ferrite, TV, resonant high-voltage transformer
EXT1	1	PVC extender tube, 3 1/2-in. OD × 7-in.	TE1	1	7-lug terminal strip with end terminals providing mounting legs
*FAN1	1	Rotron fan, or similar muffin type	WN1, WN2	2	Small wire nuts
*FU1	1	1-A fuse with fuse holder	WR1	24-in.	#18-AWG, vinyl-insulated wire
HS1	1	Dual TO3 transistor heat sink	WR2	24-in.	#24-AWG, vinyl-insulated wire
†JAR1	1	Display jar (1-gallon) to fit metal cover (CV1) with rubber seal—pumped down to 1.5 mm (torr) air (\$24.50)			
*LA1	1	NE51 neon lamp with wire leads			

†Available separately from Information Unlimited  
 \*Optional—see text.  
 A complete kit on certain individual parts—\$85.50. Order from Information Unlimited, Box 716, Amherst, NH 03031.



plusive atmosphere. Refer to the section in *Special Note on Different Gases*.

It is interesting to mention at this time that the acetic acid given off by the curing of RTV cement produces a white plasma display.

### Circuit Description

In the following discussion, please note that the symbols used to identify electrical and mechanical parts are not in conformance to the universal convention used by **Hands-on Electronics** and the electronics industry. No change was made to those symbols in the preparation of this text, so that the parts identification will coincide with supplier of the kit. Refer to the Parts List.

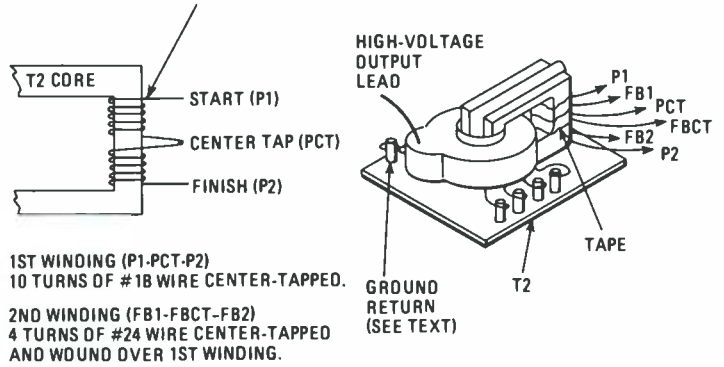
Power is obtained by polarized plug (CO1) and is fused by (FU1) before energizing the primary winding of the transformer (T1). Refer to Fig. 2. Switch S1 controls the power and serves as an on/off switch. The neon lamp (LA1) is lit when power is applied to the primary winding of the transformer. Resistor R3 limits the current through the neon lamp so that it will not destruct. Parts S1, R3, and LA1 are optional in that the line cord can be pulled from the AC outlet to disconnect the Plasma Machine. (*The editors prefer the use of the parts.*)

Transformer T1 steps down the 117-volt AC power line to 12-volts AC where diodes (D1-D4) rectify the voltage to a positive, pulsating, DC voltage. Refer to Fig. 2. That voltage

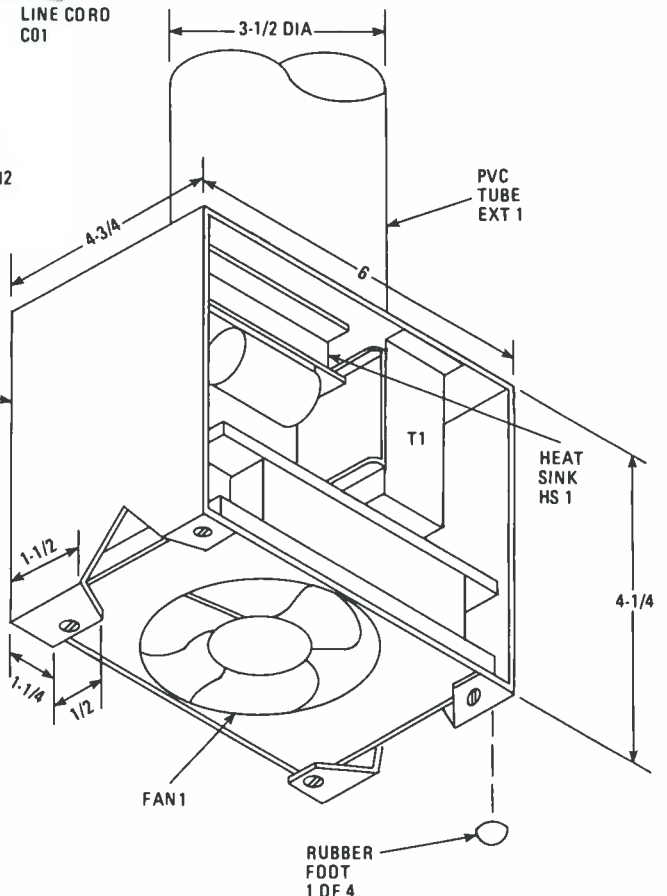
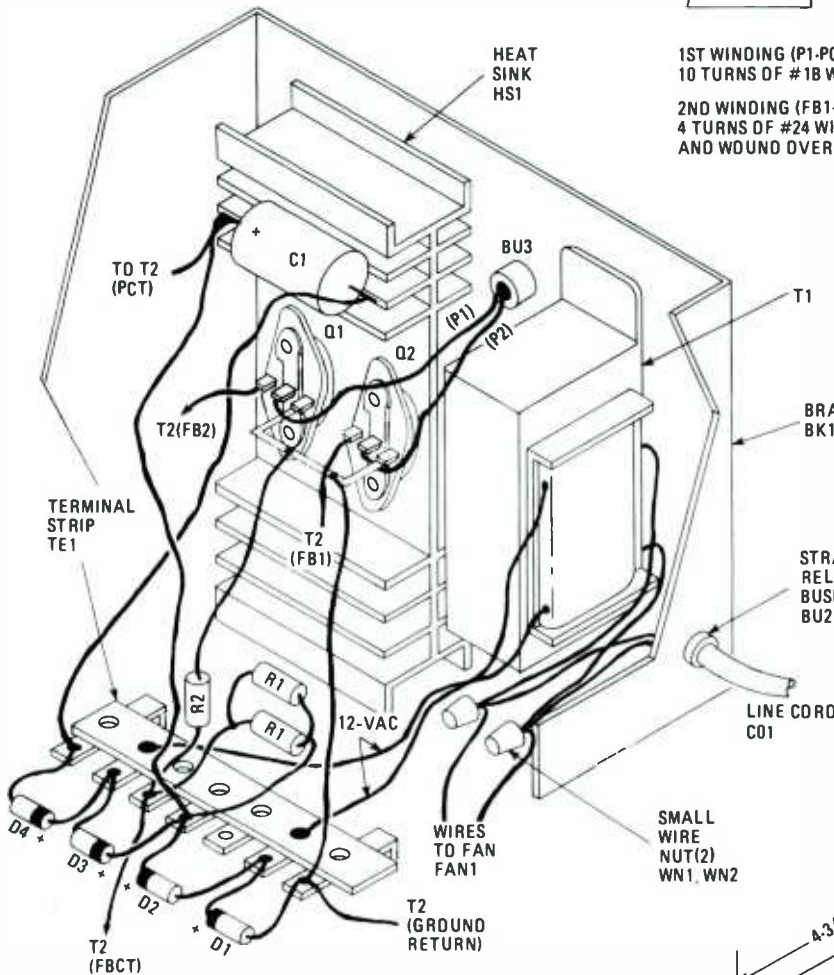
Looking down into the PVC tube (EXT1) you see the high-voltage transformer T2. The alligator clip is connected to the transformer's high-voltage output lead. The clip (CL1) connects to the cap of the display jar (JAR1) that rests on top of the tube.

**Fig. 3—**The text gives complete details on adding the two new windings to the resonant, high-voltage transformer T2. That transformer is typical of the high-voltage transformers found in consumer solid-state TV receivers. Each winding should be evenly spaced and done neatly. The primary-winding terminals are marked P1, P2, and PCT (CT for Center Tap). The feedback winding terminals are marked FB1, FB2, and FBCT.

URNS SHOULD BE EVENLY SPREAD OUT ON ENTIRE LENGTH OF CORE LEG. TAPE IN PLACE.



**Fig. 4—**Here are two views of the metal mounting bracket (BK1) with the various circuit parts and other items attached to it. You could fabricate your own bracket, but before you do obtain the plastic enclosure that you will use. Then, the bracket is designed to fit inside the enclosure, provide mounting space for the circuit elements, and offer a safe, insulated container for the high-voltage transformer inside the PVC extender tube (EXT1). The fan may be considered optional should the Plasma Machine be used for short periods only. Nevertheless, the editor strongly recommends the inclusion of the fan in the design, because once the device is running you'll spend many minutes, if not hours, watching and playing with it.



is filtered by electrolytic capacitor C1 (8000- to 10,000- $\mu$ F, 16-WVDC) to 10- to 14-volts DC.

The collectors of the transistors (Q1 and Q2) alternately switch the 12-volts DC to the primary winding of the resonant, high-voltage transformer (T2) at a period determined by the circuit's resonant frequency. Transistor base drive is obtained through the base winding and emitters' return resistor (R2). Resistor R2 is made from two 220-ohm, 2-watt resistors connected in parallel, that combination provides 110-ohms with the capability to dissipate 4 watts. The 27-ohm resistor (R1) and the usual unbalance in transistors start the oscillator. The resonant, high-voltage transformer (T2) now produces a stepped-up, high-frequency voltage. The output of high-voltage transformer (T2) is now connected to the discharge electrode (CV1) which is the metal cover of display jar.

The highly-conductive, rarified atmosphere inside the display jar (JAR1) now acts as one plate of a large capacitor. The glass wall of the display jar serves as the insulating dielectric, while the outer air around the display jar serves as the second plate. The high-frequency, high voltage now encounters a discharge path whose impedance is determined by the capacitive reactance of the system. The high-frequency current now flows through the inside atmosphere of the display jar, ionizing some of the gas, thus creating a plasma path that seeks out the path of least impedance. Any external object brought near the display jar surface assists in providing this minimal impedance path. A larger capacitance is formed at the point where the conducting object is near on the glass outer surface and attracts the plasma due to the increased capacity effect.

### Special Note on Different Gases

The Plasma Machine glass display jar (JAR1) uses the spectral and conductive property of rarified air as a vacuum is drawn down. A variety of effects are possible and can further be enhanced by the admission of other gases at different pressures. The combinations are many with an equal amount of different display phenomena. Suggested gases are helium, neon, carbon dioxide, krypton, argon, or any combination of those relatively inert gases.

#### CAUTION!

**Do not use explosive gases and combinations of gases such as hydrogen, fluorine, chlorine, methane, etc. Always use inert gases. Observe all safety precautions when using high vacuums. Never use gases from an aerosol spray can. Check with a chemist when in doubt.**



Here is the display jar assembled and evacuated. The black item on top of the display-jar cover is made from two plastic caps used to provide a joining grip between the display jar and the PVC extender tube (EXT1) on which it rests.

### Assembly Steps

Lay out all the parts and materials required to assemble the Plasma Machine on a work surface along with the tools you would expect to use.

1. Rework high-voltage transformer (T2) as shown Fig. 3. Two new primary and feedback windings are added to the flyback transformer (T2) that connect to the driver transistors (Q1 and Q2). Those windings are hand-wound on the bottom leg of the ferrite core where the original two-turn filament windings were located.

2. Remove and discard the original filament winding. In its place, wind first a ten-turn, center-tapped winding (designated P1-P2) using approximately 30 inches of #18 or larger insulated hookup wire (WR2). That is easily accomplished by winding five turns at one end of the core and then twisting a loop in the free end before adding the second five turns. The complete ten-turn winding should then be held in place with a turn or two of electrical tape with the two ends (P1, P2) and the center tap (PCT) loop all protruding. Refer to Fig. 3.

3. Connection can be made to the center-tap loop when the insulation has been carefully removed. If it becomes necessary to cut the center loop, be sure that the two ends are scraped and joined to form a mechanical as well as an electrical center tap connection to the winding.

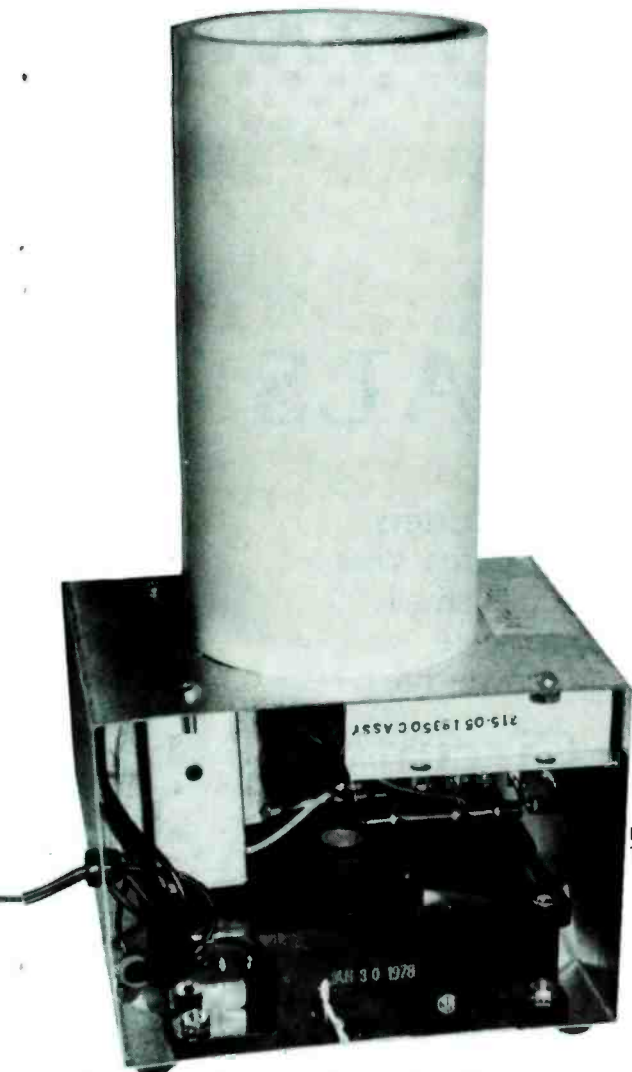
The secondary (feedback) winding should be wound directly on top of the first, but it should only have a total of four turns—two each side of the center tap. Wind two turns of #22 hook-up wire (WR1), pull and twist a center-tap loop (FBCT) and wind the other two turns. Tape that winding in place on top of the first. Do not let the center tap loops of the two windings touch each other. Mark all leads as indicated in Fig. 3. The coil-winding procedure is complete.

Determine the ground return of the output winding of high-voltage transformer T2 by selecting the pin or lead with the highest resistance reading between it and the high-voltage output lead. You will detect a finite resistance that is the largest. Do not consider an infinite-resistance reading as anything other than an open circuit.

Fabricate a mounting bracket from a piece of #22 gauge aluminum or #24 galvanized sheet metal (BK1 in Fig. 4B). The shape and size of the bracket will depend on the external housing. When a kit of parts is purchased, the bracket is fabricated to fit the housing. The bracket must be large enough to hold components shown in Fig. 4.

There are three holes located on a 3.25-inch diameter circle 120-degrees apart for securing the PVC extender tube (EXT1). Be careful not to interfere with the other components. Final assembly may be made easier by first securing the PVC extender tube (EXT1) to the mounting bracket (BK1) with three self-tapping screws (SW3).

Fabricate the PVC extender tube (EXT1) from a 7-inch length of 3/2-inch, schedule 40, PVC pipe whose actual outside diameter is 3/2-inch. The extender tube is necessary in the design of the Plasma Machine. It allows proper clearance of the jar cover from other metal parts in the device, because the cover is at a very-high voltage being connected directly to transformer T2.



A rear view of the bracket assembly with the electrical parts in place and the PVC extender tube (EXT1) installed. The 1¼-inch hole in the extender tube is not visible in this view.

Fig. 5—Here's Superman's view of the Plasma Machine—we've added the call outs to identify the parts. High-voltage transformer T2 should be kept about one inch above the top surface of the mounting bracket (BK1). To do that the high-voltage lead with alligator clip attached is kept to a length so that the transformer hangs in the correct position. As an option to that design you may want to add some PVC pipe scraps to the bottom of the PVC extender tube (EXT1) to serve as insulating spacer material. Those scraps will keep the transformer from falling to the bracket and provide the necessary spacing. The PVC material is highly resistive to the high-voltage AC. The diagram does not show a fuse location. To include a fuse in the circuit, break the lead between the power cord and switch S1, then install in that circuit gap a fuse holder that can mount on the plastic enclosure (EN1) next to toggle switch S1.

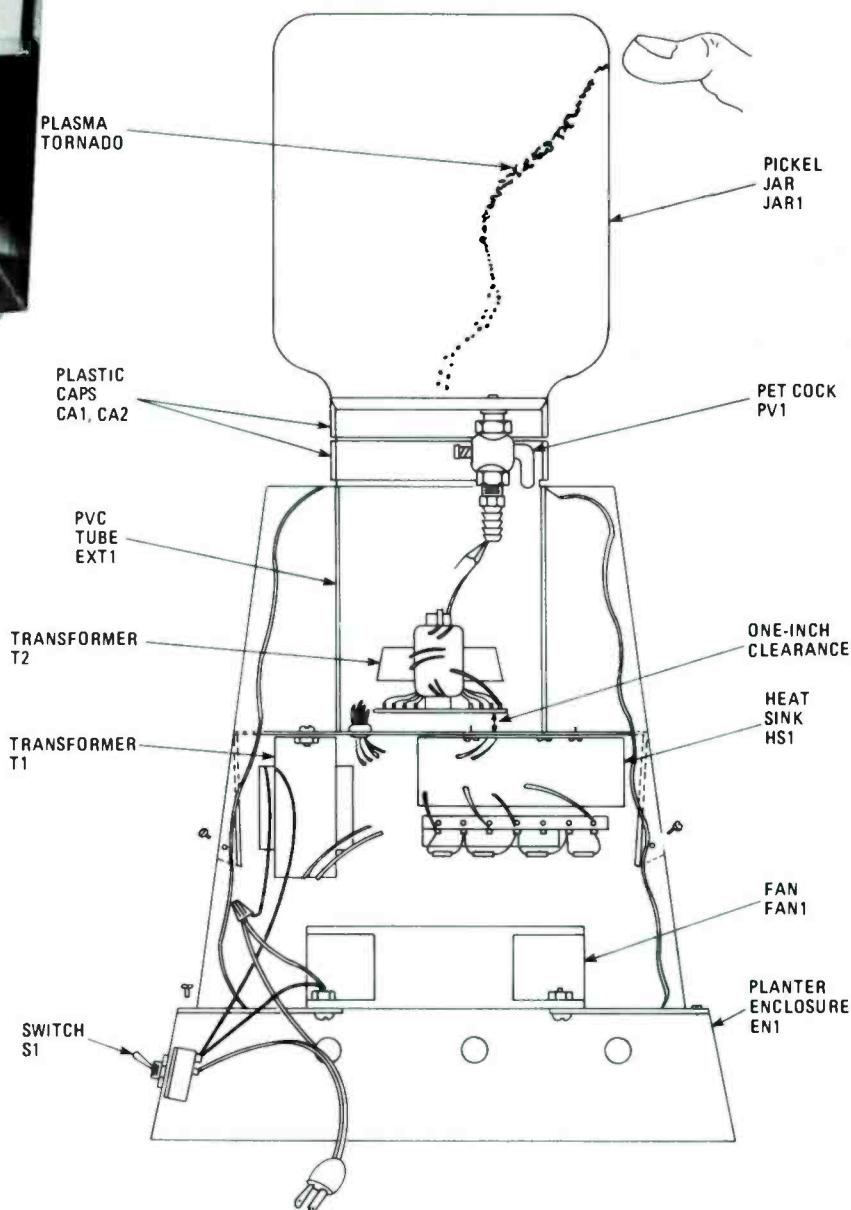
Use a hole saw to cut a 1¼-inch diameter hole with its center located two inches from what will be the top end of the PVC extender tube. That hole is used to gain access into the extender tube so that the alligator clip (CL1) from high-voltage transformer T2 can be connected to the plasma tube using the shortest possible lead between the clip (CL1) and the high-voltage transformer (T2). See Fig. 5.

Assemble transformer T1 to the mounting bracket (BK1). Then attach the terminal strip (TE1) to the heat sink. It might be necessary to drill two holes between the first and second fins. Remove burrs from the heat sink in the area of the transistor mounting holes and mount transistors Q1 and Q2 to the heat sink using transistor mounting kits (MK1 and MK2) as shown Figs. 2 and 4.

Complete the wiring following the details in Figs. 2 and 4. The leads to high-voltage transformer T2 should be long enough so that the transformer will be about one inch off the surface of the bracket. See Fig. 5. Check your work carefully.

**CAUTION:**  
High voltages are dangerous to your health and they can kill you!

(Continued on page 101)



# DIGITAL FUNDAMENTALS

Now you will discover the operation of inverters and gates, or gates and how to use logic gates. You get an insight to digital integrated circuits small-scale integration (SSI) to very-large scale integration (VLSI). And, we test your knowledge.

## LESSON 3: Digital Circuits

by L.E. Frenzel

□ THIS LESSON OF THE CONTINUING SERIES ON DIGITAL Fundamentals will discuss specifically the circuits used to make up digital logic elements that perform the basic logic functions. When you complete this lesson, you will have a good understanding of how the most popular digital logic circuits work.

In the previous lesson we introduced you to the basic digital logic elements, such as the inverter, AND gate, OR gate, and NAND NOR gates. Those are the basic logic elements that process binary signals in digital equipment. We discussed their operation in terms of the logic functions they perform. The operation of each was expressed in Boolean algebra, truth tables, and timing diagrams. Only logic symbols were used to illustrate those devices. But in this lesson, we want to take a look inside the logic symbols.

There are two basic methods of implementing digital circuits: discrete components and integrated circuits (IC's). Discrete-component circuits are those made up of individual transistors, resistors, diodes, capacitors and other components wired together on a printed-circuit board. The other type of circuit is the integrated circuit where all the components are made together on a tiny chip of silicon. Today, most digital circuits you will encounter will be of the integrated-circuit form. Occasionally, however, you will run across a discrete-component circuit in an older piece of equipment or

in one requiring some special or simple function. We will discuss both IC's and discrete-component circuits in this lesson.

### Inverters

Let's begin our discussion with the circuits used to make a logic inverter. We will talk about simple discrete-component circuits first and that knowledge will easily translate to integrated circuits. For our discussion here, zero volts or ground represents a *binary 0* and +5-volts DC represents a *binary 1*.

The main element in an inverter circuit is a switch as shown in Fig. 1A. The switch is connected in series with a resistor to the supply voltage. A binary input signal controls the operation of the switch. The binary output appears across the switch. When the input is binary 0, the switch is open. The output, therefore, is +5 volts or binary 1 as seen through resistor R1. The circuit does invert. If the input is binary 1, the switch is closed. Current flows through the switch and resistor R1. The output is 0 volts or binary 0, because the resistance of the switch is near zero.

A common bipolar transistor can be used as the switch to form a simple inverter as shown in Fig. 1B. A transistor works well in that application, because it can be turned off so that no current flows through it or so that the transistor can be turned on to act as a very low resistance and current flows through it.

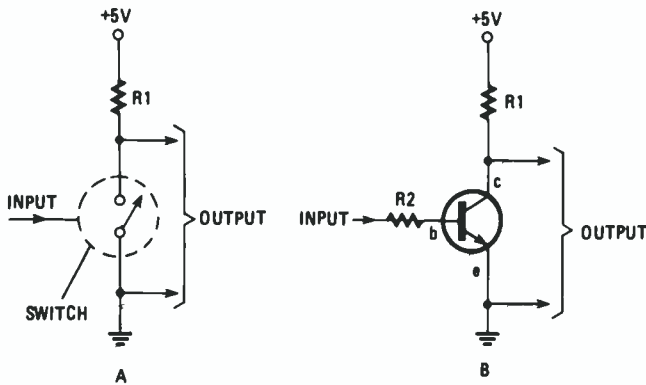


Fig. 1—A logic inverter operates like a *shunt* switch (A) in parallel with the output. A transistor (B) operated at cut-off and saturation functions in the same manner.

Recall that there are three basic operational states of a bipolar transistor: cut off or non-conducting, conducting in the linear region, and saturation. Those states are achieved by biasing. (See Review of Diode and Transistor Biasing.) When the transistor is cut off, it is nonconducting and acts as an open circuit.

With the proper bias on the transistor, it conducts in the linear region. That means that the collector current is directly proportional to the variations in the base current. That permits a small base current to control a large collector current and thus cause amplification to take place. The linear conducting mode of operation is not generally used in digital circuits.

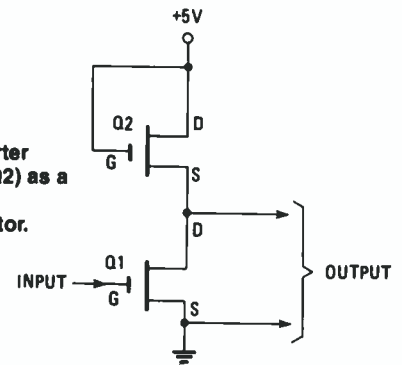
Finally, if sufficiently high bias current is applied to the base of the transistor it will conduct *hard* and it will act as a very low resistance. During that time both the emitter-base and base-collector junctions are forward biased. The voltage drop between the base and collector at that time is extremely low; therefore, the transistor appears to be a near short circuit. When in saturation, the transistor acts as a closed switch.

Using those principles, the operation of an inverter is easy to understand. If the input to the inverter in Fig. 1B is 0 volts or ground, the emitter-base junction of the transistor will not be forward biased. No current will flow through R1 or the transistor (Fig. 1B). The transistor appears to be an open circuit. Therefore, the output is +5 volts or binary 1 as seen through R1.

When a binary 1 or +5-volt signal is applied to the input, the emitter-base junction is forward biased. The value of resistor R2 is made low enough so that the base current is high enough to cause the transistor to saturate. The transistor conducts and current flows from the emitter through the base to the collector and through R2 to the supply voltage. During that time, the transistor acts as a very low resistance. A typical output voltage between emitter and collector might be 100 millivolts (.1 volt). That is sufficiently low so as to represent a binary 0.

Metal oxide semiconductor field-effect transistors (MOSFET's) can also be used to form an inverter as shown in Fig. 2. Here N-channel enhancement mode MOSFET's are used. Q1 is the inverter switch while Q2 acts as a load resistor. When the gate of Q2 is connected to the drain, the transistor is biased on and acts as a resistor. That technique is widely used in N-channel MOS (metal oxide semiconductor) integrated circuits. Transistor loads are easy to make in integrated

Fig. 2—A MOSFET inverter (Q1) using a MOSFET (Q2) as a load in place of a power-consuming resistor.



circuit form and also take up much less space than an integrated resistor.

An enhancement mode MOSFET may also act as a switch. When its gate voltage is below some threshold voltage (about +1.5 volts in common N-channel MOSFET's), the transistor is cut off. It acts as an open switch. When a positive logic signal above the threshold value is applied to the gate, the transistor conducts. Its *on* resistance is very low; therefore, it acts as a closed switch.

The operation of the inverter in Fig. 2 is simple. When the input voltage is binary 0 (near zero volts), transistor Q1 does not conduct. Q2, however, is conducting because it is biased on. The output voltage, therefore, is +5 volts as seen through Q2.

When the input voltage is a binary 1 level or approximately +5 volts, Q1 conducts. It acts as a very low resistance; therefore, little voltage is dropped across it. The output voltage is near zero volts or binary 0.

### AND and OR Gates

AND and OR gates can be constructed with diodes and resistors. For example, a simple OR gate is illustrated in Fig. 3. If both inputs to the OR gate are binary 0 or ground, neither diode conducts and no current flows through resistor R1. The output, therefore, is a 0 volts or ground as seen through R1.

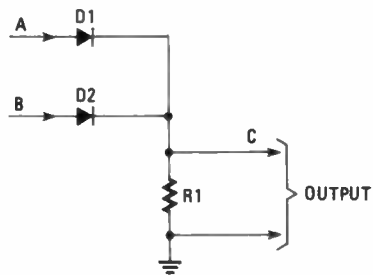
If both inputs are binary 1, both diodes D1 and D2 conduct. Current flows through resistor R1. The output, therefore, is a binary 1. Most of the voltage applied to the inputs will appear across R1 except approximately .7 volt which is dropped across each diode. With a +5-volt input, the output would be approximately +4.3 volts.

If one input is binary 0 and the other binary 1, the output will also be binary 1. For example, if input A is +5 volts and input B is 0 volt, diode D1 in Fig. 3 will conduct. The output will be approximately +4.3 volt. That will cause diode D2 to be reverse biased and it will be cut off.

A simple discrete-component AND gate is shown in Fig. 4. If both inputs are binary 0 or ground, both diodes D1 and D2 conduct. Current flows through R1. The output voltage at that point is the voltage drop across the diodes. For a typical silicon diode, the voltage drop will be approximately +.7 volts. That is a low-voltage level and represents a binary 0.

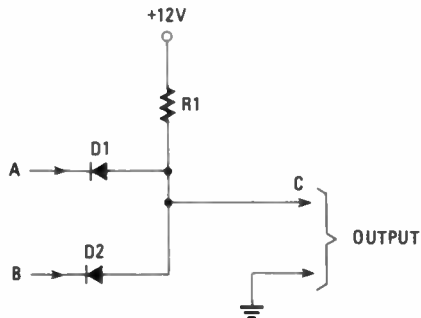
If one input is binary 0 and the other binary 1, the output will also be binary 0. For example, if input A is binary 0 and input B is binary 1 or +5 volts, diode D1 conducts. The output will be approximately +.7 volts. That means that diode D2 will be reverse biased and, therefore, cut off.

If both inputs are binary 1 or +5 volt, both diodes conduct. The output will be +5 volts less the voltage drop across the diodes. If the inputs are +5 volts, then the output will be



A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Fig. 3—Simple diode OR gate and its truth table.



A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 4—Diode AND gate and its truth table.

+4.3 volts or binary 1.

If both circuits are as shown in Figs. 3 and 4, additional diodes may be added to accommodate more inputs as needed. Further, those simple circuits can be combined with inverters to implement almost any logic function. However, discrete-component circuits take up a lot of space and are inconvenient to construct. Their performance is also generally poor. For that reason, they are used only where simple, low-performance circuits are needed.

### Digital Integrated Circuits

Virtually all pieces of digital equipment are built using integrated circuits. An integrated circuit is one in which all of the components—including transistors, diodes, resistors, and capacitors—are fully formed and interconnected on a silicon chip. Those circuit components are extremely small. Many inverters, logic gates, flip-flops, and other logic and linear circuits can be contained within a small area. A typical silicon chip is roughly square, with sides of approximately .1- to .25 inch. The smaller chips contain several gates or inverters while the larger chips might contain a complete circuit such as a microprocessor. The chip is mounted in a special package with leads that can be plugged into a socket or soldered to a printed-circuit board. The most popular form of package is the dual in-line package, or DIP. See Fig. 5. Digital integrated circuits are housed in DIP's with 8 to 64 pins.

Digital IC's come in all sizes and configurations. The simplest circuits house only several gates, inverters, or flip-flops. The most complex circuits contain complete systems or functional parts of a system. All digital integrated circuits are generally divided into four basic categories: SSI, MSI, LSI, and VLSI. Those designations, described in Table 1, show how digital IC's are classified according to size, density and function.

Digital IC's are also classified by the type of transistors used to make up the circuitry. The two basic types are bipolar and MOSFET. IC manufacturers have developed a wide variety of digital IC families using both types of transistors. Typical bipolar families include resistor-transistor logic

(RTL), diode-transistor logic (DTL), transistor-transistor logic (TTL), emitter-coupled logic (ECL), integrated-injection logic (IIL), and several others. RTL and DTL aren't used any more in new designs, but you may occasionally find them in older equipment. TTL and ECL are widely used today. IIL circuits are used in LSI and VLSI designs.

MOS logic families include both P-channel and N-channel MOS and complementary MOS (CMOS). Because bipolar circuits are larger and consume more power, they take up more space on a silicon chip and, therefore, are used primarily for SSI and MSI circuits. Some bipolar LSI are available. Most LSI and VLSI circuits are MOS and CMOS. The circuits are smaller and consume less power and, therefore, more of them can be packed into a given space.

In this lesson we are going to talk about the most popular forms of logic used today. Specifically we will focus on TTL and CMOS circuits which you are certain to encounter.

### Transistor/Transistor Logic

Probably the most popular form of SSI and MSI digital IC's is transistor/transistor logic. You may see it referred to as T<sup>2</sup>L, pronounced "T squared L." TTL is used in everything from personal computers to the most sophisticated aircraft electronics equipment.

TTL circuits use bipolar transistors and operate on a power-supply voltage of +5-volts DC. Complete families of SSI and MSI TTL circuits are available. A wide variety of inverters, gates, flip-flops, and many functional logic circuits are available in DIP form. TTL circuits are fast, versatile, and very inexpensive.

The basic TTL logic circuit is illustrated in Fig. 6. That particular circuit forms the positive logic NAND function. However, other versions of that circuit are available to per-

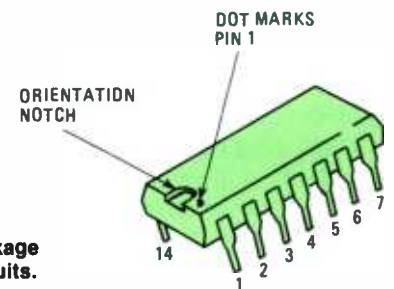


Fig. 5—Dual in-line package (DIP) for integrated circuits.

TABLE 1  
LEVEL OF IC's BASED ON CIRCUIT DENSITY

<b>SSI</b>	Small-Scale Integration—Chips containing 12 or less gates, inverters, flip-flops, etc.
<b>MSI</b>	Medium-Scale Integration—Chips containing 12 to 100 gates, inverters, flip-flops, etc., usually connected as functional circuits that do something such as counters, registers, decoders, multiplexers, and many others.
<b>LSI</b>	Large-Scale Integration—Chips with 100+ gates, flip-flops, etc., often forming complete circuits such as microprocessors, program and control circuits, memory circuits, and many others.
<b>VLSI</b>	Very Large-Scale Integration—Chips with 1000+ gates, flip-flops, and other circuits. 32-bit microprocessors, data acquisition systems, gate arrays, and much more.



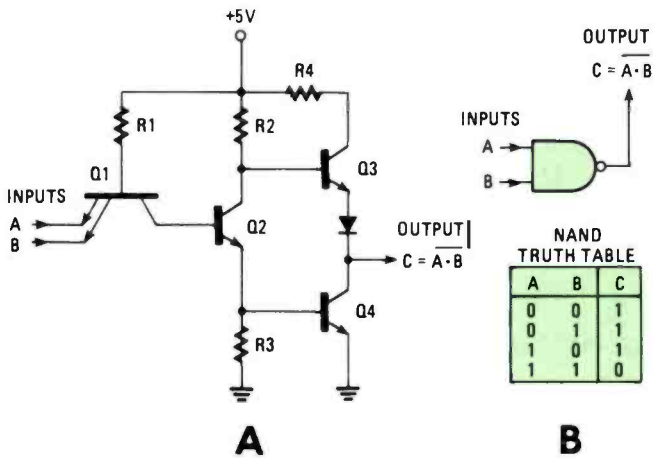


Fig. 6—TTL NAND gate simplified circuit (A), and its schematic symbol (B) and truth table.

form the AND, OR, and NOR functions. A single input version of that circuit is used as an inverter.

That circuit is made up of three parts: a multiple emitter-input transistor (Q1), a phase splitter transistor (Q2), and the output stage (Q3 and Q4). Refer to Fig. 6A. Transistor Q1 and R1 function as a simple diode AND gate where the emitter-

base junctions of Q1 are the diodes. The main purpose of the phase splitter Q2 is to furnish complementary logic signals to the two output transistors Q3 and Q4. Transistor Q4 is the output switching transistor and performs the function of an inverter. Transistor Q3 along with D1 and R4 forms an active pull-up stage. It is similar in operation to the MOSFET load resistor described earlier. Some TTL circuits are available without that active pull-up stage. Transistor Q3, D1, and R4 are eliminated and the collector of Q4 is brought out to one of the DIP pins. An external load must be connected. Those open collector circuits are useful for driving other components, such as LED indicators, relays, and other external circuits.

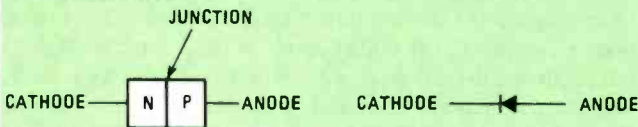
In most cases the active pull-up circuit is preferred, because it represents a very low impedance when the output of the gate is binary 1. That permits the circuit to quickly charge any external capacitance, thereby greatly reducing the rise time and speeding up the circuit.

The logic levels for the typical TTL circuit are zero to 0. + .8 volt for a binary 0 and + 2.4 to + 5 volts for a binary 1.

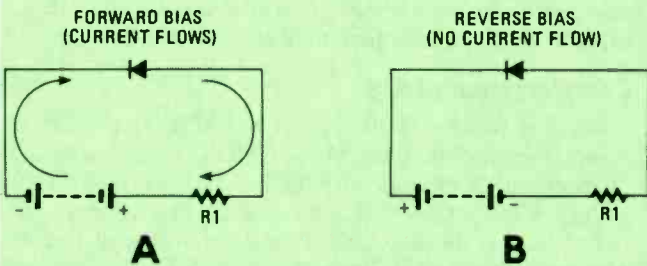
Now let's see how the TTL circuit functions. Remember that it is a NAND circuit. You can refresh your memory about how it works by referring to the truth table in Fig. 6B.

### REVIEW OF DIODE AND TRANSISTOR BIASING

Diodes and bipolar transistors are made by combining N- and P-type semiconductor materials (silicon, germanium, gallium arsenide) to form junctions. A PN junction shown below creates a diode.



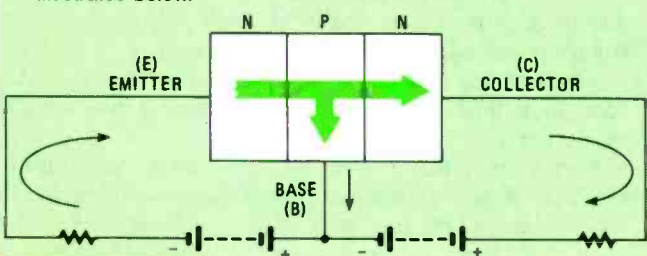
The diode symbol (above) is used in schematic diagrams. The current flowing in a diode depends on its bias, an externally applied voltage. The circuits below show the two ways to bias a diode.



If the cathode (N-type material) is made negative with respect to the anode as shown at A, the diode is forward biased and it conducts. The amount of current flowing is controlled by the resistive value of R1.

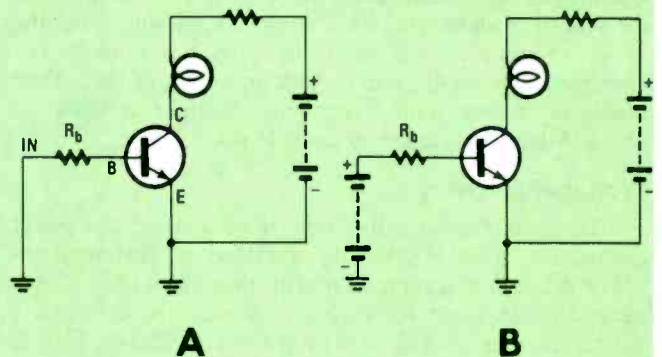
If the cathode is made positive with respect to the anode as shown in B above, the diode is reverse biased. No current flows in the circuit.

Transistor biasing follows similar rules. An NPN transistor is illustrated below.



If the emitter-base junction is forward biased and the base-collector junction is reverse biased, the transistor conducts. This is the normal condition for a transistor operating in the linear region for amplification.

In logic and switching applications, the bias arrangements shown below are used. Here the transistor is used as a switch to turn on an incandescent bulb.



If the input is grounded as in A, the emitter-base junction is not forward biased. Therefore, the transistor does not conduct and the bulb does not light. If the base is made positive as shown in B, the emitter-base junction is forward biased. The base-collector junction is reverse biased so the transistor conducts. The bulb lights.

If the base current is made high as determined by Rb, the transistor will conduct hard. Its emitter-to-collector resistance will be very low and only a small voltage will appear between the emitter (ground) and collector. The collector may be + 0.1 volt with respect to the emitter at ground. With the emitter-base junction forward biased and conducting, the voltage across it will be the same as a conducting diode or about + 0.7 volt. If the base is + 0.7 volt with respect to the emitter or ground and the collector is + 0.1 volt, then the base is positive with respect to the collector. This means that the base-collector junction is forward biased also. This condition is caused by high base drive. When both junctions are forward biased, the transistor is said to be saturated. Saturated operation is typical in bipolar transistor logic circuits.

Assume that either or both inputs A and B are at ground or binary 0. The corresponding emitter-base junctions of Q1 then conducts through R1. When Q1 is conducting, its collector voltage is such that the bias on the base of Q2 will be approximately 0 volt. For that reason, Q2 is cut off. As a result, base current is supplied through R2 to output transistor Q3 and Q3 conducts. Transistor Q4 is cut off at that time. The output voltage will be +5 volts less the voltages dropped across R4, Q3 and D1. That output voltage is typically in the +2.4- to +3.6-volt range.

If both inputs are binary 1, the emitter-base junctions of Q1 do not conduct. However, the base-collector junction of Q1 does conduct and provides base current to Q2 through Q4. Transistor Q4 saturates and effectively brings the output to near ground level.

The most popular form of TTL is Texas Instruments (TI) 7400 series. Many other manufacturers second-source that line of circuits. All kinds of gates, flip-flops, and functional circuits are available as part of that family. Virtually all of the most commonly used logic functions are implemented as TTL IC's. Individual gates and flip-flops can then be used to make up any special circuits.

The individual IC's are usually marked on the DIP housing to identify them. Some of the identifying marks are the manufacturer's logo, the device type number, and a date code. Each of the TTL manufacturers such as TI, Fairchild, Signetics, National Semiconductor, and others, has its own special company symbol. The part number designates the specific device. For example, a 7430 is a single 8-input NAND gate.

The date code tells when the circuit was manufactured. Usually the date code is made up of the last two numbers of the year of manufacture plus a number signifying either the month or week during which that circuit was made. For example, 8216 might mean the sixteenth week of 1982. Date codes vary from manufacturer to manufacturer so be sure to check if that is an important consideration.

### Propagation Delay

TTL circuits are usually rated by both speed and power dissipation. Speed is generally expressed in terms of propagation delay. Propagation delay is the time that it takes a logic change at the input to propagate through the device and appear as a logic-level change at the output. See Fig. 7. Propagation delay is typically expressed in nanoseconds. TTL circuits have propagation delays in the 2 to 30 nanosecond range. Operating frequencies up to 125 MHz are possible with the fastest TTL circuits.

Power dissipation is another important characteristic of the

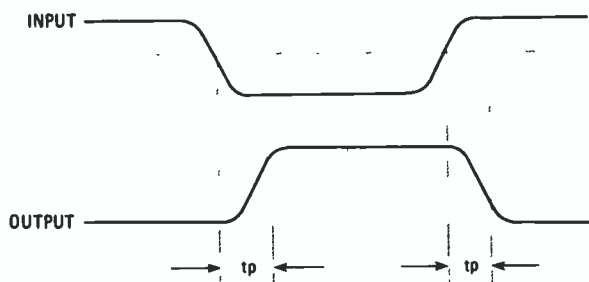
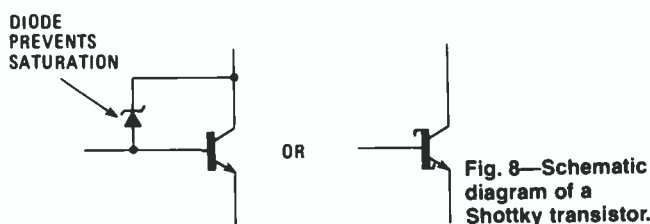


Fig. 7—Propagation delay is defined as the time offset between input and output logic level transitions.

circuit. The lower the power consumption, the better. That reduces heat and power-supply expense. However, high speed is almost always associated with higher power consumption. Typically, the faster the circuit, the more power that it consumes. Most TTL circuits have a power dissipation in the 1 to 25 milliwatt range per gate. The higher-speed versions use lower resistance values and, therefore, draw more current. The slower circuits use higher resistance values and consume less power.

### Going Faster

A special form of TTL circuit uses Schottky diodes to speed up circuits while reducing power consumption. Essentially, each transistor in the circuit has a Schottky diode connected between the base and collector as shown in Fig. 8. The Schottky diode is made up of semiconductor material and a metal, and is used primarily to prevent the transistors from saturating.



When saturated transistors are used in an IC, it takes a finite amount of time for the circuit to turn off. That condition known as *charge-storage* puts a limit on the speed of operation. However, if a Schottky diode is used, saturation does not occur and there is no charge storage problem. As a result, switching speeds are faster and propagation delays are lower. By increasing the value of the circuit resistors, power dissipation is dropped but high speed is maintained, because of the non-saturated operation. The most popular TTL circuits today are the so-called low-power Schottky devices that have propagation delays as low as 2 nanoseconds. Those are designated by an *LS* in their part number (i.e. 74LS20).

### Complementary MOS

Another popular family of SSI and MSI logic circuits is complementary MOS or CMOS. CMOS circuits use both P-channel and N-channel MOSFETs, thus the prefix *C* for *complementary*. CMOS IC's are available in many configurations of gates, flip-flops and other functional logic circuits. The power supply-voltage is typically +5 volts, although most CMOS circuits can operate reliably with supply voltages in the +3- to +18-volt range.

Fig. 9A shows a basic CMOS logic gate. That circuit performs the NOR function as indicated by the symbol and truth table in Fig. 9B. Note that Q1 and Q2 are P-channel MOSFET's while Q3 and Q4 are N-channel MOSFET's. All four transistors are enhancement-mode MOSFET's meaning that the transistor is normally off until the threshold gate voltage is exceeded with a logic input signal.

Now let's see how that CMOS NOR circuit operates. Assume logic input levels of 0 and +5 volts for binary 0 and binary 1, respectively.

Keep in mind that in order for an N-channel MOSFET to conduct, its gate voltage must be positive with respect to its source. Usually the threshold value is approximately +1.5 volts. Any input voltage greater than that will cause the

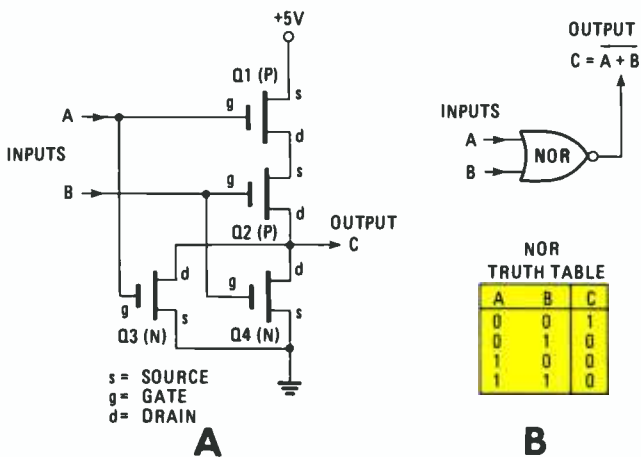


Fig. 9—Schematic diagram of a CMOS NOR gate (A), and its schematic symbol (B) and truth table.

transistor to conduct. Otherwise, the transistor will be cut off. In P-channel MOSFET's, the gate must be made negative with respect to the source. Again, the threshold value must be observed.

Referring to Fig. 9A, assume that both inputs A and B are at 0 volt or at ground potential. Since ground is more negative than +5 volts, the gates are negative with respect to the sources so both Q1 and Q2 conduct. Transistors Q3 and Q4 will be cut off at that time, because their gates are at zero volts and below the threshold level. As a result, the output will be +5 volts as seen through Q1 and Q2.

If either input A or B is binary 0 while the other is +5 volts or binary 1, then either one but not both transistors Q1 and Q2 will conduct. For example, if input A is 0 and input B is +5 volts, Q1 will conduct but Q2 will be cut off. If input B is binary 1, Q2 will be cut off but Q4 will conduct. With Q4 conducting, the output will be brought to binary 0.

With both inputs binary 1, both Q1 and Q2 are cut off. However, both Q3 and Q4 will conduct keeping the output at binary 0. The truth table sums up all possible conditions of inputs and outputs of the NOR gate. Naturally, additional inputs and transistors may be added to create gates with 3, 4 or 8 inputs.

CMOS IC's are very popular for implementing digital circuits. Their main advantage is super low-power consumption. The only time current really flows in the circuit is when the output switches from one state to another. The power dissipation of a typical gate is in the 10-nanowatt range. That is very low-power consumption and makes power supplies simpler and cheaper, and heat dissipation from the IC practically non-existent. Low-power consumption makes CMOS very popular for battery-operated equipment.

Even though low-power consumption is the primary virtue of CMOS circuits, that does not mean that they are necessarily slow. They are typically slower than TTL circuits, but fast enough for many applications. Typical propagation delays are in the 10 to 50 nanosecond range.

Another advantage of CMOS circuits is their high-noise immunity. Noise, of course, is any extraneous signal, pulse, glitch, or undesirable input. High-noise immunity means that the circuit is essentially superior at ignoring input noise. Because of the high-threshold levels of the enhancement-mode MOSFET's, CMOS is very tolerant of external noise. As a result, it is excellent for use in industrial and automotive applications where high noise is common.

The two most popular lines of CMOS circuits are the RCA 4000 series and the Motorola 14000 series. Both have a wide variety of gates, flip-flops, inverters, and functional logic circuits such as counters, registers, multiplexers, decoders, and others.

### Using Logic Gates

Figure 10 shows how TTL gates are used. Figure 10A illustrates a common TTL IC, the popular 7400 quad 2-input NAND. The power and input/output pin designations are given. Figure 10B is a typical logic circuit implemented with the four NAND circuits in the 7400. The numbers at the inputs and outputs in Fig. 10B correspond to the pin terminations on the DIP shown in Fig. 10A. In most logic diagrams, the IC is given a number such as IC23 or U14 and each gate is designated with a letter. The IC number is usually screened on to the printed-circuit board next to the IC identification.

There are two points to note in Fig. 10B. First, unused inputs should be connected together or to the supply voltage through a resistor. Open inputs should not be permitted, because they are potential noise sources. Second, a gate may function as an inverter if all the input pins are connected together.

The circuit in Fig. 10B can be altered so the NAND circuit element a and d, or any other paired combination, may be interchanged without altering the circuit. In this magazine the circuit elements inside of a dual, quad, hex, etc., IC are identified by the letters a, b, etc. (lower case), beginning with the element that has the lowest pin number. That is not a hard and fast rule. Other publications and engineering groups vary somewhat. As for which circuit element not to use when there is an excess of elements, the choice is left to the man who will lay out the printed-circuit board.

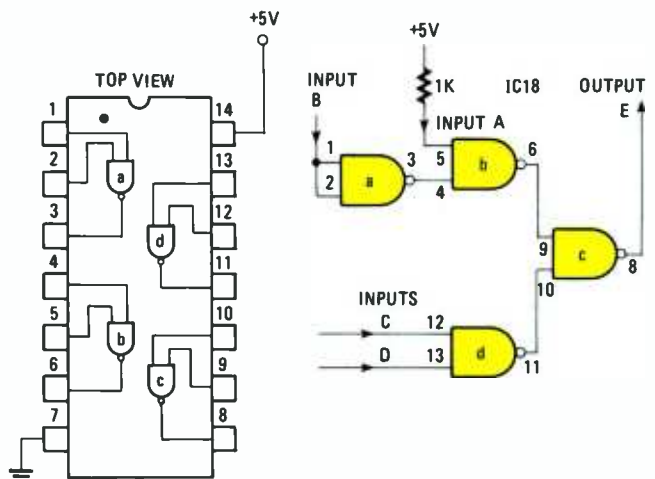


Fig. 10—Schematic diagram of a TTL quad 2-input NAND gate (A) and a logic circuit made from the quad sections of a 7400 IC.

Figure 11 shows how the wiring of the circuit in Fig. 10B would appear on a printed-circuit board. That is the pattern on the bottom of the board. Using Figs. 10A and 10B as a guide, trace the circuit to confirm to yourself that it duplicates the logic diagram. Keep in mind that you are viewing the bottom of the IC while Fig. 10A shows the top. Pin 1 is designated to get you oriented.

Figure 11 does not agree completely with Fig. 10B, because logic diagrams often leave out the IC's connection to the power supply. Note that in Fig. 10A +5 volts is connected to

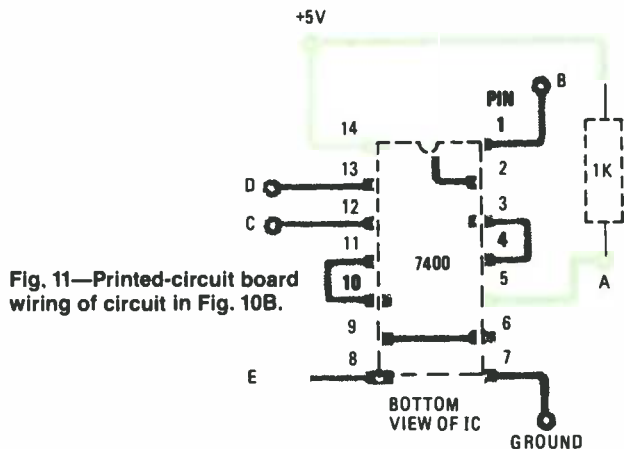


Fig. 11—Printed-circuit board wiring of circuit in Fig. 10B.

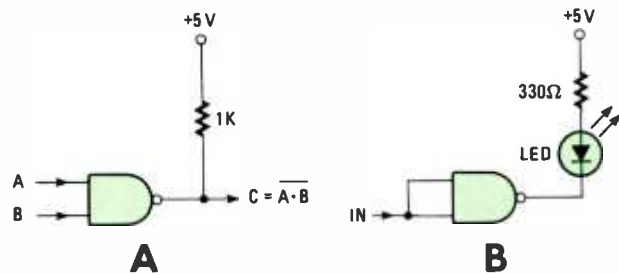


Fig. 12—Using a 7401 open-collector 2-input NAND integrated circuit as a NAND (A), and as an inverter LED driver (B).

pin 14 and the ground return is connected to pin 7. If power is not connected to the IC, the circuit will never work. Thus, in Fig. 11, when you trace the foil circuit, you will find pins 7 and 14 properly connected. In some diagrams the power supply connections are shown only once in dual, quad, hex, etc., IC's since all the circuit elements are interconnected to the power source within the IC itself.

Figure 12 shows another IC circuit application. Here a 7401 IC is used. The 7401 is similar to the 7400 in that it is a quad 2-input NAND. However, the NAND outputs are all open-collector—meaning that they require an external load or pull-up resistor. The pull-up resistor is shown in Fig. 12A.

Figure 12B shows how the gate is used as an inverter and

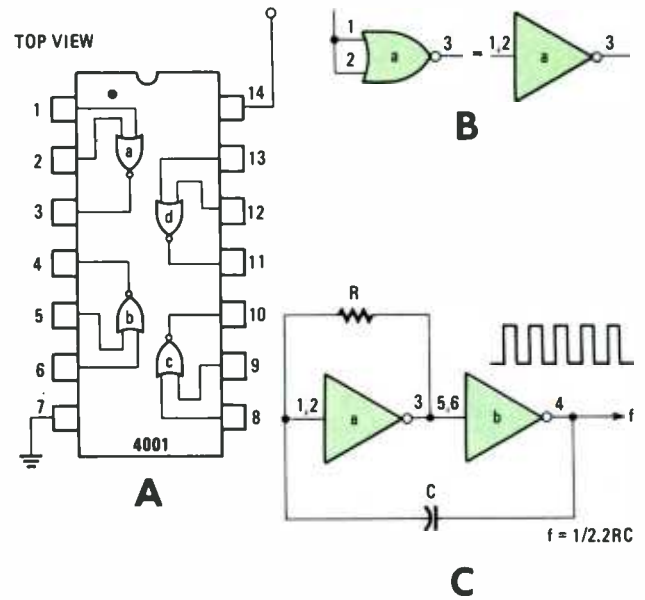


Fig. 13—CMOS 2-input quad NOR integrated circuit is shown in A. With the two inputs tied together (B) the gate becomes a simple inverter that can be used to for the pulse generator shown in C. The numbers indicate the pin termination in A.

LED driver. The output load is an LED and a resistor to set the current value. When the input is low (binary 0), the output is high and the LED is off. If the input is high (binary 1), the output is low and the LED turns on.

A CMOS circuit application is shown in Fig. 13. The device used is a 4001 quad 2-input NOR gate as illustrated at A. Two of the inputs are wired together forming an inverter (Fig. 13B). Two gates wired as inverters are connected to form a simple astable multivibrator usually called a clock circuit (Fig. 13C). The output is a continuous rectangular-pulse train whose frequency is determined by the values of resistance and capacitance in the circuit. With the values shown, the output frequency is  $F = 1/2.2RC$ , where  $R = 10,000$  ohms and  $C = 1000$  pF, and the frequency is 45,454 Hz or 45.454 kHz.

### SHORT QUIZ ON DIGITAL FUNDAMENTALS—LESSON 3: DIGITAL CIRCUITS

- In logic circuits, the transistor is used as a:
  - resistor
  - diode
  - switch
  - capacitor
- When both junctions of a bipolar transistor are forward biased, the transistor is said to be \_\_\_\_\_.
- To save space on an integrated-circuit chip, a \_\_\_\_\_ is used as a pull-up or load in a MOS inverter.
- The basic TTL gate performs which logic function:
  - AND
  - NAND
  - OR
  - NOR
- The inputs to a 7400 TTL gate are +0.1 and +3.8 volts. The output will be:
  - cut off
  - conducting
- Which of the following is not a type of bipolar logic?
  - NMOS
  - ECL
  - RTL
  - DTL
- Logic circuits using both N-channel and P-channel MOSFET's are called \_\_\_\_\_ MOS.
- An enhancement mode N-channel MOSFET has a threshold of +1.5 volts. The gate voltage is +0.7 volts with respect to the source. The MOSFET is:
  - cut off
  - conducting

(Continued on page 100)



# THE DRIVE TO COMPUTERIZE YOUR CAR

**It's more than an electronic revolution. Communications, voice recognition, graphics, and other scientific developments are coupled with microprocessors to make your car of the future safer and more enjoyable to drive.**

By Marc Stern

□ WOULD YOU BE SURPRISED IF YOUR CAR STARTED TALKING to you? Well, you shouldn't be, because cars have been talking—using voice synthesis, of course—for a couple of years now. It's all part of the auto industry's movement toward the *computerized* car. It's a movement that started ten years ago, and which shows no signs of abating.

In fact, voice synthesis is only a small, although highly noticeable, part of the revolution that is sweeping the automotive world. Voice recognition is another. In the near future, you may very well be talking to your car, because of the developments now going on in the auto industry. Imagine telling your car to turn on its headlights or activate its windshield wipers and having the car respond. Or, imagine having your car sense that you've become drowsy behind the wheel and having it wake you up. That's being worked on, too!

It's not the realm of science fiction or fantasy, either. The Japanese automaker Nissan has announced that it is working on such a system and has shown it publicly in its NRV-II concept car. In that vehicle, the driver can talk with the vehicle. By pressing a switch on the steering wheel, the driver activates a system that accepts 26 commands. The microcomputer responds with an electronically synthesized voice.

That system can recognize any repeatable sound, so it can work in any language; however, it must learn a driver's voice characteristics before it can be used. A driver trains the system by using a checklist beforehand to record the desired command for each function. The microcomputer stores that

information in a digital template of sound equivalents and uses it later.

That car also has a certain degree of intelligence in that it can also ascertain if the driver is sleepy, based on changes in steering input that aren't in the programmed parameters. If the inputs the microcomputer receives do not match those parameters, the car issues a warning, waking the driver.

Those are only a few examples of the electronics revolution taking place in the auto industry. It will make the *computerized* car a reality in the next three to five years.

## The First Few Steps

To say that the automotive electronics revolution is a new development is somewhat misleading. Although the steps toward it were halting, there were unmistakable signs of the inevitable movement 20 years ago. At that time, solid-state electronics began appearing in cars; however, their application was limited to solid-state ignition systems and voltage regulators. That limited use continued for about ten years, until the auto industry began to feel the impact of the clean-air movement.

The only way the auto industry could meet anti-pollution guidelines was to turn to electronics. It had tried to meet them with mechanical methods but, as 1974 approached, the guidelines became too strict. The mechanical devices the industry had used—weights and pumps, for example—weren't up to the exacting requirements needed to maintain an engine at the proper point for both clean emissions and

fuel economy. The industry had to turn to other means to maintain the air-fuel ratio of 14.6-to-1.

Fortunately, integrated-circuit devices capable of handling those chores were appearing. In 1974, Chrysler Corporation became the first company to use a microcomputer to control emissions. Actually it was an analog comparator system that maintained proper engine operation by comparing the analog signals it received with information stored in memory; it then advanced or retarded the timing to compensate.

It took four years of development for the real breakthrough to occur. At last large-scale integration and  $\mu$ P's (microprocessors) were advanced enough to permit Chrysler, General Motors, and Ford to begin phasing them in. That development was the result of work by the auto industry's research and development departments, which haven't been idle since. Their work is yielding smarter cars.

For example, for the last three years, Chrysler and Ford have had cars that talk through digital voice synthesis. Voice messages have replaced the traditional red warning lights.

Instrumentation is changing, too. The traditional speedometer and red warning lights will soon be things of the past as vehicular cathode-ray tubes and liquid-crystal displays take their place. They promise a far denser information flow than they were ever capable of by simple displays.

Take the cathode-ray tube, for example. The first automotive application was developed by Zenith in 1981; it is now

being used in the Buick Riviera. The Riviera's CRT combines a touchscreen to activate the functions it is capable of—entertainment center and climate control, for example.

Multicolor, liquid-crystal, and flat vacuum fluorescent displays are also being used for driver information. In the next couple of years, satellite navigation systems and compact disc players for information storage will also appear, but more about that later.

One area of development and expansion has been in the use of memory. During the last five years, automakers have gone from using roughly 8K of Read-Only Memory (ROM) to 40K, or more. Along with that increase in memory capability has come an increase in the power and sophistication of automotive microcomputer systems.

The CRT-equipped Buick Riviera uses two eight-bit 6801  $\mu$ P's, each of which has 32K of ROM for graphics and 8K of ROM for logic.

### Multiplexing Still Experimental

You would think that along with the proliferation of  $\mu$ P's in cars there would have been a concomitant advance in micro-to-micro communication, but there hasn't.  $\mu$ P's are still dedicated to single tasks. Multiplexing, which will bring total vehicle management, is needed to make that happen.

To show what multiplexing means, let's say your car is headed down a steep grade. The engine-control system would

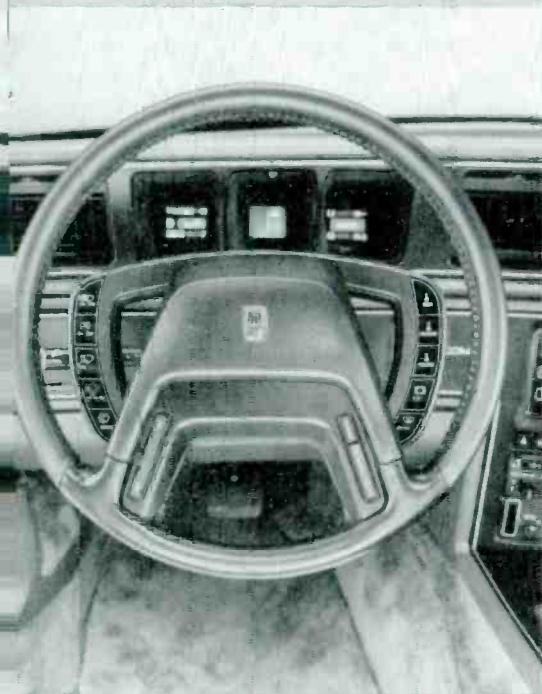
This dramatic view of a digital dashboard is in the 1985 Subaru XT Coupe. The electronic instrument display brings a three-dimensional look to digital dashboards. 3-D blocks, which light up in increments, display conditions for both fuel and coolant temperature. The tachometer and boost gauges are triangular-bar gauges which "come to you" from a central vanishing point.



Here's Chrysler's new concept in automotive navigation. The prototype car keeps in touch with a U.S. NAVSTAR satellite. The system can bring you to within a football-field length of your destination anywhere reachable by land. The prototype car incorporates the Chrysler's laser Atlas and Satellite System that features broad capabilities in the area of safety and convenience.



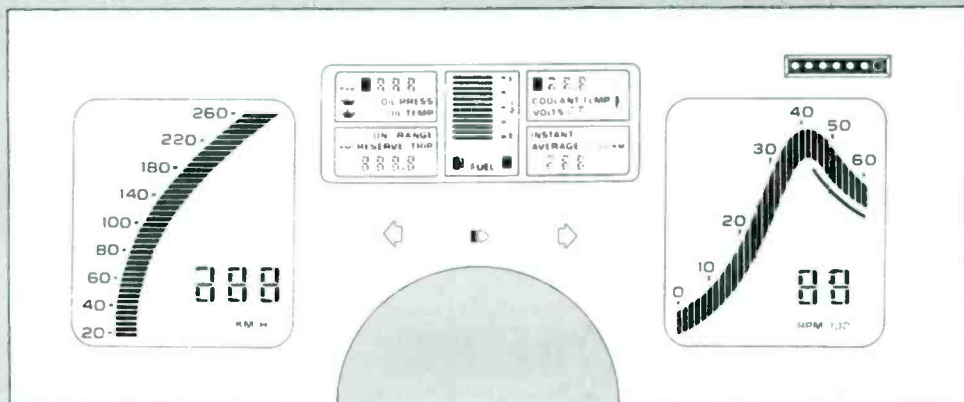
Extra interior cooling is provided for the Saab 900 Turbo EV-1 weather-control system thanks to solar cells in the car's all-glass roof. Solar cells power a fan that ventilates the interior when the car is parked and powered down. The greenhouse heat-buildup effect is reduced.



The driver of Ford's 1985 Mark VII Comtech experimental car can operate a number of functions without removing his hands from the steering wheel. Ten switches (see photo at left)—five on the left of the steering column and five on the right—permit fingertip control. The instrument-panel cluster behind the steering wheel consists of three modules with liquid-crystal displays. The cathode-ray tube (top panel in photo at right) in the Mark VII Comtech displays driver information and also permits manipulation of such items as the climate-control system simply by touching the screen. Below it is the advanced radio/audio system with automatic Dolby, AM/FM stereo, graphic equalizer, and dynamic noise reduction (DNR).



The microprocessor-controlled instrument cluster diagrammed here was first used in the 1984 Chevrolet Corvette. The instrument cluster consists of three separate multi-colored liquid-crystal displays. Both the car's speed and engine RPM are displayed with analog and digital readouts. Other information provided are oil pressure, oil temperature, coolant temperature, system voltage, instant or average fuel economy (liters per 100 kilometers), trip mileage, fuel level, and "almost-out-of-gas" indicator.



know almost immediately that conditions were changing because the load on the engine was much lighter. That information is locked within the system, because it doesn't communicate with any other. However, if multiplexing were used, the engine microcomputer's signals would be monitored by a master microcomputer which would be able to determine, after consulting other subsystems, that the car is heading downhill and that other systems might need to be alerted.

Thus, master microcomputer could issue a command to the system controlling the brakes—an anti-skid braking system now in use is controlled by  $\mu$ P's—to help slow the car down and it could issue a command to the transmission to drop down a gear to compensate for the lighter load. Therefore, the car would be safer to drive. And, if there were a four-wheel-drive system, it might also order the second set of driving wheels to engage automatically. Finally, it could further order the ignition system to optimize the timing for top fuel economy. That's the advantage of multiplexing. It gives you a total vehicle-management system.

As another example, let's look at fuel economy. Today, some cars have simple systems that indicate your car's average mileage, based on current engine-operating parameters. They can't suggest ways to increase fuel economy. With multiplexing, fuel use, and vehicle-operating information could be compared with information stored in ROM and suggestions on how to improve fuel economy in a given situation could be displayed.

The list of possibilities goes on and on, but they all point to a total vehicular-management system.

Every automaker is excited by multiplexing. GM, Ford, and Chrysler all have prototype multiplexed vehicles in Detroit, as do the imported marques.

### Micro's Revealed

The automotive industry uses a variety of  $\mu$ P's. Ford uses a powerful 16-bit microcomputer to drive its EEC-IV engine-control system. Using an Intel 8061  $\mu$ P, the EEC-IV system not only controls the engine, but also handles diagnostics. At the moment, that is its only function, although it can handle far more. Ford's multiplexing system is still too experimental to unlock the power of that microcomputer.

Displays, for the most part, are handled by 8-bit  $\mu$ P's of the Motorola 6801 series. General Motors, which uses the 6801 in other systems, also uses it for its  $\mu$ P-driven displays.

One of General Motors' most advanced displays is found in the Chevrolet Corvette. The Corvette's multicolor liquid-crystal display is driven by a dedicated microcomputer with a 6K memory. It takes inputs from various systems and provides the driver with real-time information updates on engine-operating parameters, as well as trip information. It may seem as if that would tax the microcomputer to its limits—but it doesn't, because it is capable of executing a program at more than 300,000 instructions per second and it uses roughly half its capacity. It also uses CMOS RAM to store information.

Chrysler, too, uses the 6801 in its engine-control module.

### Looking Ahead

The future of the *computerized* car is best seen in a series of concept cars; the Buick *Questor*, Ford Motor Co.'s *Continental Concept 100* and *Comtech Mark VII*, the Chrysler *Stealth*, Nissan NRV-II, the Mazda MX-02, and the Saab 900 Turbo EV-1.

The Buick *Questor* is an idea car from that GM division to serve as a developmental *test bed*. It sports many cutting-edge ideas, but its most important feature is the fact that it uses 14  $\mu$ P's, multiplexing them into an integrated system that provides a total vehicular-management package.

But while the  $\mu$ P's may be the most important feature, it does have some other innovations worth mentioning. For example, that car uses an infrared door-lock system; an automatic level, attitude, and spoiler control system; a "systems sentinel," which monitors the status of vehicular systems; and a heads-up, line-of-sight display for the speedometer and gauges at the top of the instrument pod. There's also a map and navigation system; automatically aimed headlights that pivot as the steering gear moves; theft deterrent system; voice-actuated radiotelephone; road-surface traction monitoring system; television rear-view mirror system, and a touch command center for entertainment, comfort, and convenience functions.

The heads-up, line-of-sight display works much like the sight in a jet fighter. A specially angled screen displays information for the driver and always remains visible. It is directly in the driver's line of sight, but doesn't block the view of the road ahead because it is transparent. It appears to overlay the road ahead. It is the first time that that technology has been used in a car.

The traction sensor system uses special motion sensors at each wheel to determine the traction characteristics of the road surface and the  $\mu$ P. It then compensates for any changes.

All the foregoing technology is under the skin. More visible are the dual CRT's in the passenger cockpit, and a control pod in the center of the steering wheel that allows fingertip control of comfort, convenience, and safety systems.

*Questor* also sports a navigation system. It can display states, area, or metro maps on one of two display screens, mounted in the center control console. In the navigation mode, a dot on the screen shows the location of the vehicle and moves when the vehicle moves. An electronic compass display gives the directional heading at all times. It uses cassette storage for that function.

The Chrysler *Stealth* is equipped with the Chrysler *Laser Atlas Satellite System* (CLASS). That concept combines not only navigational satellite-receiving technology, but also optical disc and touch-screen CRT technology into a package that can position your car to within 300 feet of a desired intersection. It is the first vehicle to use optical disc storage.

Microprocessor-controlled, the CLASS system interacts with the five operational NAVSTAR satellites in orbit around the earth. A network of 18 satellites is ultimately planned. The receiver takes positional inputs from the satellites as they circle the globe and constantly updates the car's position. The  $\mu$ P, in turn, is able to translate that information in four dimensions, latitude, longitude, height above sea level, and time. A pressure sensor determines and provides input about the car's height above sea level.

After that system has taken those inputs, it compares the information with that stored on an optical disc and it is able to give you a map display of the car's position on the system's 9-inch color CRT. It takes quite a sophisticated algorithm to handle that.

The optical disc-storage system can store up to a maximum of 13,300 maps that encompass the continental United States. Further, those replaceable discs are capable of storing as



SAFETY AND CONVENIENCE

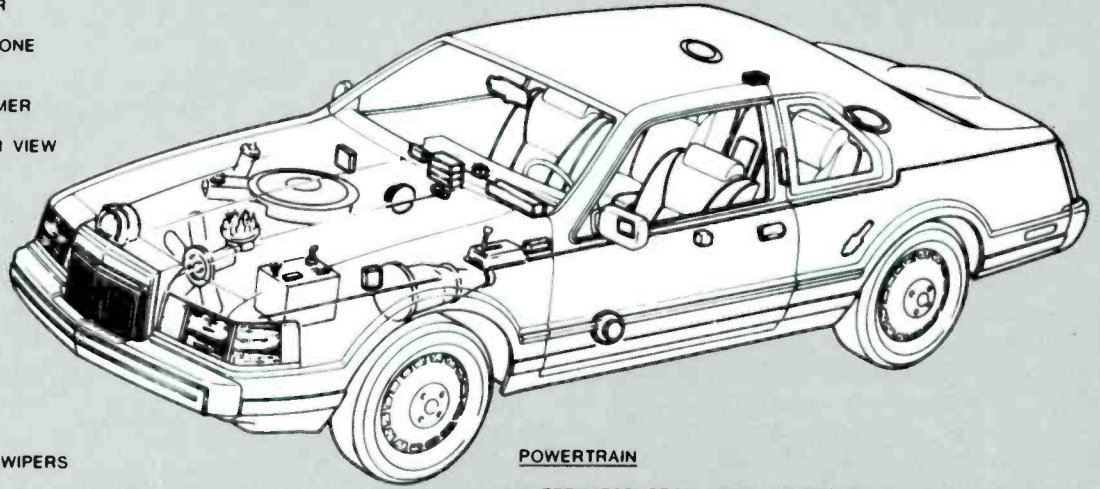
- ELECTRONIC CLIMATE CONTROL
- ILLUMINATED/KEYLESS ENTRY
- AUTOMATIC HEADLAMP DELAY OFF/DIMMER
- GARAGE DOOR OPENER
- ELECTRONIC CHIMES/TONE WARNING
- HEATER BACKLIGHT TIMER
- AUTO DAY/NIGHT REAR VIEW MIRROR
- ELECTROLUMINESCENT COACH LAMPS

AUDIO

- ELECTRONIC RADIO WITH CASSETTE
- GRAPHIC EQUALIZER
- PREMIUM SOUND
- CB RADIO

DRIVER INFORMATION

- ELECTRONIC CLUSTER (SPEEDOMETER, FUEL, TEMP, ODOMETER)
- OUTSIDE THERMOMETER
- MESSAGE CENTER/TRIPMINDER
- GRAPHIC WARNING DISPLAYS
- COMPASS
- CLOCK



VEHICLE CONTROLS

- SPEED CONTROL
- INTERVAL WINDSHIELD WIPERS
- ELECTRONIC AIR SUSPENSION
- ANTI THEFT

POWERTRAIN

- ALTERNATOR/REGULATOR
- THICK FILM IGNITION
- EEC IV
- UPSHIFT INDICATOR

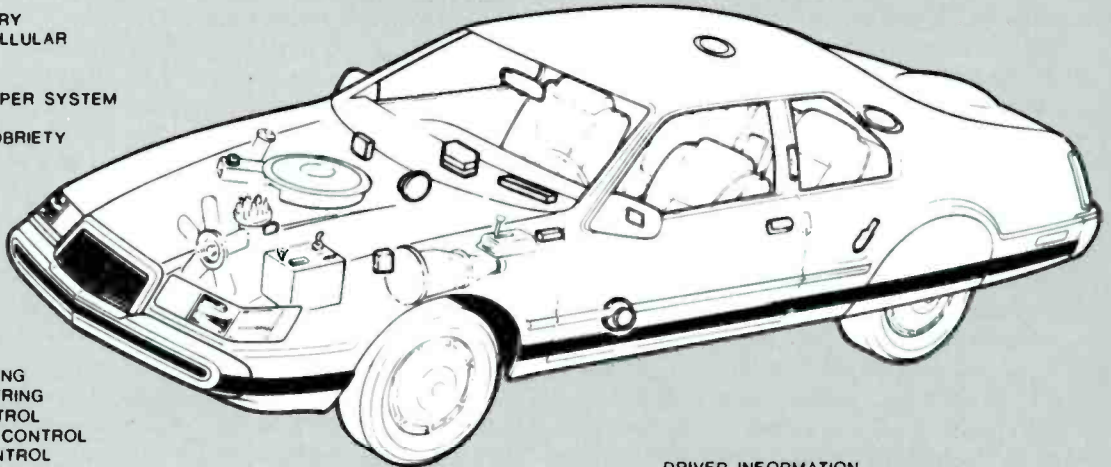
What we now have (above) and what we will soon have within five years (below) is depicted in the drawings by Ford engineers. The drawings itemize electronic and computer features in the following categories: safety and convenience, audio, driver information, vehicle controls, and power train.

POWERTRAIN CONTROLS

- THIRD GENERATION EEC-IV
- DIESEL ENGINE CONTROLS
- TRANSMISSION CONTROLS
- IDLE SPEED CONTROL
- ELECTRONIC ENGINE MOUNTS
- DISTRIBUTORLESS IGNITION
- INTEGRATED THROTTLE BODY
- HYBRID SPARK CONTROL
- COMPUTERIZED DEALERSHIP DIAGNOSTICS LINK TO FORD SERVICE

SAFETY AND CONVENIENCE

- HEATED WINDSHIELD
- REMOTE KEYLESS ENTRY
- MOBILE TELEPHONE-CELLULAR SYSTEM
- POD CONTROLS
- SMART WINDSHIELD WIPER SYSTEM
- KEYLESS IGNITION
- DRIVER ALERTNESS/SOBRIETY WARNING
- QUICK HEAT SYSTEM
- DUAL/REAR SEAT CLIMATE CONTROL



VEHICLE CONTROL

- ANTI-LOCK BRAKING
- LOAD SENSITIVE BRAKING
- SPEED SENSITIVE STEERING
- HARD/SOFT RIDE CONTROL
- DYNAMIC SUSPENSION CONTROL
- VEHICLE ATTITUDE CONTROL
- ELECTRIC LOAD MANAGEMENT SYSTEM
- VARIABLE SPEED ACCESSORY DRIVE
- MULTIPLEXED WIRING SYSTEM
- VEHICLE DATA COMMUNICATIONS LINK

AUDIO SYSTEMS

- DIGITAL AUDIO DISK
- REAR SEAT CONTROLS
- ELECTRONIC RADIO AND PREMIUM SOUND WITH MOTIONAL FEEDBACK AND OVERHEAD SOUND

DRIVER INFORMATION

- VEHICLE MAINTENANCE/SERVICE INTERVAL MONITOR
- FUEL COMPUTER
- NAVIGATIONAL SYSTEM (COMPASS/SATELLITE)
- CRT INFO SYSTEM/INTERACTIVE DISPLAY
- HEADS UP DISPLAY

many as 25,000 images per side.

CLASS uses an icon (video image to represent the car) to indicate your car moving along the map's surface and the driver has the option of zooming in to a relatively small area of a map, as small as 50 square miles, or zooming out to a map displaying as much as 1,600 square miles. The choice is handled with the touch-sensitive screen.

One navigation system that is here today is manufactured

by Etak, Inc. Rather than relying on satellites, the Etak system relies on wheel-mounted sensors and a compass module for positional information. The compass module sends its information to a  $\mu$ P, while wheels transmit distance information.

In turn, the  $\mu$ P takes those inputs and, using a cassette-based program storage system, compares the data with that stored on tape and determines the car's position. Much of the

positional logic comes from a series of proprietary Etak programming tapes. Positional information is displayed on a high-resolution CRT. A small icon depicts your car's position. As with the Chrysler system, you can zoom in and out of specific map views.

The Ford Comtech, like the other concept cars already mentioned here, combines a CRT display device and wheel-mounted controls to give the driver a complete automotive information system. For example, without lifting your fingers from the wheel, you can turn on the windshield wipers, adjust the heater and defroster, and tune the radio. Further, the CRT gives you not only travel information, but also service information.

### Diagnostics a Key

At the moment, though, the primary use of automotive microcomputers is for diagnostic purposes.

Information related to engine function, is generated by each engine-control subsystem and is stored in scratch-pad memory as a series of numeric codes. They can be accessed by anyone quite easily. All it takes is turning the ignition off and on again within five seconds and the *engine check* light will begin to blink with a series of codes. The codes indicate any diagnostic problem.

Even though the  $\mu\text{P}$  is providing that information, it is still elementary. At the moment, you are only given an indication of a general area where a problem may lie. You must then follow a long, paper-based series of checks to determine the exact problem. But multiplexing will probably solve that, too.

In the multiplexed car of the future, the engine-control  $\mu\text{P}$  will handle far more than it does now. Since it will be part of an integrated automotive system, it will most likely play a role not only in engine control, but also safety, fuel economy, and maintenance. For an example of the latter category, let's look at the BMW maintenance reminder system.

Instead of being a simple mileage reminder, the BMW system uses its  $\mu\text{P}$  to evaluate the type of driving you do. After evaluating your driving, the  $\mu\text{P}$  then sets an oil-change warning interval. The variables it evaluates to set that include engine speed, coolant and oil temperatures, and miles driven and uses that data to determine the interval. Nine light-emitting diodes indicate the service interval. There are five green LED's; one yellow, and three red. When servicing is first done, only the green LED's glow and they begin to flash off when you accumulate mileage. When no more LED's are lit, it indicates that it's time for service. After a time the yellow LED begins issuing a reminder that you're past due and if you continue to ignore it, the red LED's sequence on at about 1,000-mile intervals.

Imagine what will happen when that type of information is available to a multiplexed system. For starters, instead of relying on an LED display, the information will be presented on the display and, since the entire engine system will be monitored, you will receive not only information on when to change oil, but also when to change other fluids, filters, and components. Further, since the master microcomputer in that system will have a record of the type of driving you do, it may even be able to instruct the engine-control system to adjust things to maximize service life. It's an exciting prospect. Also, imagine having the entire service record of your car at your fingertips, as well as recommendations for future service. All of that could be built into that system.

That type of capability hasn't always been the case. As recently as nine years ago, there were few devices capable of operating in the harsh underhood environment. For example, GM needed a sensor that could work reliably in the engine bay, in an environment which ranged from  $-40$  to  $+120$   $^{\circ}\text{C}$ . Since one wasn't available, the company's Delco Division developed it. It developed a piezoelectric sensor to transmit pressure changes within the manifold. Using analog-to-digital transformation, the signals were digitized and were sent to the engine control  $\mu\text{P}$ . That was a case of the auto industry seeing the problem and developing its own solution, where none had existed before.

Another breakthrough occurred in Europe, when such auto makers as Volkswagen and Volvo developed oxygen sensors which could function directly in the air-fuel flow, and which were long-lived devices. Those devices enabled the auto industry to more precisely measure changes in the air-fuel requirements of an engine; similar technology was also used to measure pollutants in the exhaust manifold. Those and other developments brought electronic engine control to fruition.

By 1981, most automakers could say with confidence that their entire fleet of cars was equipped with  $\mu\text{P}$  engine control.

### Eight-bit Microcomputers

The auto industry relies to a great degree on the 6800 series of Motorola eight-bit  $\mu\text{P}$ 's. GM, for example, uses custom-masked versions of 6800 series  $\mu\text{P}$ 's. Chrysler, too, uses 6800 series  $\mu\text{P}$ 's for its engine-control system.

In operation, the  $\mu\text{P}$  takes inputs from various sensors—manifold air pressure, coolant temperature, oxygen sensor, exhaust gas-recirculation, and more—and, comparing the data input against the values stored in a firmware algorithm, instructs the engine components to vary air flow, fuel flow, or timing, according to changing conditions.

Engine control systems include circuitry which performs analog-to-digital conversion. That is of necessity, since the sensors produce voltage changes to register changes in engine state. Those changing voltages must be digitized before they can be used by the microcomputer.

For example, the coolant-temperature sensing unit is actually a thermistor-based device. Its resistive qualities vary according its temperature environment, and as those qualities change, it responds with changes in voltage. Those voltage changes are then sent to the  $\mu\text{P}$ , which performs the A-to-D conversion, and then compares the information with that stored in ROM and reaches its decision.

As we have noted, each system is capable of generating diagnostic and fault information based on the inputs it receives. For example, let's say the microcomputer receives some information which is outside the parameters set by its algorithm. When it does, it determines that that information belongs to the diagnostic class and therefore stores it in RAM for later reference. The Chrysler system has 192 bytes of CMOS RAM for that function; other systems contain varying amounts, depending on the number of systems monitored and the number of fault codes generated.

That information serves as the basis for far more than simple diagnostics, though, because it is also the basis for each  $\mu\text{P}$ 's fail-safe mode. For example, if the information matches a set of instructions that relate to catastrophic failure, then the microcomputer establishes a set of fail-safe operat-

(Continued on page 96)

# INSIDE THE OSCILLOSCOPE

**A benchtop tool that compares electrical signals against time, so that you can see and understand!**

By Roger M. Stenback and Carl Laron (Associate Editor)

□ THERE ARE FEW TEST INSTRUMENTS IN ELECTRONICS THAT are as important or versatile as the oscilloscope. After all, oscilloscopes do more than measure—they let you “see” the signals at various stages of a circuit.

But what do you know about oscilloscopes? Have you ever wondered how they convert the signal measured at the probes into a visible signal? Have you ever wondered if you are getting the most you possibly can out of a scope? What about scope specifications—do you know what they mean and which are most important? In this article we are going to answer those questions, and more.

With so much to cover, let’s get to it.

## Inside an Oscilloscope

Look at an oscilloscope, and the first thing you’ll notice is the cathode-ray tube (CRT). Much as the case in a TV set, it is the job of the CRT to convert a stream of electrons that are emitted from a set of electrodes at one end into a visible, usable display. Figure 1 shows a typical CRT. Like a TV CRT, the electron gun located in the narrow end of the tube generates a beam of electrons and propels it in the direction of the wide end of the tube. At the wide end, of course, is a phosphor-coated screen. Whenever the beam strikes the phosphor, the phosphor glows.

In addition to the electron gun, the narrow end of the tube has two pairs of deflection plates—one vertical, the other horizontal. As their name would suggest, the purpose of

those plates is to deflect the beam in either the horizontal or vertical direction. To do that, voltages are applied to the plates. The deflection that occurs is based on the principle that the negatively charged electron is attracted to a deflection plate when that plate is more positive than its counterpart opposite it.

Let’s see how those plates do their job. If the voltages on the vertical deflection plates are equal, and the voltages on the horizontal deflection plates are equal, the electron beam is not deflected (actually the pull or repulsion is equal) and the beam will strike a point at the center of the screen (see Fig. 2-a). If, on the other hand, the voltage on the right deflection plate is more positive than that on the left, the beam will strike a point to the right of center (assuming that the voltage on the top and bottom vertical plates is still equal); that is shown in Fig. 2-b. The amount of deflection is determined by the difference and polarity in voltage. If the left plate had the greater positive voltage, the beam would, of course, be deflected to the left. Vertical deflection takes place in a similar manner.

That takes care of up-and-down and left-and-right positioning. Positioning the beam in other locations on the screen is handled by combinations of vertical and horizontal deflections. If, for instance, the beam were deflected equally in the up and right directions, it would be positioned as shown in Fig. 2-c.

The next step is to consider what would happen if we were to replace the DC voltages on the deflection plates just discussed with changing voltages. The result would be that those changing voltages would cause the beam to constantly

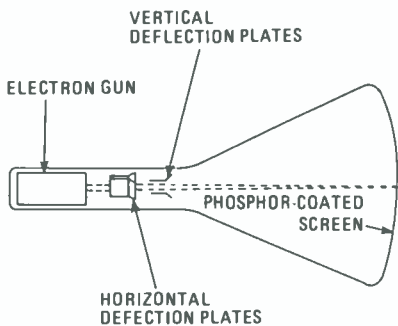


Fig. 1—The cathode-ray tube is diagrammed here to show how the electron beam is projected from the electron gun to the phosphor-coated screen. The electron beam passes between the vertical and horizontal plates that are used to deflect the beam sidewise and vertically.

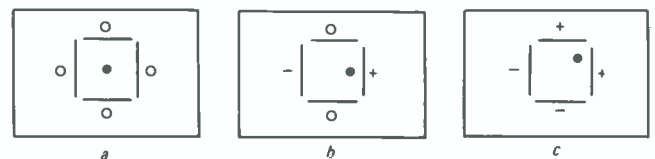


Fig. 2—Looking at the phosphor-coated screen we can get an idea of how the deflection plates operate on the electron beam. The four lines that appear as an open-cornered box are the deflection plates. The solid dot inside the box is where the electron beam strikes the screen, and the 0, -, and + signs indicate the voltage polarity, or no voltage, applied to the plates. The text describes the action that takes place.

move, or scan across the screen. If, for instance, a sawtooth voltage were applied to the horizontal deflection plates so that the right plate would go positive, the beam would scan from left to right. On the descending edges of the waveform, the period where the sawtooth goes from its maximum voltage to its minimum, the beam would quickly snap back from the right to the left side, due to the rapid voltage change. As a sawtooth is a periodic (repeating) function, that process repeats itself over and over. The result is a visible horizontal trace, called the sweep.

During all that, we have assumed that there has been no voltage applied to the vertical deflection plates. If, there is a voltage on the vertical deflection plates, the result is no longer a horizontal line. Let's see what happens.

For our example, let's assume that the voltage placed on the vertical deflection plates is a sine wave. Now, a varying positive voltage is placed on the top deflection plate during the first half-cycle of the sine wave and a varying positive voltage is placed on the bottom deflection plate during the second half-cycle. As the beam is swept from left to right, during the first half-cycle it is also pulled upward in response to the voltage on the top plate. During the second half-cycle, the beam is pulled downward in response to the voltage on the bottom deflection plate. The result is that the varying voltage pattern of a sine wave is traced on the oscilloscope screen. In a similar fashion, other types of waveforms, such as square waves, triangular waves, or more complex waveforms (such as a video signal) can be displayed.

Figure 3 shows a simplified block diagram of an oscilloscope. The signal to be input is fed to a vertical amplifier. In that stage, the signal is applied first to a calibrated attenuator and then to the actual amplifier. From the amplifier, the signal is applied to the vertical plates of the CRT. We'll talk more about the attenuator when we look at how a scope is used, a little later on in this article.

Part of the input signal is split off and fed to the sync system of the scope. That system is used to trigger the start of the sawtooth waveform that we spoke of earlier. The waveform itself is generated by the horizontal deflection circuit.

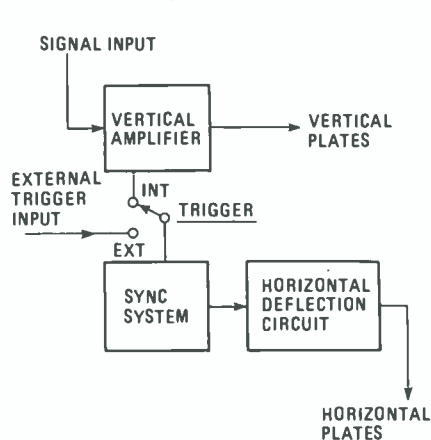


Fig. 3—A simplified block diagram of the deflection sections of an oscilloscope. The TRIGGER switch and TIME/DIV are front-panel controls.

## The Sweep Signal

The sync section (Fig. 3) is important as the sawtooth waveform must be synchronized to the input signal. If the sawtooth is not synchronized to the input—that is, if their periods were different—the display would be hopelessly jumbled.

In the simplest oscilloscopes, the task of synchronization is handled by using a free-running generator to create the sawtooth. Such a unit is called a recurrent sweep oscilloscope. The scope is synchronized by adjusting the sawtooth generator until its output waveform has the same frequency, or some multiple thereof, as the input signal. To achieve that aim, the vertical signal is sampled, and injected into the generator. The generator locks onto that sample, and follows the frequency and phase of the input.

While recurrent sweep is the lowest-cost type of synchronization, it has many drawbacks and is rarely if ever used in modern scopes. Among its limitations are that it is difficult, if not impossible, to change the point where triggering starts and it is difficult to determine the period of the sweep signal.

Those problems can be solved through the use of a triggered sweep scope. In that type of scope, the free-running generator is replaced with a one-shot, and the sawtooth waveform is replaced with a ramp. The one-shot is set, using a comparator circuit, to output its ramp at a specific point on the input waveform, assuming that the scope is used in its internally triggered mode. The user, using a time-base control, usually labeled as VOLTS/DIV, can select the exact period of the sweep signal.

Thus far, we've considered only internally triggered scopes; that is, scopes that trigger the sweep at a specific point on the input signal. Most scopes also have provisions for the input of an external trigger signal. When a scope is externally triggered, the sweep generator outputs its ramp at a specific point on the trigger waveform. Needless to say, the trigger waveform should be time related to the input waveform. Otherwise, the display would not provide useful information as triggering would be random.

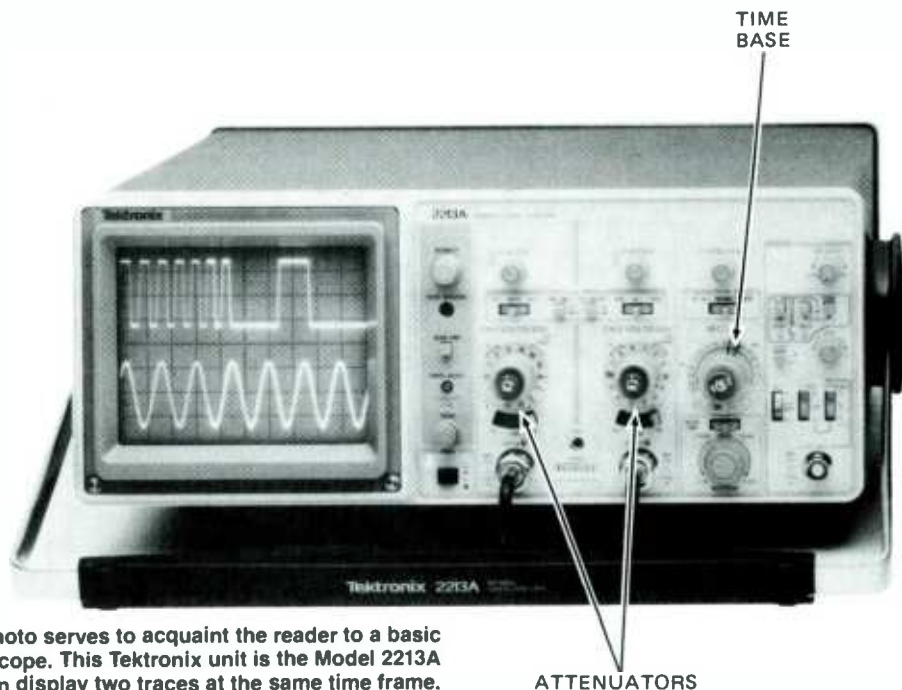


Fig. 4—The photo serves to acquaint the reader to a basic oscilloscope. This Tektronix unit is the Model 2213A that can display two traces at the same time frame.

## Calibration

Look at the CRT of almost any modern scope and you will notice that it features a square grid, called the *graticule*. On a typical scope, the graticule is a 10- by 10- or 8-division calibration grid with 1-centimeter by 1-centimeter spacing.

Figure 4 shows the front panel of a modern oscilloscope; in this instance, we show the Tektronix 2213A, 60-MHz unit. Take note of two of the controls we've already briefly touched upon—the time-base control, and the vertical attenuator.

Except for low-level signals, input signals can not usefully be displayed directly on the screen. That is because most input signals would extend above the top and bottom of the screen. Thus, all scopes have some type of input attenuator. The vertical attenuator is usually made up of two parts. One is a precision attenuator, calibrated in volts-per-division, although it might be calibrated in volts-per-centimeter. The other is an infinitely variable, uncalibrated control that allows for adjustment between the switch positions if needed or desired. Note that for calibrated operation, the uncalibrated control must be fully clockwise; usually there is a detent in that position. The calibrated control is usually set up in the familiar 1-2-5 scheme. For a typical scope, the lowest setting might be 0.1 volt, and the highest possibly 500 volts.

The time-base control is used to set the period of the sweep signal. It, like the attenuator control, usually consists of two parts—a calibrated rotary switch, and an infinitely variable uncalibrated control. The uncalibrated control allows for selection of a time base between two switch positions. If calibrated operation is desired, the uncalibrated control must be turned fully clockwise until it snaps into a detent. The calibrated time-base control is usually set up in the familiar 1-2-5 pattern.

## Analyzing a Display

Let's now look at a display, and see how our two basic controls effect it. Figure 5 shows a squarewave. For our example, let's assume that the attenuator is set for .5-volt-per-division, and the time base has been set for 0.2 millisecond-per-division. Both controls are set for calibrated operation.

In the figure, the distance between the leading edge of two adjacent pulses is 4 divisions. With that information, the period of the input waveform can be determined. It is quite simply  $4 \times 0.2 = 0.8$  milliseconds. Once the period is known, it is a simple matter to convert to frequency using the formula,

$$f = 1/T = 1/0.0008 = 1250 \text{ Hz.}$$

If you needed to know pulse duration, it can be found in a similar manner by counting the number of divisions between the leading and the trailing edge of a single pulse. In our example, it is one division, so our pulse duration is simply 0.2 milliseconds.

Input voltage is found by simply counting the number of divisions between the positive and negative peaks of the input signal. Here, it is four divisions, and since our control is set for .5 volt-per-division, we have an input signal of 2 volts.

We now have a complete picture of our input waveform. It is a squarewave with a frequency of 1250 Hz, a pulse duration of 0.2 millisecond, and a voltage of 2 P-P (peak-to-peak).

Let's look at a second example. This time it is the sinewave shown in Fig. 6. We will assume that this time the attenuator is set for 0.5-volt-per-division and the time base for 50 microseconds.

As before, the peak-to-peak voltage can be found easily

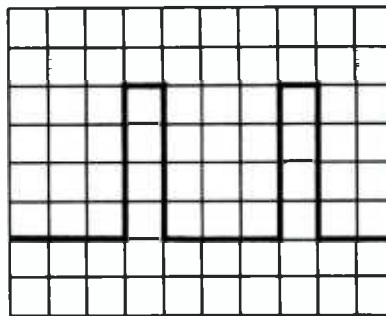


Fig. 5—Here is a simple bi-symmetrical square that is displayed to coincide with the graticule on the oscilloscope. The setting of the calibrated time base control and vertical attenuator permits the viewer to determine the frequency and peak-to-peak voltage accurately. Text gives details.

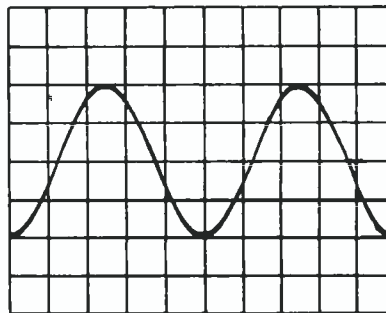


Fig. 6—What's good for the squarewave should work for the sinewave. In this instance the frequency and voltage of the sinewave can be determined with accuracy.

enough by counting the number of vertical divisions. In this case, it is four, so our peak-to-peak voltage is  $2 (4 \times .05 = 2)$ .

To find frequency, we first need to find the period of the waveform. That's done by measuring the divisions between two like points on two successive cycles. For instance, from the crest of one peak to the crest of the next. In our example, there are five divisions between one crest and the next, thus the period is  $5 \times 50 = 250$  microseconds. The frequency is then found from  $f = 1/T = 1/(250 \times 10^{-6}) = 4000 \text{ Hz} = 4 \text{ kHz}$ .

## Dual Trace Oscilloscopes

Thus far, we've talked only about single-beam scopes. In such a scope, only one input can be displayed at a time. But it is often useful, if not essential, to compare signals at different parts of a circuit—typically at the input and the output. You could, if you wish, examine the signal at the circuit input and then move the probes to the output to examine the signal there. There are some obvious drawbacks to that. The chief one is that, because neither trace remains on the screen once the input is removed, it is difficult to do useful comparisons. The way to overcome that, of course, is with a dual beam or a dual trace oscilloscope.

A simple block diagram of a dual-beam scope is shown in Fig. 7. That scope uses a special CRT with two electron guns, two pairs of vertical deflection plates, and a single pair of horizontal deflection plates. Both electron beams are deflected from left to right simultaneously by the horizontal amplifier. As to vertical deflection, each beam responds only to the signal from the appropriate vertical amplifier and deflection plates. In essence, such scopes act as two independent scopes sharing a common display. Often, however, such dual-beam scopes are prohibitively expensive.

Because of that, dual-trace oscilloscopes are much more  
(Continued on page 95)

# PUT YOUR TELEPHONE ON HOLD

**What was once considered an exclusive service of the telephone company can now be had at home as an add-on or built-in low-cost project!**

By Herb Friedman

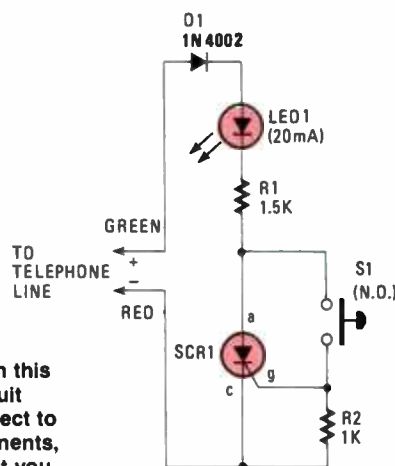
□THERE ARE MANY OCCASIONS WHEN IT'S NECESSARY TO prevent our voice or office sounds from being fed into the telephone. While it's easy enough to do that with a multi-line office telephone having a *hold* button that disconnects the handset while maintaining the telephone connection, those of us with conventional telephones are reduced to clamping our palm over the handset's transmitter, or whispering. While there are commercial devices in the marketplace that add a hold function to a conventional phone, most of the gizmos sell in the \$30-\$50 price range. On the other hand, for as little as \$5 you can build the universal *Telephone Hold* described in this article. The Telephone Hold functions almost the same way as the hold button built into many office telephones.

Push the button on the Telephone Hold and hang up the phone. The hold feature in our nifty gadget seizes the telephone line to maintain the circuit even though the telephone is on-hook. Lift the handset (off-hook) to resume your conversation and the hold feature automatically releases. A light-

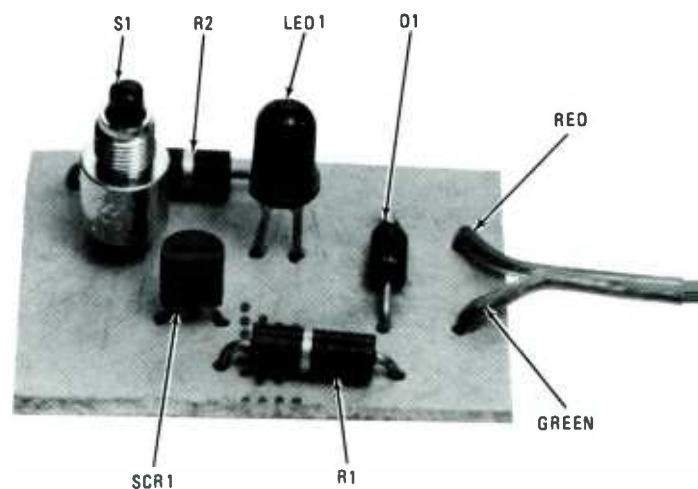
emitting diode (LED) built into the device glows when the line is seized and the call is *on hold*.

What makes the Telephone Hold universal is that it is powered directly by the telephone line; hence, it can simply be connected across the telephone wires. There's no need to modify or even open the telephone. Because the Telephone Hold is connected across the "talking pair," it can be also automatically released by extension telephones. If the Telephone Hold is used to seize the line in, say, the kitchen, lifting a handset in the garage or the basement playroom will automatically disengage the hold. You don't have to return to the Telephone Hold in order to turn it off.

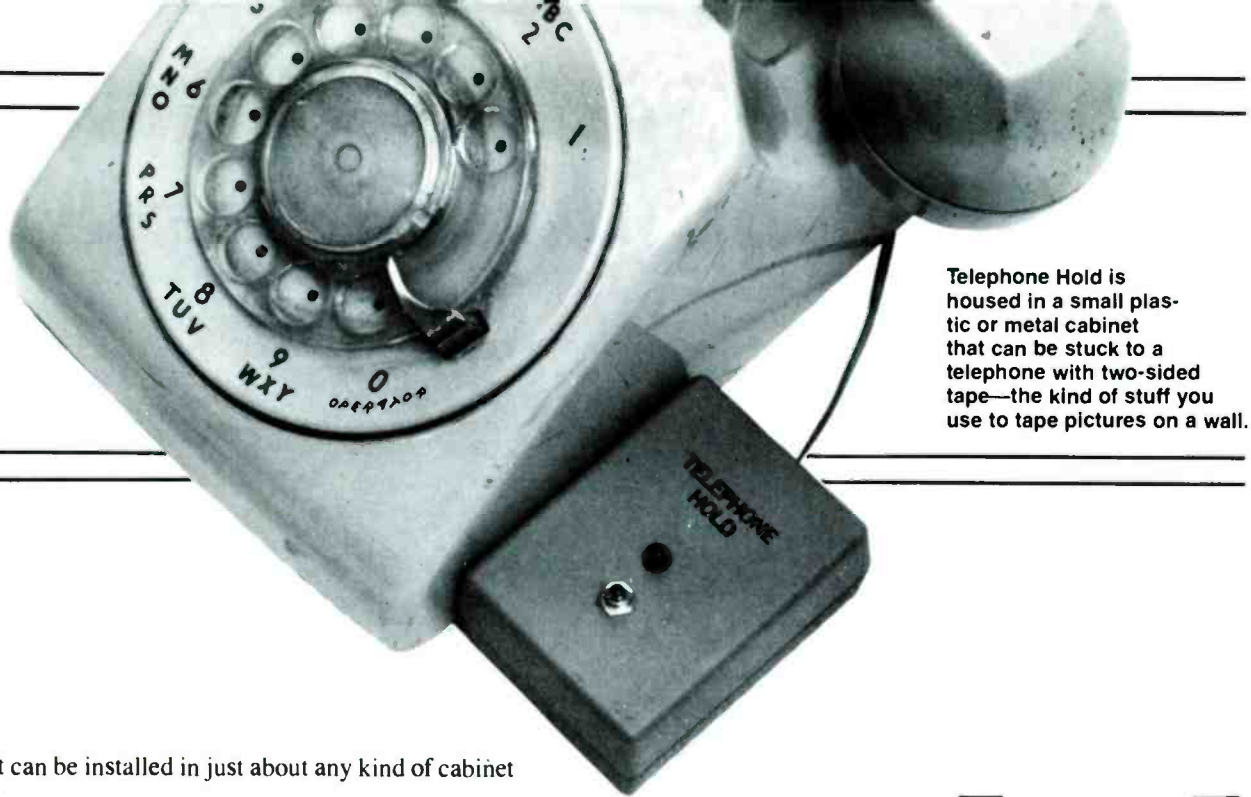
Although the unit shown is built into a small plastic cabinet, it could just as easily be installed directly in a telephone, because its 1½ × 1⅛-in. printed-circuit board is actually smaller than a commemorative stamp. Or, the device can be installed in a small plastic pillbox that is cemented with two-sided adhesive tape to the telephone. In short, the device is so



**Fig. 1—The circuit for Telephone Hold project in this diagram looks like a circuit fragment. You would expect to see several more components, maybe an IC or two. What you see is what you need! In order for circuit to operate properly, it relies on the DC power from the local telephone exchange, and the ohmic resistance of the telephone line. You pay for it, so why not use it!**



**The complete Telephone Hold is assembled on a printed-circuit board about the size of a postage stamp. Take note how light-emitting diode LED1 is raised above the printed-circuit board so that it will protrude through the cabinet. The assembly is held in place by the mounting nut that comes with S1.**



Telephone Hold is housed in a small plastic or metal cabinet that can be stuck to a telephone with two-sided tape—the kind of stuff you use to tape pictures on a wall.

small that it can be installed in just about any kind of cabinet or housing.

### How It Works

Telephone Hold is connected across the telephone “talking pair.” That usually refers to the red and green wires of the telephone interconnecting cable. In many houses and offices, the two telephones are wired using a 4-conductor cable, in which case one talking pair is red and green, the other pair black and yellow. Refer to Fig. 1. Keep in mind that for properly installed conventional telephone wiring, the green wire has a positive DC voltage, while the red wire is negative. If the red wire is positive, then someone has reversed the wires’ polarity. Reversed polarity normally won’t affect rotary telephones, but it will make the Telephone Hold inoperative.

The on-hook (no load) voltage across the red-green wires originates at the telephone exchange as 48-volts DC, and will be that value or slightly less in your home when all telephones are on-hook (disconnected). When any telephone goes off-hook the load current flowing in the telephone causes the red-green voltage to fall below 5-volts DC. The voltage drop between the exchange and your telephone is caused by the resistance of the telephone wires.

Fig. 2—The reason you should go for a printed-circuit board is this: You will be asked by friends to make similar Telephone Hold units for them, one for each telephone in their home. You’ll be surprised how many friends you have!

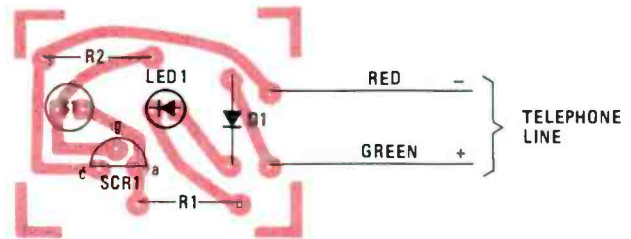
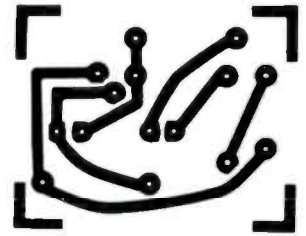


Fig. 3—Here’s an x-ray view of the printed-circuit board with the foil surface hidden and the parts in position.

Although the Telephone Hold is connected across the red-green wires, silicon control rectifier SCR1 is open: so there is no current path across the telephone line. Imagine, however, that you are speaking on the phone and want to hold the call. Because the phone is off-hook, the red-green voltage is 5-volts DC. You depress normally-open switch S1 and hang up the telephone (still depressing S1). When the phone goes on-hook the red-green voltage jumps to 48-volts DC. Since switch S1 is closed, a positive voltage is applied to SCR1’s gate, which causes SCR1 to conduct, thereby completing the circuit across the telephone line through D1, LED1, R1, and SCR1. The current that flows through those components also causes the LED to light up—indicating that the telephone line is being held. The effective load across the red-green wires is the 1500-ohm value of R1, which is sufficient to seize the line while limiting the current through the LED to a safe value.

When the telephone, or an extension, is once again placed off-hook the red-green voltage falls to 5 volts or less. But

(Continued on page 103)



The type of plastic or aluminum box you use is determined by your resources and desires. If you wish, the parts for telephone hold may be placed inside your telephone should you own it! The pushbutton and light-emitting diode should be placed for convenient use.

# ●TORMENTOR●

Turn the tables on your persecutors and get sweet revenge as this simple circuit makes them climb the wall!

By Herb Friedman

□NO MATTER HOW JUST OR RIGHTEOUS YOUR CAUSE MIGHT be, there are times when you just can't win! You can't even break even! An incompetent gets the raise or bonus you so justly deserved. You catch the blame for someone else's faults; or you get left out in the cold because someone is on the take. About the only satisfaction you can get at times like these is to even the score, and one of the most effective ways to even it up is with the *Tormentor*, a device certain to have your best, or worst enemy climbing the walls.

The *Tormentor* is a small, battery-powered, solid-state project that emits a brief *eeep!* every few minutes. Imagine sitting in a quiet room or car and every so often hearing an *eeep!* that seems to come from everywhere, but when you search, you can't find what caused the noise because it's gone. You go back to work, or sleep, or whatever, and ".....*eeep!*"

Think of the torment as 24 hours a day, day after day, your enemy is *eeeped!*

And if you want to really personalize the sound, you can change the output from an *eeep!* to a *foop!*, a *pfzsz!* or an *eeeoop!*.

As shown in the photographs, the battery powered *Tormentor* is completely self-contained on a printed-circuit board. No power switch is needed or used because the intermittent sound results in a very low average current and the battery will last several months, possibly a year or more. If you want to silence the *Tormentor*, you simply unsnap the battery terminals until you're ready to get your revenge. Also, no cabinet is necessary because the entire project is contained on a printed-circuit board. If you want to use a cabinet, it can be put in any kind of enclosure, from a plastic box to a brown paper bag. The *eeep/s* will work their way through any kind of enclosure: plastic, metal or paper.

## How It Works

Transistors pairs Q1/Q2 and Q3/Q4 form independent R-C oscillators. Refer to Fig. 1. The oscillation period of transistors Q1/Q2 is approximately one-half minute to several minutes. The time interval is determined primarily by R2 and C1. Transistors Q3/Q4's frequency, which is reproduced by the speaker (SPKR1), is determined primarily by R6 and C2, with a slight assist from R5. However, transistors Q3/Q4 cannot oscillate until Q3's base is forward biased. When power is first applied, the rush of current to charge capacitor C1 results in a voltage across the capacitor almost equal to the bias applied to Q1's base through resistor R1, and Q1 is cut off. Since there is no Q1 collector current, there is no voltage drop across R3. Since Q3's base and emitter are connected across R3, the potential at Q3's base is the same as at the emitter, so Q3 is also cut off and there is no oscillation, hence, no sound is heard from the speaker.

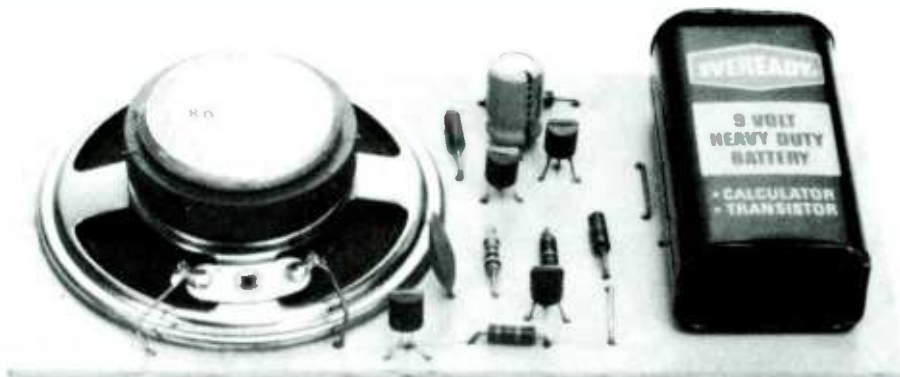


Meanwhile, C1 is discharging through R2, Q1's base-emitter and R3. See Fig. 1. Eventually, the voltage at Q1's base is determined by R1 so Q1 conducts, thereby causing Q2 to conduct. Q2's collector current causes a voltage drop across R3 which biases Q3 on, and Q3/Q4 oscillates, thereby producing a sound in the speaker.

However, at the instant Q2 conducts, the voltage drop across R3 causes C1 to charge through R1 and R2. In less than a second, the charge on C1's negative lead is almost equal, but opposite, to the bias through R1, so Q1 cuts off, disabling the Q3/Q4 oscillator. The result is a short burst of sound from the speaker at intervals of approximately 0.5 to several minutes depending on the values selected by the user for R2 and C1.

The sound quality emitted by the *tormentor* is determined primarily by R6, C2, and to a lesser extent by R5. Refer to Fig. 1. The values shown produce a *pfzsz!*. Decreasing the value of C2, or increasing the value of R2 (not more than  $\times 2$ ) will raise the pitch and change the sound quality to *eeep!*. Increasing the value of C2 or decreasing the value of R6 will lower the frequency and change the sound quality to a *foop!*. Resistor R5 can be replaced by a jumper. As the resistance of R5 is increased the sound is generated with a slide: *eeep!* becomes and *eeeoop!*.





Here's the Tormentor completed and ready for application. The parts layout is not dense at all. Unsnap the battery terminal clip to power down the circuit.

A resistance of 270 ohms for R5 gives a nice lilt to an *eep!*, while 1000 ohms produces an *eeeoop!*. For reliable operation, R5 should not be larger than 1000 ohms.

The values shown in the Parts List were selected for easy checkout and testing, providing an easily recognized sound every half minute. For maximum torment, we suggest lengthening the period between the burst of sound to two or more minutes by increasing C1's value to 100 or 200  $\mu$ F—experiment to get the exact effect you want.

### Construction.

The *Tormentor* is built on a 2 $\frac{3}{8}$  × 4 $\frac{1}{4}$ -inch printed-circuit board, for which we provide a full-scale template. See Fig. 2. The component mounting holes are made with a #56, #57 or #58 drill bit. The two holes not connected to any foils are for a wire strap that secures the battery. Actually, the battery is secured by double-sided tape: the wire only helps the tape to keep the battery in position. Drill all the indicated holes first, then install all components except the battery and the speaker. Refer to Fig. 3.

The transistors aren't critical and just about any *silicon* general equivalents for the type specified in the Parts List can be used. Do not substitute germanium transistors for the silicon types. Their relatively high leakage current causes a continuous tone or unreliable sequencing. The optimum results are attained when Q1 and Q3 are complementary types for Q2 and Q4. But if you have any reasonable substitutes lying around, try them first; they will probably work okay.

The printed-circuit board's foil connections are for the EBC (emitter-base-collector) transistor lead arrangement (refer to the pin-out diagram in Fig. 1 and the parts-placement diagram in Fig. 3). If the transistors you use are ECB (emitter-collector-base) make certain you twist their leads so the base

**PARTS LIST FOR TORMENTOR**

**SEMICONDUCTORS**  
 Q1, Q3—ECG-123A, NPN transistor (or equivalent)  
 Q2, Q4—ECG-159, PNP transistor (or equivalent)

**RESISTORS**  
 (All fixed resistors are ¼-watt, 10% units)  
 R1—1-Megohm  
 R2—27,000-ohm  
 R3—1800-ohm  
 R4—100,000-ohm  
 R5—Jumper (zero ohms) or 270-ohm (see text)  
 R6—1000-ohm

**ADDITIONAL PARTS AND MATERIALS**  
 B1—9-volt transistor-radio battery  
 C1—30- $\mu$ F, 10-WVDC, electrolytic capacitor (see text)  
 C2—0.05- $\mu$ F, 10-WVDC, disk or Mylar capacitor (see text)  
 SPKR1—8-ohm, 2-inch PM speaker  
 Misc.—Battery terminals, printed-circuit board materials, cement (see text), etc.

and emitter leads fit into the correct holes. Be careful not to introduce any shorts.

The printed-circuit template has been specifically drawn so the *flat* side of all transistors face the same direction. If the *flat* of one or more transistors face in a different direction, you have done something wrong.

Capacitor C1 is an electrolytic type so make certain that it is installed on the printed-circuit board with the correct polarity.

The value shown will provide a delay of approximately 0.5

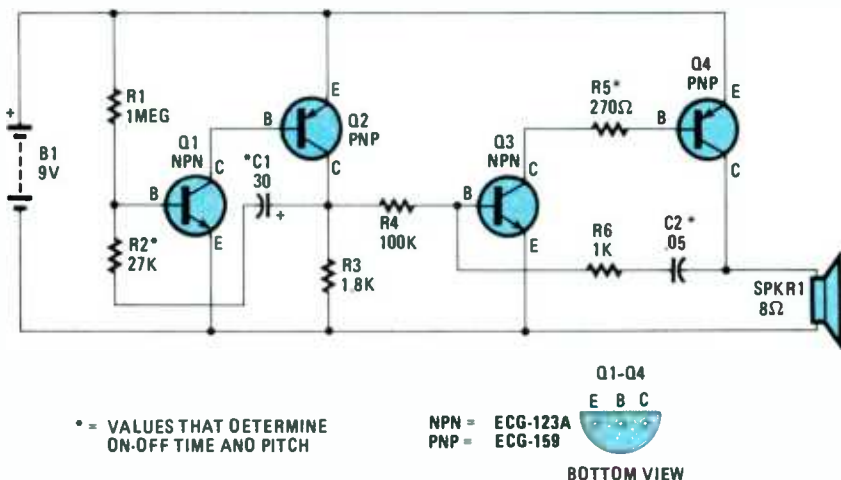


Fig. 1—The Tormentor consists of two simple oscillator circuits. It is simple enough to breadboard on a perfboard; however, you may be asked by friends to make several more. The printed-circuit layout may be duplicated inexpensively.

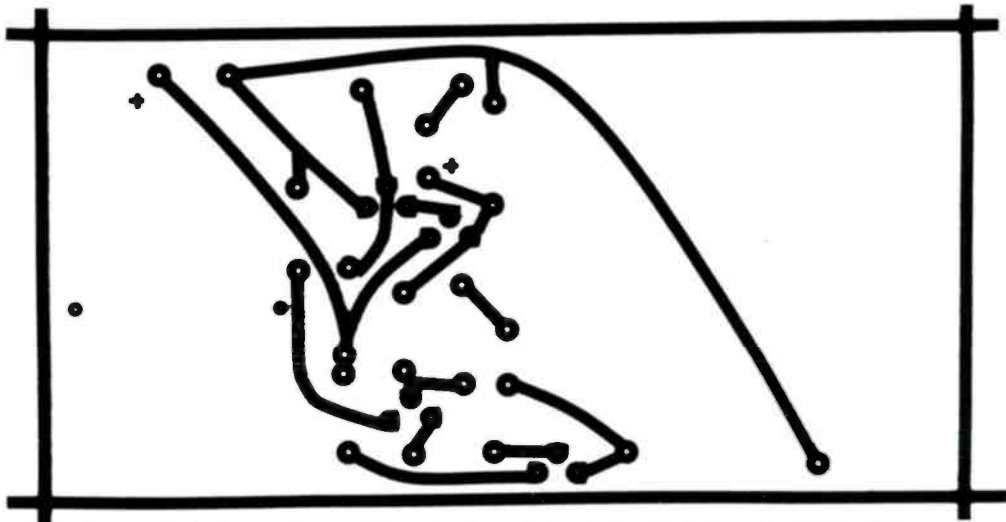


Fig. 2—Same-size layout for the Tormentor's printed-circuit board. Should you decide not to mount the speaker on the PC board, you can then reduce the overall size of the layout.

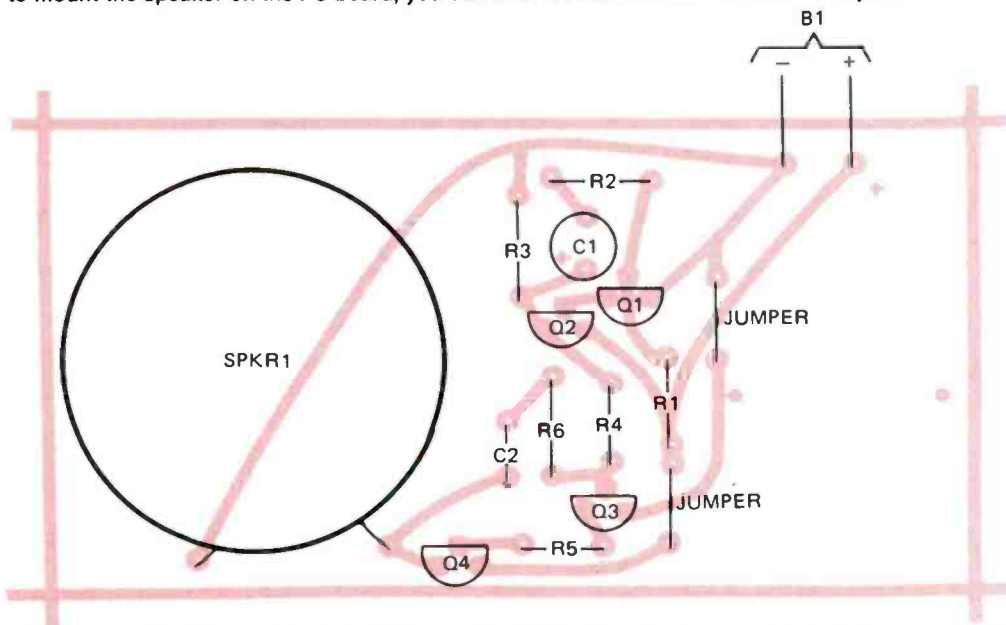


Fig. 3.—Shown here is the layout diagram of the Tormentor. The foil pattern is shown in an x-ray view.

minute between *eeep!*'s. Increase the value of C1 to increase the time between *eeep!*'s. 100  $\mu\text{F}$  will provide a delay of almost 2 minutes; 200  $\mu\text{F}$  will delay almost 4 minutes. To shorten the length of time the *eeep!* is heard decrease the value of R1, but try to go no lower than 500,000 ohms. If you think you'll be experimenting with different tone frequencies and time delays, leave a little extra length on the leads of the components indicated in the schematic diagram (Fig. 1) with an asterisk symbol (\*). Don't fold the parts' leads flat to the printed-circuit board when you solder them. That technique will permit you to remove them easily.

The speaker is the next to last component installed. The battery is last. The speaker is cemented face down on the component side of the printed-circuit board. If you use a good contact adhesive such as Barge (available from shoe repair shops) it will never come loose because Barge is what's used to glue soles and heels on shoes. Apply a thin bead of adhesive around the rim of the speaker, carefully position the speaker over the board, press it down, then remove the speaker and let the adhesive dry completely. Then very carefully position the speaker over the board directly in line with the adhesive ring and apply the speaker. You get only one

chance because the instant the speaker contacts the board it will be cemented and impossible to remove without damage, so get it right the first time.

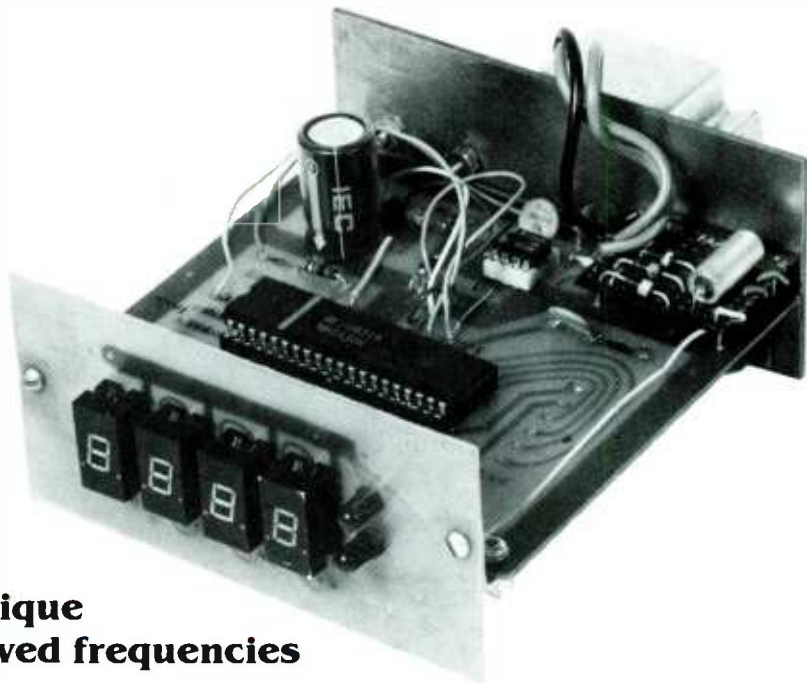
Finally, place a strip or two of Scotch double-sided tape on one side of a 9-volt battery and press the battery to the board. If desired, you can back up the tape with a wire loop, passing the wire through the extra holes in the printed-circuit board.

### Checkout

Start the *Tormentor* by installing the battery connecting clip on the battery terminals. The instant the battery terminals are applied, you should hear a tone that lasts for about a second or so. If C1 is very old the tone might last several seconds as the capacitor is reformed. If the tone continues and does not stop, check for proper installation of the transistors and C1. If the tone stops, simply wait for the next tone. It will seem like an eternity, but the tone should sound in about a half minute if you used the specified values. If several minutes go by and there is no tone, once again check the installation of the transistors, and C1 and C2.

If the *Tormentor* sounds off every few minutes, it's ready for use. Now whom do you dislike the most? ■

# ADD A DIGITAL DIAL



**Add an accurate, digital-tuning indicator to an inexpensive or antique radio to read out AM and FM received frequencies**

By Warren Baker

□ A DIGITAL TUNING DISPLAY CAN BE MORE THAN A DECORATION. It serves as a precise indication of tuning accuracy, which is why the newer and better shortwave and amateur-radio receivers offer that feature. The Digital Dial described here is both accurate and attractive.

Simplicity is the key to this handy circuit addition. It uses a dedicated integrated circuit (IC) available from National Semiconductor distributors. Included in the compact 40-pin DIP chip is everything that you need to do the job. The MM5430 (U1) is a monolithic N-channel MDS integrated circuit containing all the necessary logic, timing, control switching, and segment drive circuits to display AM or FM radio tuning frequency on a 3½-digit LED display.

The receiver has to be a superheterodyne design, because the circuitry senses and measures the local oscillator frequency of the receiver, subtracts the IF (intermediate frequency), and displays the difference on the 7-segment LED display. The only other requirement is that the IF stage(s) must operate on one of three selectable frequencies. They are: 262.5 kHz, 455 kHz, or 460 kHz for AM use. On FM, the IC can accommodate frequencies in the range of 10.6 to 10.8 MHz. The use of a DS8629 divide-by-100 prescaler IC is required when operating in the FM mode. The DS8629 will divide the oscillator intermediate frequency down into an acceptable range for the counter circuit. (Refer to Fig. 1.)

Several options are available to the user that will make the National Semiconductor IC more versatile. Since all AM broadcast stations in the United States are assigned frequencies ending in a zero, proper connection of a pin on the MM5430 (U1) will hold that digit of the readout at zero. Similarly, the least significant digit (LSD) on the FM dial is configured to show only odd integers in the U.S.A. mode. That also agrees with the station assignments. The feature can be appreciated better when you consider that it eliminates the possibility of the last digit switching back and forth from zero to a 1 or from nine to zero. Also, it will overcome minor tuning errors, etc.

## The Easy Way

We have taken the easiest method to get the Digital Dial operating. We have one option that allows us to use the 60-Hz power-line frequency as the "clock." For use in portable or automotive equipment, the MM5430 accepts a crystal for proper generation of the clock frequencies. A 60-Hz output is also available under those conditions, which may be used for driving a real-time clock in the vehicle.

When you order the IC, request a specifications sheet. The item sells for under \$10.00 in quantities of one or two. Think of the number of small parts that item saves and then add up their costs to see why we call this IC "amazing." The DS8629 may also be ordered from National Semiconductor, and has been listed in some Jameco advertisements, too.

## Construction

Although only a few parts are needed, many individual wires interconnect the circuitry. There are at least twenty-five leads between U1 (Fig. 1) and the readout board (Figs. 2, 3, and 4). Refer to Fig. 2 to understand the significance of the letters *a* through *g* and the elements of the display numerals. A printed-circuit board simplifies construction. Refer to Figs. 3 through 6. The full-scale layouts provided can be used for either direct-etch or photo systems. The prototype board was made using a direct-etch method. The latter is quick, and easier to use when only one board is to be etched. If you prefer, perfboard and wire-wrap can be used as well.

First, mount the parts on the board, soldering as you work. Mount the IC's in sockets—including the readout LED's. That saves work if one component is bad and replacement is required. The use of circuit pins may be helpful for the input leads to the IC's from the oscillator pick-off, the +9-volt DC supply, and the 60-Hz input. Wire the readout board so that it can be located up-front (Fig. 4). That requires longer wires from the main board to the small board (Figs. 4 and 6). Flat ribbon cable can be used for that purpose.

Along the edge and top side of the printed-circuit board are

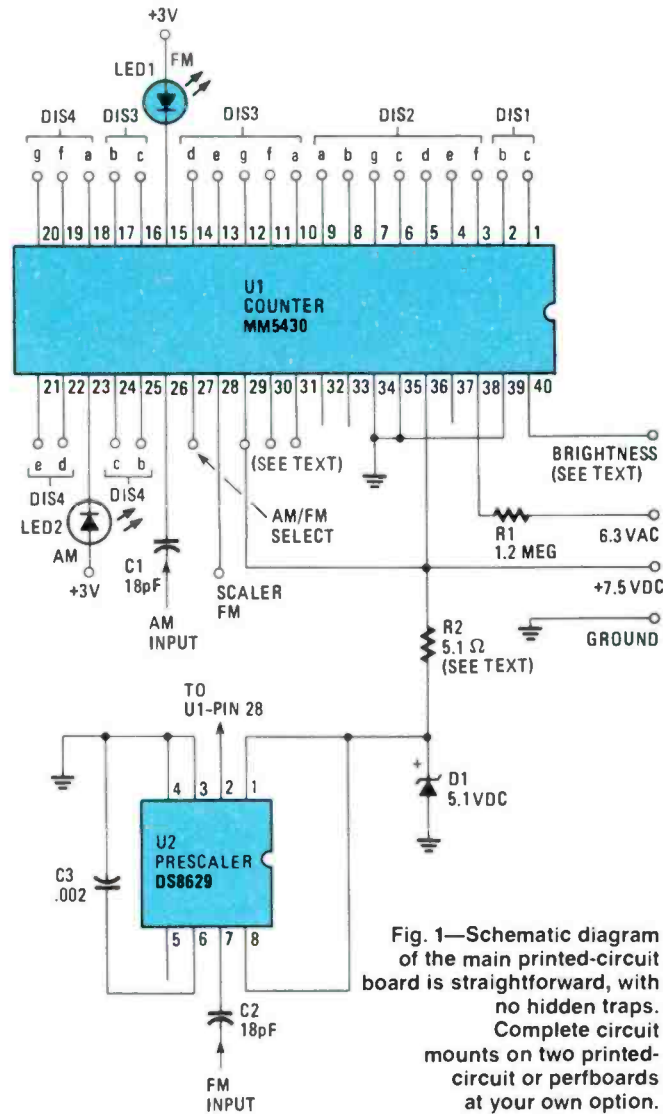
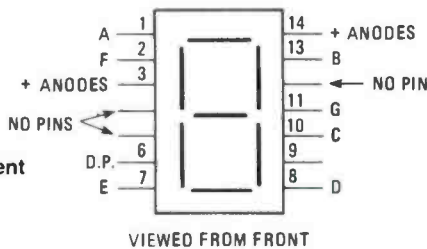


Fig. 1—Schematic diagram of the main printed-circuit board is straightforward, with no hidden traps. Complete circuit mounts on two printed-circuit or perboards at your own option.

Fig. 2—Front view of typical Xciton XAN352 seven-segment numerical display. Four are required for the project.



### PARTS LIST FOR DIGITAL DIAL

**SEMICONDUCTORS**  
 U1—MM5430 counter integrated circuit  
 U2—DS8629 prescaler integrated circuit  
 LED1, LED2—Light-emitting diode  
 D1—Zener diode, 5.1-volt, 1-watt  
 D2-D4—1N4001 silicon rectifying diode  
 DIS1-DIS4—7-segment, common-anode, LED display (Xciton XAN352 or equivalent)

**RESISTORS**  
 R1—1.2-Megohm, 1/4-watt, 10%  
 R2—5.1-ohm, 1/2-watt (see text)  
 R3—10,000-ohm, linear potentiometer (optional—see text)

**CAPACITORS**  
 C1, C2—18-pF, ceramic disc  
 C3—.002-μF, ceramic disc  
 C4—50-μF, 10-WVDC electrolytic  
 C5—500-μF, 15-WVDC electrolytic

**ADDITIONAL PARTS AND MATERIALS**  
 T1—Power transformer; 117-volts AC to 12-volts CT, .5A  
 Printed-circuit board materials, hardware, wire, solder, suitable enclosure

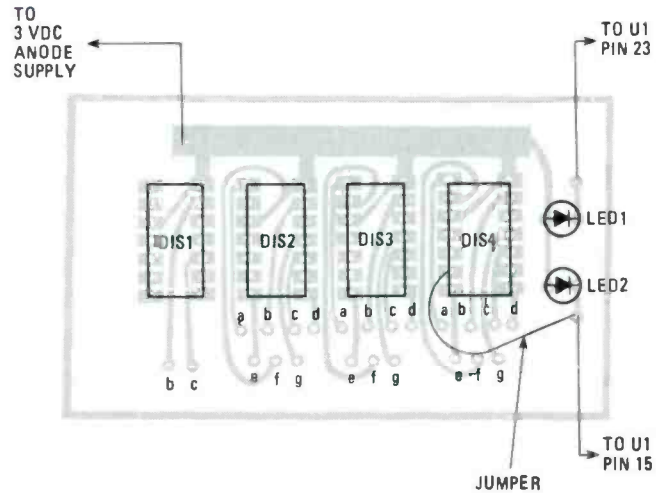


Fig. 4—The components for the display's printed-circuit board are shown in position with the foil side down.

several holes labeled from A to G. Those are for the leads going to the readouts. The letters will match the segment assignments of the display. In the photo, our unit is shown as a self-contained assembly. That has been done for presentation; yours does not have to be made that way. Since ours is self contained, it will probably use the power source (and the 60-Hz clock signal) from the host receiver.

After mounting all the parts and wires, and carefully soldering them to the board, you are ready to check to see which pins must be jumpered to what levels.

### Checking

Determine what intermediate frequencies are used by your receiver. Assume that they are 455-kHz and 10.7-MHz IF's, for our example. Pins 30 and 31 of U1 govern the selection of the IF offset needed in that case. Refer to Table 1. Pin 31 is for

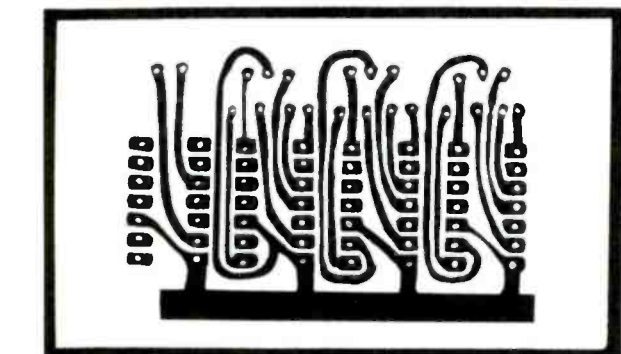
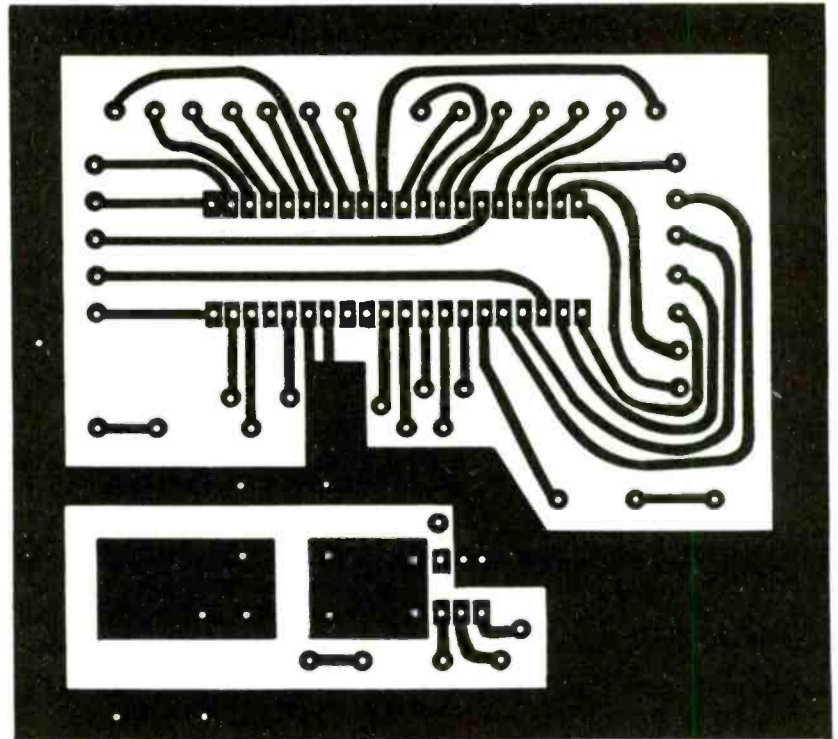


Fig. 3—Foil-side view of the display's printed-circuit board shown same size so that it can be photocopied for reproduction.

**TABLE 1—U1 PIN SELECTIONS**

<b>Readout Resolution—Pin 29</b>	
Low = Europe	1-kHz AM 100-kHz FM
High = USA	10-kHz AM 200-kHz FM
<b>AM IF Selection—Pin 31</b>	
Low =	262.5 kHz
High =	460 kHz
Floating =	455 kHz
<b>FM IF Selection—Pin 30</b>	
Low =	10.8 MHz
High =	10.6 MHz
Floating =	10.7 MHz

**Fig. 5—Foil-side view of the main printed-circuit board shown same size. Positioning of circuit elements are not critical so that should you opt for another layout, remember to keep the AM-input and FM-input signal leads short.**

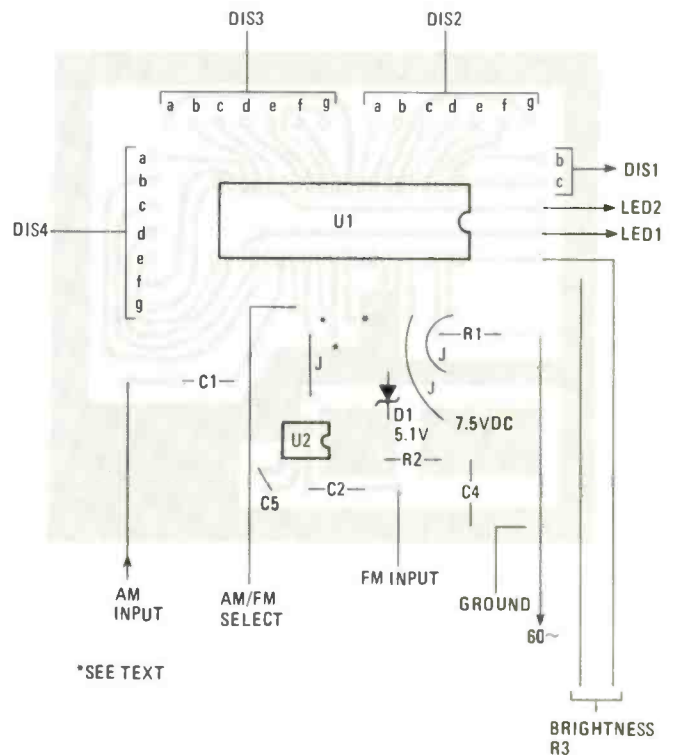


AM and will be proper for that choice (455 kHz) when left floating. If the IF is 460 kHz, the pin should be connected to the +9-volt DC source. By pulling pin 31 of U1 low (ground), the logic will decode and display the proper frequency when the IF is 262.5 kHz. Similarly, the FM IF's are compensated for by a similar action on pin 30. In our example (10.7 MHz), we leave pin 31 floating. A "low" condition on 31 will set it up to use a 10.8 MHz intermediate frequency. Using the above information, select the proper connection for your receiver's IF stage.

Since your project will probably be used in the United States, pin 29 of U1 is connected to the high (9-volts DC). Refer to Table 1. The display will readout in 10-kHz increments on the AM band; 200 kHz when in the FM position. By removing the high on pin 29 and changing it to a low, the resolution will be 1 kHz on AM and 100 kHz when reading FM signals.

There is one small external problem. When you change your receiver bandswitch from AM to FM, it will be necessary to inform the Digital Dial of that choice. Pin 27 of U1 (see Fig. 1) must be switched low for AM and high for FM. As an example, you could hold the pin high through a 1000-ohm resistor, which will keep the dial in the FM position. An extra switch may be ganged with your bandswitch, which will ground the pin and return the Digital Dial to AM display.

Pin number 40 of U1 must be connected to a high for the display LED's to be active at all times. By returning that pin to +9-volts DC through a 10,000- or 20,000-ohm potentiometer (R3), the brightness of the display segments can be adjusted. Another interesting control of the readouts can be had by the manipulation of logic levels on pin 39. In normal use, you will want a continuous display; however, by allowing it to float, the display will be extinguished whenever there is no activity on the segments. If you were to tune through the entire AM or FM frequency spectrum on your radio, the dial would continue to read. When you stopped on a station, where the frequency would remain steady, after about 4–6

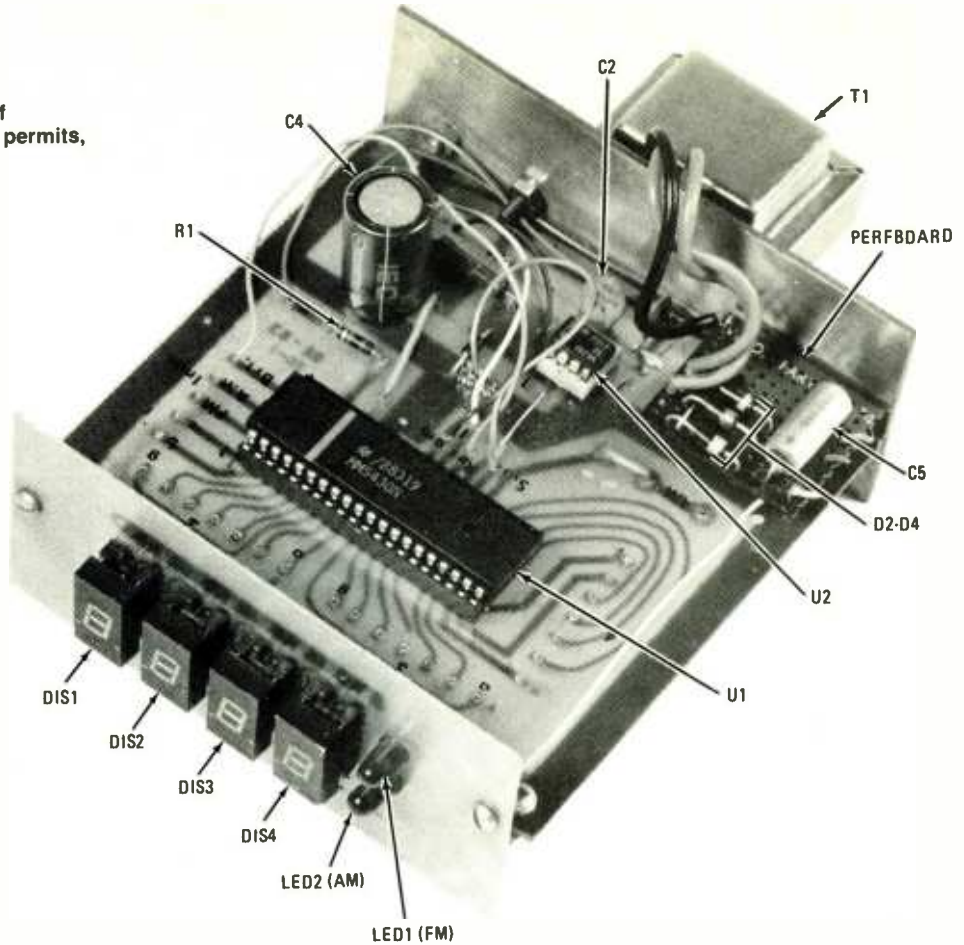


**Fig. 6—Component placement on the main printed-circuit board is shown here. Mount all components carefully, soldering them in place as you work. Use sockets for the IC's to facilitate removal should the need arise. Constantly refer to the text and Fig.1 for placement of jumpers and connections.**

seconds the display would blank. Cause the frequency to change again and the display would once more appear and the process would repeat. For normal use and a continuous readout, connect pin 39 to a logic low.

For FM use, the oscillator frequency must be scaled (divid-

As you can see, the Digital Dial lends itself well to behind-the-panel mounting if room permits, or it can be mounted in a small cabinet.



ed) by a factor of 100 to 1. That is done by a DS8629 IC (U2) and provisions have been made on the printed-circuit board for that circuit. Refer to Fig. 1. U2 tends towards oscillation unless certain precautions are considered. The layout provided works well; but if you should use another method, such as point-to-point wiring, you may have to make changes to stabilize it. The output of U2 is directly connected to pin 28 of U1. Note that the divider IC operates from 5-volts DC rather than the +9-volts DC as previously. The 5-volts DC is stabilized by a 5.1-volt Zener diode, D1.

### Power-Supply Requirements

The schematic diagram of the power supply used with our prototype is shown in Fig. 7. Three-volts DC is ample for the anodes of the display devices. Anything greater will increase the drivers' dissipation of heat. Using half-wave rectification from a small transformer's secondary winding solves the problem. The one in use is about 12-volts center-tapped, which gives about the 3-volt level as mentioned and by full-wave rectifying the total secondary winding, we obtain about 7.5-volts for the counter's operation. Note that about 6-volts AC is taken from one side of the secondary winding and is used for the 60-Hz source needed by the counter's system clock.

The counter IC is non-critical as to voltage limitations. Specifications indicate that voltages within the 7- to 11-volt range should be acceptable. Our 7.5-volts works well. Your power transformer for T1 may have a higher voltage—and as

long as it is within the indicated voltages, use it. Resistor R2, feeding current to pins 1 and 8 of the scaler IC (U2) may have to be chosen to provide the proper regulation current for Zener diode D1. If your voltage is greater than 7.5-volts DC at the power supply, R2 will have to be changed to a higher value. If the transformer is higher than 6-volts AC, you may not need capacitor C5. That is true if you are able to obtain +3-volts without it. If unable to do so, add the capacitor; its value is not critical.

The Digital Dial shown in the photos contains a small perfboard (about 1-inch square) mounted at the right rear corner. It holds capacitor C5, diodes D2, D3, and D4, and interconnects those devices and interfaces them with the main printed-circuit board. The heavy leads from the transformer on the back apron can be seen connecting to the board. We mounted C4 to the main board. There is lots of room and its location is not critical.

Some regulation should be provided ahead of the counter when powered from a 12-volt DC supply. Since U2 has a design limit of about 11-volts DC, an automobile charging system may cause damage to the unit.

### Testing

Thoroughly recheck all your solder joints for loose connections and/or solder bridges. Be especially careful on the pins of the two IC's. Make a check to be sure that all the leads leading to or from the boards are correct and that all parts and jumpers have been installed. If everything is to your satisfaction, proceed to apply power to the two boards. The common (ground) lead should be connected first followed by the +9-volts DC and the +3-volts DC to the readout board.

Now you should see some readout activity. If you do not  
(Continued on page 95)

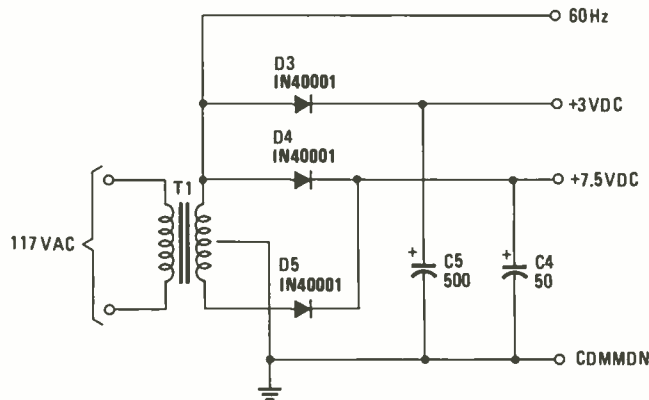
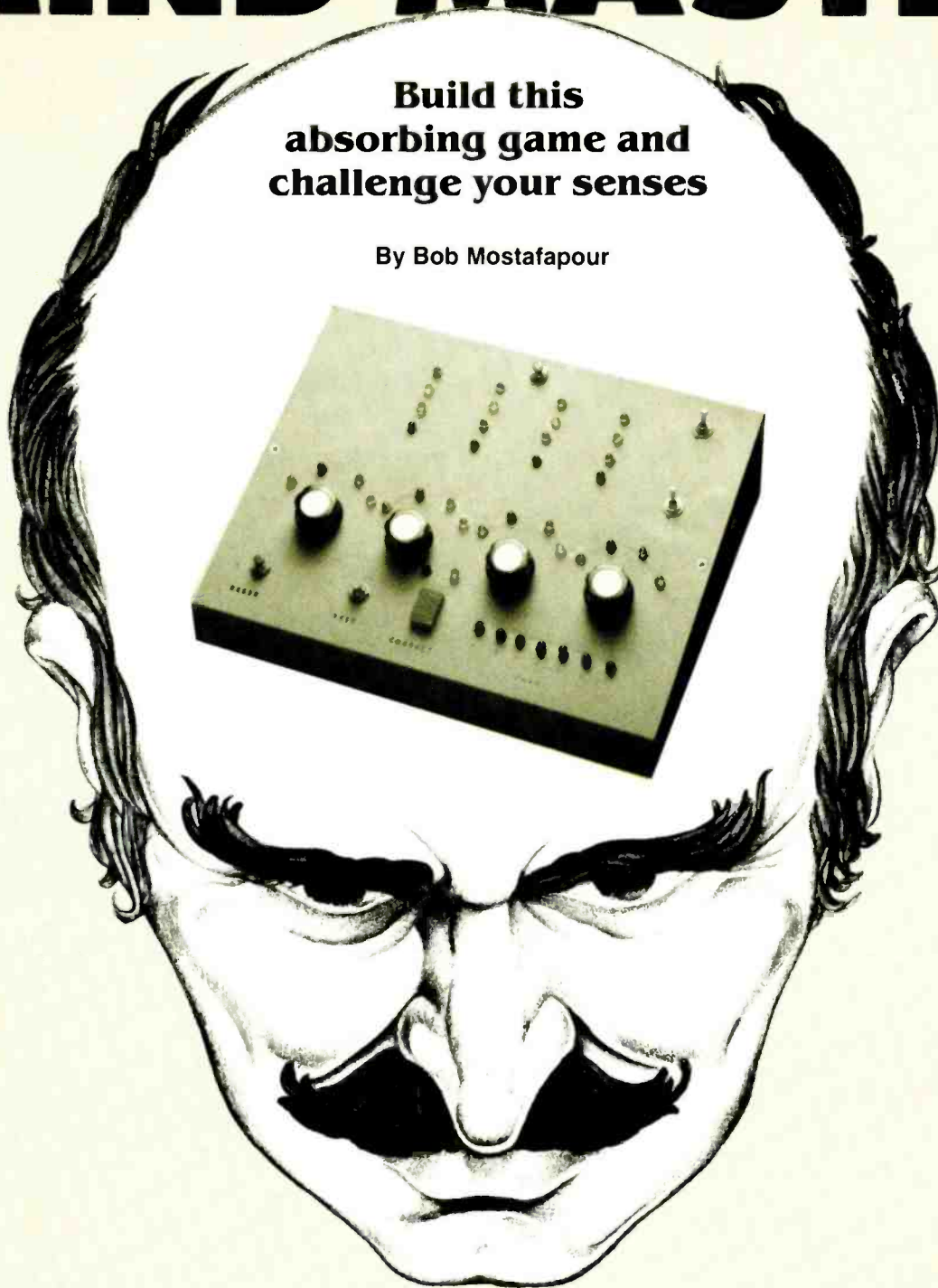


Fig. 7—This power-supply schematic diagram is provided in the event that you are required to build one. In most cases, you can steal power from the host receiver.

# MIND MASTER

**Build this  
absorbing game and  
challenge your senses**

By Bob Mostafapour



□MANY NEW GAMES THAT OTHERWISE MIGHT BE COST-prohibitive have been made possible with the development of the integrated circuit (IC). All sorts of games—from educational to purely entertainment gadgets—have flooded the market. But here's one, the Mind Master, that you can build and have twice the fun! Not only is it fun to build and play with, but its options can be tailored to suit your own taste. Such convenience is not without its tradeoffs.

To optimize minimum IC usage and maximum game effects, certain tradeoffs are required. The two basic options

are wired logic and programmed logic. The advantages of wired logic are lowered costs and greater ease of "debugging." On the negative side, you have problems with interchangeability and flexibility.

In programmed logic, an externally-programmed microprocessor plays the game, and suitable peripheral devices are used. Such a system is easier to re-program and allows more-complex play without having to add more IC's to the system. The big disadvantage is that the average hobbyist doesn't have the ability to burn a programmable read-only memory

(PROM) or use software on a microprocessor to play a game. Mind Master, however, uses simple logic.

First you apply power and press the RESET switch. You then press the RANDOM switch for as long as you like to scramble the secret code. Next, select your combination of colors and press the TEST switch and the CORRECT seven-segment display indicates how many are right, and the game advances your turn.

The TURN light-emitting diodes tell you how many turns you have to determine the correct combination. (A provision in the design is included to vary the number of turns per player.) Should you guess the correct combination within seven turns, a green light-emitting diode located above the CORRECT display lights to tell you that you've won.

On the other hand, if you do not guess the correct combination in seven tries, the console freezes, no additional turns are allowed, and a red LED (above the CORRECT display) indicates that you've lost. By turning on the DISPLAY switch, you can then check to see what was the winning combination.

### System Architecture

To make the operation of the Mind Master more understandable, we'll break the circuit down into several operating groups. Refer to the block diagram of the circuit shown in Fig. 1 (which has been separated into five sections) as we go through this exercise.

The first group we'll concern ourselves with randomizes numbers—produces random colors. It consists of a basic pulse/counter/decoder combination multiplied by four. It is user-actuated, and depends on how long the RANDOM switch (S1) is held down. At power-up, all light-emitting diodes are green. Pressing the RANDOM switch scrambles the combination (light-emitting diode) display.

That random information is compared to the switch settings and the resultant is forwarded to the next group, the

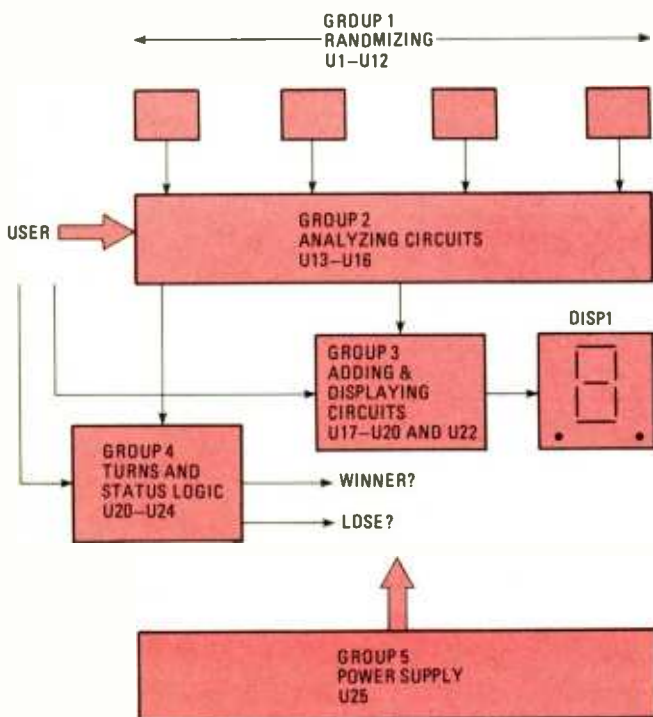
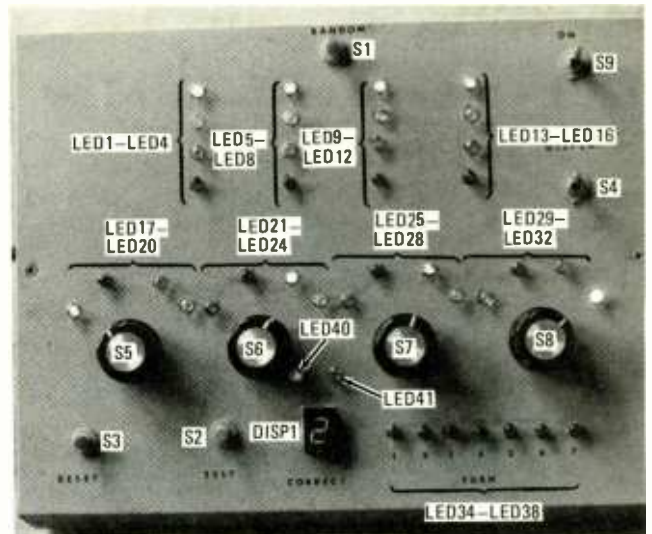


Fig. 1—The block diagram of the Mind Master is broken down into five separate groups to facilitate the understanding of how the game operates.



Looking head-on at the front panel of the Mind Master, you see a complex array of switches and indicators. After all holes are drilled and deburred, apply a coat of paint and allow to dry. That covers all nicks and scratches.

adding/display section. The RANDOM switch, which is pressed at the start of the game, should not be pressed again or the comparing circuits will confuse current data with invalid codes.

The adding/display group accepts the analyzed binary data and adds it. The results of that addition is then converted to decimal, and prepared for viewing on the CORRECT display when prompted. That display shows how many correct guesses you've made.

The next group deals with the winner-loser indications. The heart of that stage is the TEST switch, (S2). That group advances the TURN light-emitting diodes when the TEST switch is pressed, checks to see if a winning combination exists, and verifies whether the turns have been exhausted. It freezes the console if they are, or lets the unit operate normally if they are not.

The RESET switch (S3) is a direct input to the system. And finally, there's the power-supply, the one section with no decision-making capability. Now let's get into some of the specifics.

### Circuit Description

Refer to Fig. 2, the schematic diagram. The first section we'll look at consists of U1 through U12, the first four of which are 555 timers (U1-U4). Each timer sends pulses at different frequencies, as determined by the timing resistor. That frequency difference serves to offset any possible parallel color timing that may be transferred down the line.

Note that each 555 timer has its positive power wired to switch S1; thus, they operate only on command. Counter IC's, U5 through U8, are wired to count from 00 to 11 and then recycle or begin again. That way, U9-U12 (74LS155 2-to-4 line decoder multiplexers) which follow can count normally. Those dual-output (four outputs per section) units accept two-bit binary inputs and decode them to provide four sequentially-low output lines.

That allows each of the four possible binary numbers (00, 01, 10, and 11) to sequentially pull one of four outputs low from a normally high state. To sum it up thus far: The 555's pulse, the 74LS90's count, and the 74LS155's choose a color.



## Analyzing circuit

The analyzing circuit, U13 through U16, consists of four 74LS85 four-bit comparators. Those IC's accept two groups of binary numbers for comparison to determine whether one is less than, greater than, or equal to the other. The circuit considers only the equal-to's and ignores the other two outputs. The two binary numbers that are analyzed are the products of the random circuits and the rotary switches, as selected by the player.

The dual output option of the 74LS155's is used, with one set going to light-emitting diodes LED1-LED16 and the others routed to U13-U16. Since the outputs of the 74LS155's are selected by a "low" signal, the rotary switches are connected to ground and left open when not in use. Keep in mind that TTL logic assumes a "high" when left floating.

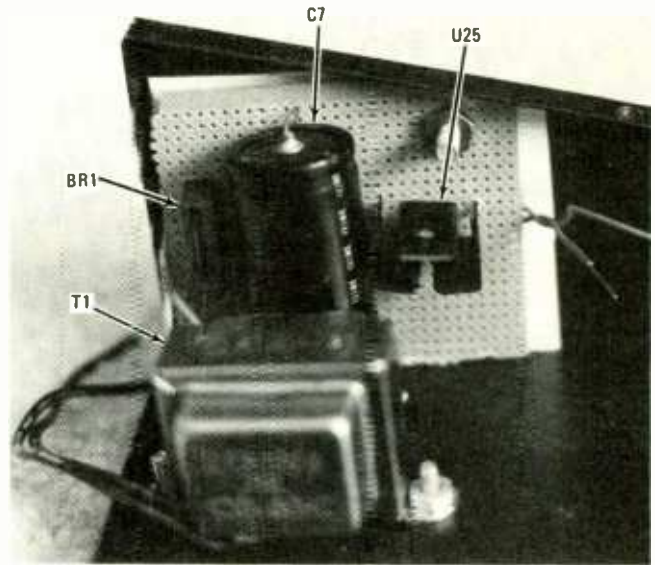
The 74LS85's compare the player's settings with the random settings and outputs a logic "1" whenever the two match. Therefore, the best that can possibly be achieved is four ones, indicating a winning combination.

## Adding and display circuits

The adding and display group receives data from U13-U14, and is enabled by a press on the TEST switch. Under normal conditions—when the player hasn't lost and play continues—point "B" is low. That low forces U22 (a 74LS47 seven-segment latch/decoder/driver) to extinguish the seven segment readout, DISPI, so that the player has no continuous indication of how many colors he has correct.

Only when the player presses the TEST switch (and hasn't as yet lost) does the junction formed by point "B" go high enabling U22, which then lights DISPI. Note that the seven-segment display has only one 190-ohm dropping resistor, R13, connected to its +V input. That unit is sufficient for the display specified in the Parts List. If another type display is used, it may be necessary to replace that unit with another value.

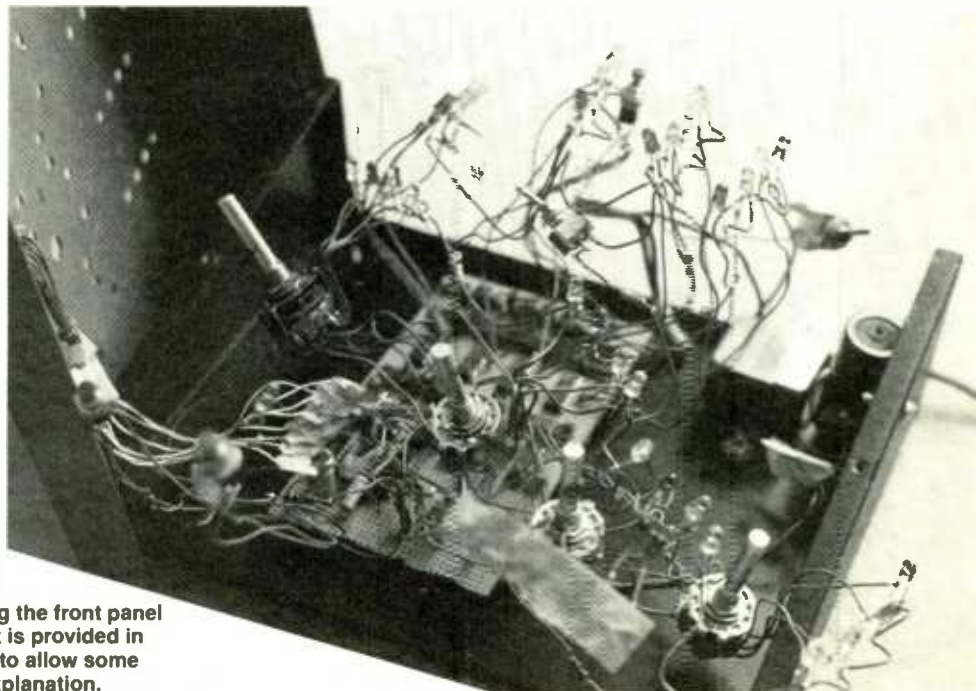
Logic IC's, U17, U18, and U19 accept groups of four one-bit binary numbers in any order, and adds them. The sum is



Looking into the cabinet, we see the power-supply board and the chassis-mounted power transformer, T1. Refer to the Parts List for component values.

fed to the U22, which decodes the input and feeds the CORRECT display to show the number of correct colors or guesses. Thus, if U14 and U16 each output a 1 (signifying a correct color) and U13 and U15 output 0's (denoting incorrect colors), the display would read 2.

The adding circuits take care of any combination. Note that only three binary digits are input to U22. That's because the binary equivalent of 4 is "001," which is three digits and the maximum number that can be correct at one time on Mind Master. The most-significant digit input to the U22 (pin 7) is grounded so that it acts as a leading zero. The only real input to this section of the circuit is from S2, the TEST switch. The other two inputs to this group, from 1/4 of U20 and reset, are less significant.



Here's the wired unit just before putting the front panel into position. Note that sufficient slack is provided in wiring all panel-mounted components to allow some maneuverability. See text for further explanation.

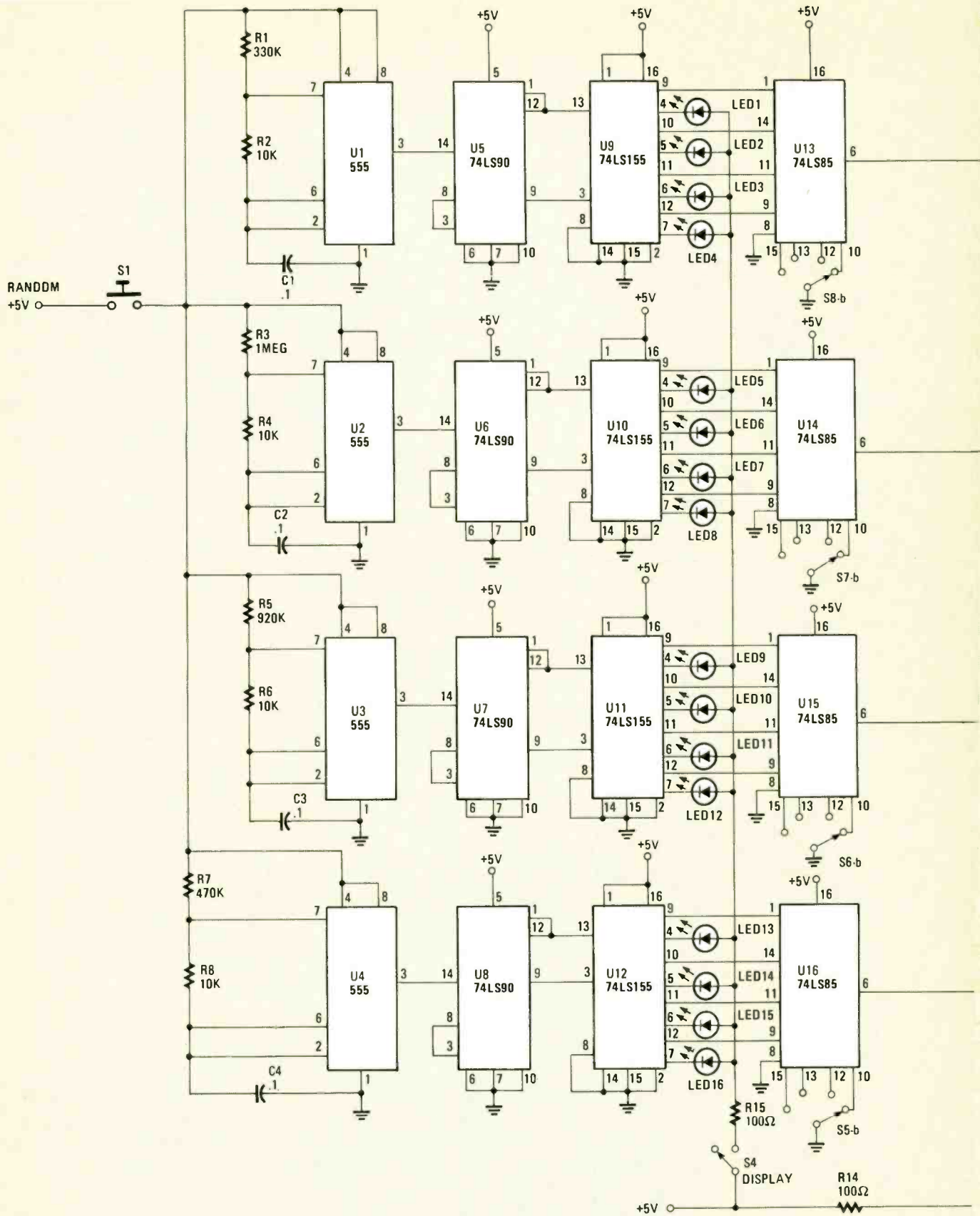
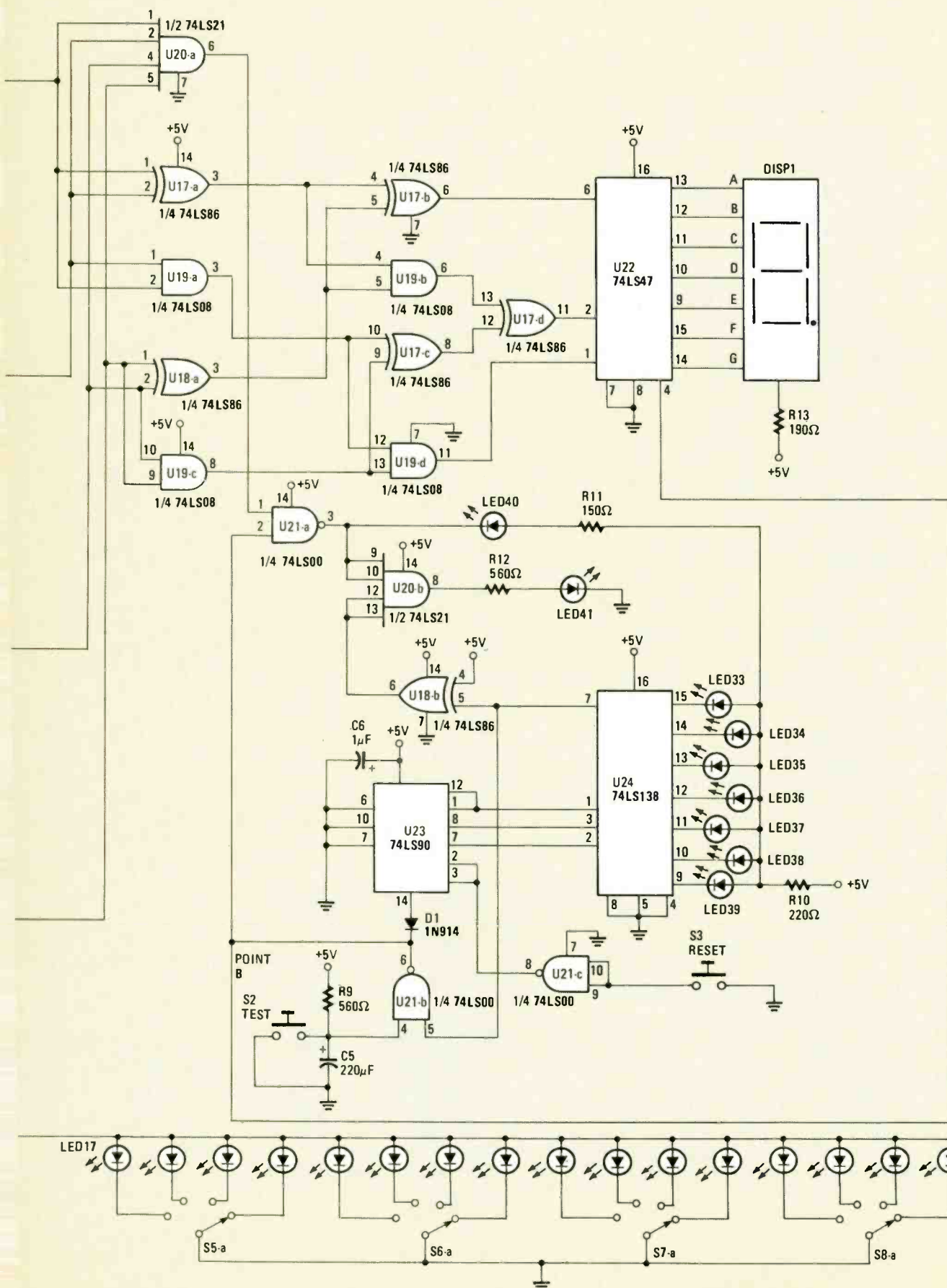


Fig. 2—Complete Schematic of entire circuit except for power supply. Refer to text while studying the schematic as many of your questions will be answered there.



The TEST switch (S2) is debounced by C5 and R9. When S2 is pressed, a low is sent to U21-a (one-fourth of a two input NAND gate). And if pin 7 of U24 is high, as it would be when the player hasn't lost, the NAND gate sends a high to point "B." That, in turn, enables DISPI, which then shows the number of correct guesses; enables NAND gate, U21-a, to determine if there is a winning combination.

U20-a monitors the outputs of U13–U16 so that when all are high, a high is relayed to U21-a, which gets a second input from point "B." If a winning combination exists, and the TEST switch is pressed, LED40 glows acknowledging the win. U21-a also drives U20-b, whose inputs are shorted in pairs to create a two-input AND gate. That gate determines whether to fire LED41, indicating that you've lost.

The pin 7 output of U24 is fed to one leg of U18-b (a quad two input EXCLUSIVE OR gate) and the other leg of the gate is connected to +V. If pin 7 of the U24 is low (indicating that the last turn was used) U18-b outputs a high (the inverse of the input), feeding it to U20-b. Normally, that high is accompanied by a high signal from U21-a. The combination of two highs at the inputs of U20-b cause its output to go high and fire the LED41.

There is, however, the possibility that on the last turn, a winning combination exists. If a winning combination is present, as determined by U20-b, LED41 will not fire after the last turn has been used. That IC permits the Mind Master to "think" and allow the correct display to light so that confusion will not result.

### Turns and status logic

The signal at point "B" also drives an all-sensitive 74LS90 decade counter/divider, U23. Unlike the other 74LS90's in the circuit, U23 operates in decade mode, driving U24, an 74LS138 three-to-eight line decoder/demultiplexer. The signal from S2 is routed through D1 to debounce the switch. Capacitor C6 is included in the circuit for decoupling to minimize power-up spikes.

Pins 2 and 3 of U23 are fed via U21-c. When S3 is pressed, the two inputs to U21-c are grounded causing, it to output a high, which resets U23. That's required at the end of a game, as well as at power-up to clear all random numbers. U23 feeds U24, which is designated as the "turnskeeper" It keeps track of the numbers of turns taken.

Normally at power-up, the RESET switch is pressed, U23 sets to zero, and U24's first TURN light-emitting diode glows to indicate turn one. Each time the TEST switch is pressed, U24 advances the turns indicator by one to a full count of seven. On the eighth turn, instead of lighting a light-emitting diode, pin 7 goes low and disables the TEST switch via U21-b. It also sends a signal to the winner/loser logic to tell it that the last turn has been used.

The number of available turns can be altered. If you only wanted four turns per player, pin 11 could be connected instead of pin 7 and LED9–LED11 eliminated. Other combinations are possible.

### Power supply

Turning to Fig. 3, the power supply, we see standard components and techniques used to produce 5 volts at 650 mA. While a 4,700  $\mu\text{F}$  capacitor is shown, anything larger than that value may be substituted. Also the 7805 power tab regulator, U25, may be replaced by an LM309K. But whichever regulator is used, remember to heat-sink it.

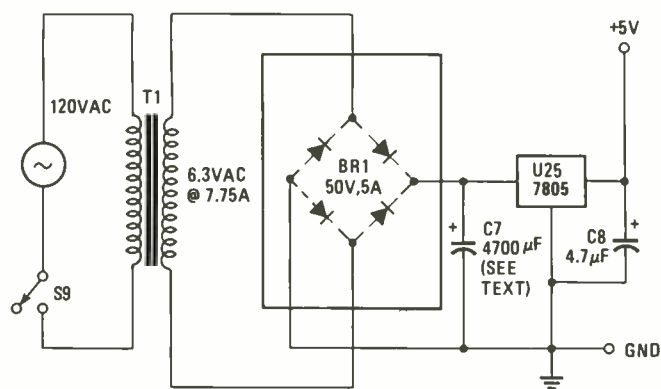


Fig. 3—Complete schematic diagram for the power supply. It is recommended that U25, the five-volt regulator, be heat sinked as it can suffer thermal damage during the circuits operation.

### Construction

Since construction is not particularly critical, there is some measure of flexibility. The author's unit was built on perforated construction board and housed in a simple metal cabinet.

If you choose to use perforated construction board, Fig. 4 will help you to get over the rough spots. First, position the parts on the board as shown. Note that R1–R15, C5, and C6 are vertically mounted. If desired, provided that your board is large enough, those components may be flush mounted. Also, when wiring the circuit, be sure to observe the polarity of the electrolytic capacitors and diode D1.

Once the parts are in place, use masking tape to hold them in position, and flip the board over. So as not to confuse the IC's pin connections from the underside of the board, wire all power connections first, using the bus method. Bare two lengths of solid wire for each IC power connection, one for positive and the other for negative. (Color coding is a good idea.)

Using Fig. 2 as a guide, connect all negative power-supply wires to the negative or ground bus, all positive to the 5-volt bus. When that's complete, use a substitute power source to be sure that all power connections are wired properly. When satisfied, proceed. Next, wire the 555's, U1–U4; after which, power up the circuit and use a logic probe at pin 3 of each unit, while pressing S1. Each IC should have a pulsing signal on pin 3 at this time.

If you have no logic probe, connect a light-emitting diode to ground through a 100-ohm resistor and, with the other end, touch pin 3 of each 555 individually. If the light-emitting diode blinks for each IC, everything is fine. If not, check your wiring. If all is well, continue with the wiring.

When U5–U12 are fully wired, stop. Power the circuit up again and press S1. All light-emitting diodes coming off U9–U12 should be continually and sequentially blinking. If a group is not blinking, backtrack and see what is wrong. Shorted or crossed wires could be producing an incorrect logic level.

Next, wire the board to the switches and lights leaving about six inches or so of slack in the wire. That slack will be needed when the chassis is assembled.

### Circuit Debugging

Once the entire circuit is completed, power it up and see what happens. Turn on the random display via S4. Press

## PARTS LIST FOR MIND MASTER

### SEMICONDUCTORS

BR1—50 volts, 5 A. bridge rectifier  
 D1—1N914 small-signal, silicon diode  
 DISP1—.3-in. common-anode seven-segment, light-emitting diode display  
 LED1, LED5, LED9, LED13, LED17, LED21, LED25, LED29, LED33—LED39, LED41—Light-emitting diode, jumbo red  
 LED2, LED6, LED10, LED14, LED18, LED22, LED26, LED30—Light-emitting diode, jumbo yellow  
 LED3, LED7, LED11, LED15, LED19, LED23, LED27, LED31, LED40—Light-emitting diode, jumbo green  
 LED4, LED8, LED12, LED16, LED20, LED24, LED28, LED32—Light-emitting diode, jumbo amber  
 U1—U4—555 timer integrated circuit  
 U5—U9, U23—74LS90 decade counter integrated circuit  
 U9—U12—74LS155 2-to-4 line decoder/demultiplexer integrated circuit  
 U13—U16—74LS85 4-bit comparator integrated circuit  
 U17, U18—74LS86 quad 2-input EXCLUSIVE OR gate integrated circuit  
 U19—74LS08 quad 2-input AND gate integrated circuit  
 U20—74LS21 dual 4-input AND gate integrated circuit  
 U21—74LS00 quad 2-input NAND gate integrated circuit  
 U22—74LS47 BCD-to-decimal decoder/driver integrated circuit  
 U24—74LS138 3-to-8 line decoder/demultiplexer integrated circuit  
 U25—7805 5-volt regulator

### RESISTORS

(All resistors are 1/4-watt, 5%, fixed units)  
 R1—330,000-ohm  
 R2, R4, R6, R8—10,000-ohm  
 R3—1-Megohm  
 R5—920,000-ohm  
 R7—470,000-ohm  
 R9, R12—560-ohm  
 R10—220-ohm  
 R11—150-ohm  
 R13—190-ohm  
 R14, R15—100-ohm

### CAPACITORS

C1—C4—.1- $\mu$ F, ceramic  
 C5—220- $\mu$ F, 10-WVDC, electrolytic  
 C6—1- $\mu$ F, 10-WVDC, electrolytic  
 C7—4700- $\mu$ F (or greater), 10-WVDC, electrolytic  
 C8—4.7- $\mu$ F, 10-WVDC, electrolytic

### ADDITIONAL PARTS AND MATERIALS

S1, S2, S3—SPST, momentary-contact switch  
 S4, S9—SPST toggle switch  
 S5—S8—4P2T rotary switch  
 T1—Power transformer: 117-VAC primary; 6.3-volt, .75A secondary  
 Perfboard, IC sockets (optional), dry decals, wire, aluminum cabinet, knobs, solder, hardware, power cord

RESET switch S3: the first TURN indicator (LED33) should light to indicate turn 1. If that doesn't happen, check the reset, which via U21-c is responsible for U23's clear pins (pins 2 and 3).

Next, move S5, S6 (Combination Selector switches 1 and 2) to all possible positions making sure that LED7—LED32

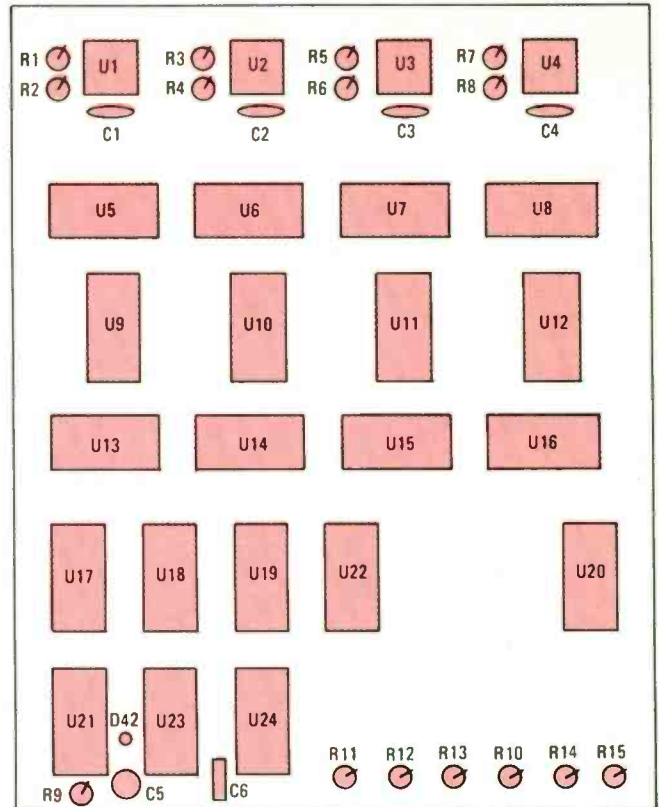


Fig. 4—Parts layout for the circuit if perforated construction board is used. After placing components, apply a layer of tape so they don't drop out when board is inverted. Be certain not to confuse pinouts when the board is flipped over.

all light corresponding to the switch positions. Then press S2 (TEST) as many times as necessary, until DISP1 lights and extinguishes to use all turns. Make certain that the TURN light-emitting diodes transfer smoothly. If they skip or jump turns, check debouncing components C5, R9, and C6. Be sure that LED41, the Loser indicator, is lit if your combination is incorrect.

Problems in this area can usually be tracked back to the EX-OR gate and the U20-b conversion to a two input AND gate. Now press RESET. Position the four Combination Selector switches, S5—S8, to the corresponding colors on the Combination display, LED1—LED16. Press the TEST switch. The green "Winner" indicator, LED40, should light. If it fails, check its polarity.

If that's OK, make sure that each pin 6 on U13—U16 is high. If any are not, there is a wiring error some between switches S5—S8 and U13—U16. When you come across a unit with a low output on pin 6, trace back to the switch to determine which is incorrectly wired. If all outputs from U13—U16 are high and the green light-emitting diode doesn't light when S2 is pressed, trace back from LED40 to U21-a, making sure all connections are correct.

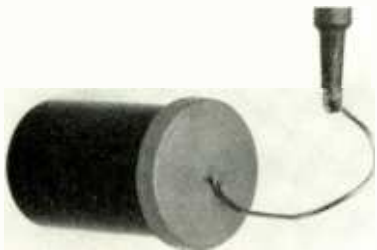
The last step in debugging is to make sure DISP1 is showing the number of correct colors (or guesses). With S4 (DISPLAY) closed, operate the Combination Selector (rotary) switches, until the correct colored light-emitting diode corresponding to that switch lights. Make one correction, then test. Make the second correction then test, and so on, until all four are correct.

(Continued on page 105)

# TESTBENCH TIPS

## Rolling Along

An unused 35-mm plastic film container that comes in a factory-packed carton will make a handy benchtop or toolbox solder dispenser. The next time you shoot a roll of film, save the plastic container. Roll up several feet of solder on a 1/2-inch or 3/4-inch dowel (one layer only) and slip the dowel free. Place the rolled



solder inside the can and poke one end out through a small hole in the center of the cap. Now there is no need to grope for that elusive bit of solder. In fact, make a few solder dispensers so that as one runs out you have another to work with.

—Evert Fruitman

## Slot Card

Some edge-card connectors are polarized by small plastic inserts inside the connector. The polarized kind won't fit unslotted printed-circuit edge terminals unless a slot is cut in the board between two terminals. I found that the abrasive

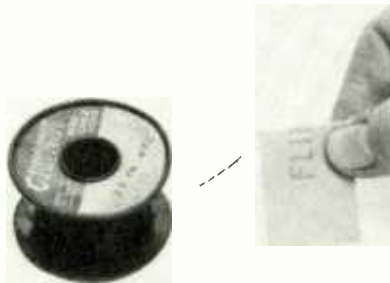


disk wheel for a hobbyist's hand grinder cuts a slot having exactly the required width for the polarizing insert in the matching connector. Make a practice cut on a piece of scrap printed-circuit board before you proceed.

—H. Friedman

## Scraping Clean

It was next to impossible for me to scrape enamel insulation from very fine wire, because the instant my knife touched the wire I cut through. To be

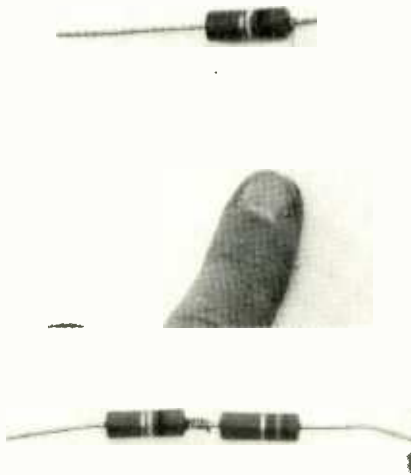


honest, I have a "heavy" hand. But by folding and squeezing a small strip of common flint sandpaper over the wire and then pulling the paper straight off, I found that I can remove the insulation without damaging the wire. A few passes removes the enamel insulation. I have tried enamel removers and find that they always leave a fine film that requires scraping or sanding before the solder takes. This *heavy hand* now has a light touch!

—T. Mann

## Summing Up Short

In my service business, I frequently have to series-connect two resistors using



The very next time you come up with a simple, but clever, idea that helps you build a better project, or do a better job of installing, or testing, a project, let us know about it. Put your idea on paper (typewrite it), spelling out the details on one sheet. Take a black-and-white photo of the idea in action and send it to the Editor. (Color photos lose too much contrast.) If your tip is used in this column, you will receive a check for \$20. Sorry, we will be unable to return your tip or photo, and all entries become the property of **Hands-on Electronics**. Send all mail to **Hands-on Electronics Testbench Tips**, Room 1101, 200 Park Avenue South, New York, New York 10003.

the smallest possible leads. I need a connection that's more reliable than tack-soldering. So I solder a thin wire to the stub of one resistor, then wrap it several times around both stubs. A squeeze with pliers holds the resistors firmly in position until I can flow solder over the connection. Use just enough heat to make a neat joint.

—Sid Steit

## Bends and Holds

The plastic see-through cover of my impact printer was typical of most units



like it. The cover is not secured to the printer itself; it was constantly falling to the floor when raised for a closer look at the printed document. I cured the problem by using two short lengths of plastic electrical tape as hinges. The tape provides enough support to keep the cover where it belongs, and after several months of use showed no sign of cracking or tearing.

—David Meagher

(Continued on page 105)

# CALLING ALL HAMS

## Getting covered by a multi-band umbrella dipole antenna!

□ ARE YOU INTERESTED IN A CHEAP three-bander that requires no tuner, won't come down, has no guys, goes up easily, has one transmission line, is not complicated, and works? It is a standby antenna that is always there when others fall, are being replaced or experimented with, or require switching and retuning when changing bands. Such a simple dipole configuration is a fine stopgap antenna and one you can pack away for portable operations. You can set up that three-bander almost anywhere.

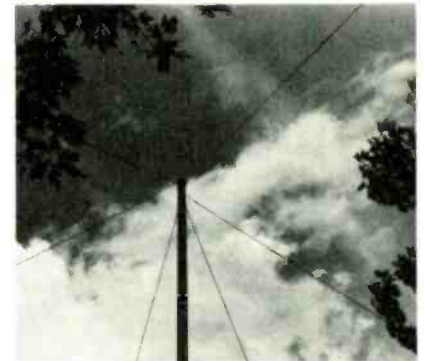
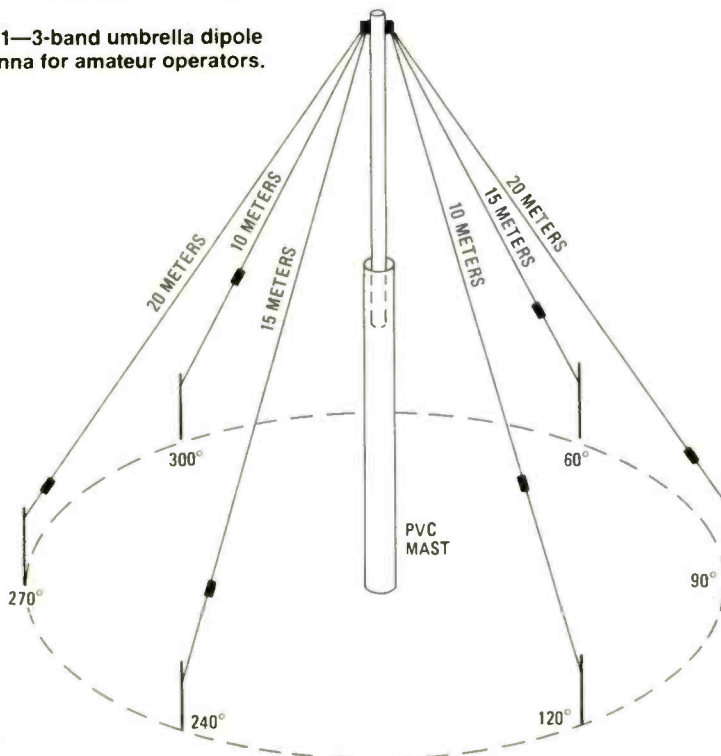
The mast for the umbrella dipoles consists of two telescoping 10-foot sections of PVC piping, or three shorter ones if you wish to break the length up into smaller lengths for hauling. Also required are approximately 75 feet of 16 gauge vinyl-covered wire, six insulators, assorted nuts and bolts, coaxial line, rope, and a metal fence post. Previous issues of **Hands-on Electronics** have presented considerable

**TABLE 1—DIMENSION TABLE FOR 10-, 15, AND 20-METER DIPOLES**

Band	MHz	$\lambda/4$ Length
10-Meters		
Novice	28.15	8' 4"
Sideband	28.6	8' 2"
FM	29.5	8' 0"
15-Meters		
CW	21.05	11' 2"
Novice	21.15	11' 1"
Sideband	21.30	11' 0"
20-Meters		
CW	14.05	16' 8"
Sideband	14.20	16' 6"

details on the construction of PVC masts. Construction details are given in Fig. 1 and a look-up view of the umbrella in Fig. 2. The antenna terminals at the top of the mast are shown in Fig. 3. Note that solder joints are used to attach the aerial wires to

**Fig. 1—3-band umbrella dipole antenna for amateur operators.**



**Fig. 2—Looking up at the umbrella antenna—ant's eye view.**

the terminals. Shown are the three aerial wires on one side of the dipole configuration. Another set of three connect to the other terminal to complete the antenna. Space the three dipoles as shown in Fig. 1. Each set of three are spaced 30 degrees.

Coaxial transmission line is fed up through the PVC mast, and the center conductor and braid is connected internally to the terminals. On the very top is a weather-proof cap. At the base of the lower PVC mast, the coaxial line feeds through a hole drilled into the mast. As shown in Fig. 4, a coupler is used to connect the coaxial line plug to the plug of the transmission line that serves as a link to the radio room.

Table 1 gives practical dimensions for the 10-15-20 meter dipoles according to  
(Continued on page 97)



**Fig. 3—Connecting the dipole segments to the mast's top terminals. Note cap to keep inside of mast dry.**

## FRIEDMAN ON COMPUTERS

(Continued from page 23)

function, *Schematic Drafting Processor* is specifically intended for the preparation of electronics schematics. A library of conventional symbols such as transistors, diodes, integrated circuits, gates, resistors, capacitors and other commonly-used components are built into the program. You draw a schematic diagram by using the arrow keys or a joystick to place the cursor where you want a symbol to appear, press a key(s) to rotate the symbol to the desired direction, and then enter the symbol by pressing the symbol's key.

Unlike high-performance drafting programs whose library—if there is one—is extensive, but fixed, the hobbyist and technician oriented *Schematic Drafting Processor* provides only the most commonly used symbols. However, it does permit the user to create 10 additional library symbols through a BASIC program.

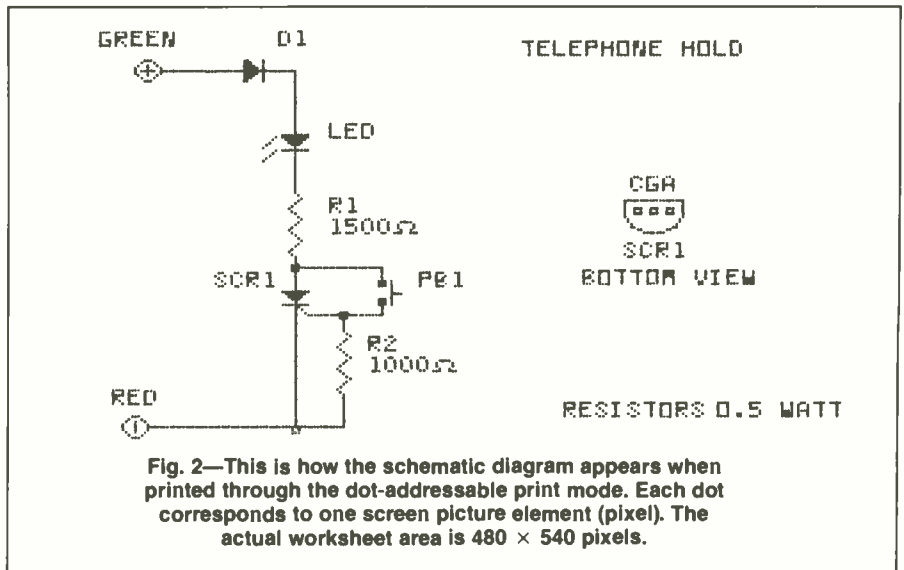
### Symbolic Symbols

Figures 1 and 2 show what you can expect from *Schematic Drafting Processor* (or a similar program). I have used the schematic diagram of the *Telephone Hold* project covered elsewhere in this issue so you can easily compare computerized drafting with a schematic diagram prepared using conventional templates.

Figure 1 is a photograph of the computer screen made when the schematic diagram was completed. (Using an *erase* function would allow any number of changes.) The finished version can be saved to disk and then modified or updated at a later time, or it can be printed.

Figure 2 is the same schematic as printed by an Epson MX80 with Grafrax. Notice that the print very closely resembles the screen display, although the characters don't appear to be entirely conventional. Also, take note of the *ohm* symbol after the resistance values. How did that get printed, because we know the MX80 printer's character set doesn't include an Omega symbol? The reason for the unusual size characters and the Omega symbol is that drafting programs intended for use with conventional printers (as opposed to plotters) generate the entire hard-copy schematic—including characters—through dot-addressable graphics, what is often called bit-mapping. That is, the printer prints a single dot for each pixel or picture element on the screen.

If you could examine the screen's smallest picture elements with a magnifier, you would see that each is represented in the printout by a single dot. Unfortunately, you would also see some picture elements in the screen which don't exist as such in the print. For example, the top and bottom lines of the "E" character



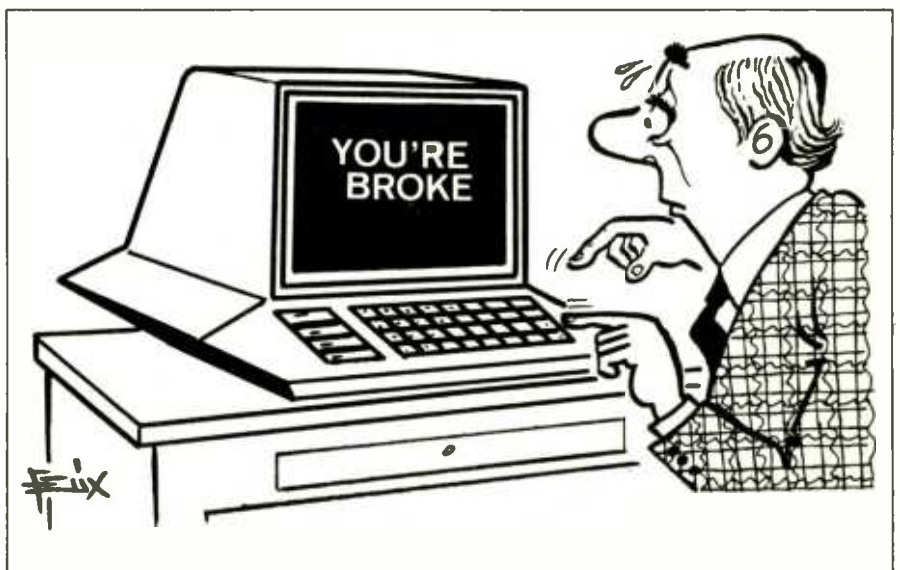
appear on the screen as solid lines, yet in the print they are formed by four horizontal dots. Actually, on the screen they are also four horizontal dots, but they are spaced so close together that they bleed into a solid line.

Unlike conventional schematics, symbols generated by a computer using low-cost programs often don't have what we usually expect as conventional shapes, because to do so would simply take too much programming and/or memory. For example, look at the SCR symbol in Figs. 1 and 2. Although an SCR's *gate* is generally drawn on the left, the program's author preferred the gate on the right. It would take considerable effort for the user to modify the position of the gate (unless he creates his own library symbol). Similarly, there is no circle around the LED symbol although one is commonly used. In this instance, however, a circle from the program's symbol library could easily be "pasted" over the LED's symbol. (As an

example, the partial circle used for SCR1's bottom view is actually a cut-down circle from the library with the C, G and A terminals superimposed on it. The terminals are actually the symbols normally used to indicate wire connections, such as the junction of R1, SCR1, and PBI.)

### Go for It

Even though we have barely scratched the surface of electronic drafting, you can see that it can be a lot of fun to do. It's certainly something that should be tried and learned if you intend to make a living in electronics, because in a few years, that's the way all schematics will be prepared. If you decide to get into it, make certain that you get software that's designed to prepare schematics, not something for general drafting. It's hard to create resistors and capacitors from bits and pieces of lines and rectangles; it's easy to simply punch them in from a symbol library. ■





## INSIDE THE OSCILLOSCOPE

(Continued from page 73)

popular. Figure 8 shows a simple block diagram of a dual-trace scope. That scope is similar to our single-trace scope except that the circuit uses two vertical preamplifiers. In addition, there is an electronic "switch" that is used to connect either of the preamplifiers to the main amplifier. The switch is controlled by the sync circuits, or by an internal oscillator, and operates in one of two modes: alternate or chopped.

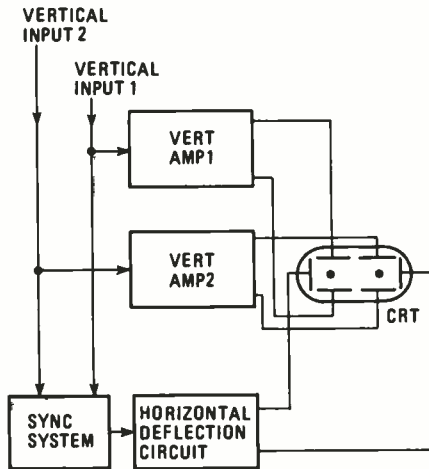


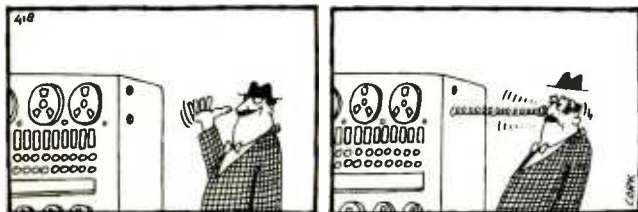
Fig. 7—Here is a block diagram of a dual-beam oscilloscope. Note that the box array shown in Fig. 2 has been altered here because there are two electron guns generating two electron beams to hit the oscilloscope screen. Both beams are sync'd in the horizontal sweep section; however, each beam can be vertically manipulated to display two waveforms both time related to each other.

In the alternate mode, the switch is changed from one preamplifier to the other (and hence from one input to the other) after each horizontal sweep. Thus, on the first sweep, input 1 is displayed; on the second sweep, input 2 is displayed; on the third sweep, the first input is displayed, and so on.

The alternate mode works well for sufficiently fast sweep rates. At those speeds, the first trace will not have time to fade during the interval that the second one is being displayed.

At slower speeds, however, a flicker problem may result. In those cases, the chopped mode is used. In the chopped mode, the switch is no longer changed after successive sweeps. Instead, its operation is controlled by an internal oscillator. The oscillator operates at a frequency of from 50 to 200 kHz.

In the chopping mode, both channels are alternated at a rate equal to the oscillator frequency. In operation, the input 1 signal is applied to the deflection plates for a very short interval, and then the input 2 signal. At the frequencies involved, as long as the chopping rate is greater than the frequency of the input signals, it will appear as if two continuous traces are being displayed.



## Next time

Take a look at any modern oscilloscope and you'll notice that there's a lot more there than the attenuator and time-base controls. What those controls are, what they do, and how they are used are just some of the topics we'll cover next time. ■

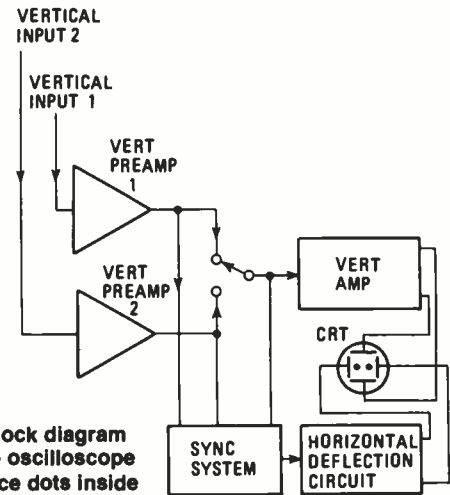


Fig. 8—This block diagram of a dual-trace oscilloscope shows two trace dots inside the boxed area of a conventional CRT. The action here is that one input is displayed first and the other then follows. The switch shown is an electronic type deep inside the oscilloscope.

## DIGITAL DIAL

(Continued from page 82)

have the dial connected to a receiver, temporarily connect a jumper wire from pin 27 of U1 to ground. That will adjust your dial to the AM position and with no input from the receiver's oscillator, your readouts should be reading 1540. Actually, had you left the resolution pin (29) in the 1-kHz position, the dial would be reading 1545. Since we have set up the chip to read on 10 kHz increments, it has been rounded off to the 1540 figure.

Let's examine the reason for that figure. The specification sheets make no comments along that line. The "1540" represents the offset that has been programmed into the MM5430. Since the readout is only 3½ digits, that means that the highest reading to be used will be 1,999. If 1545 is programmed into the counter at the start, the counter will read only to 1,999 and return to zero. You have already noted that 1545 plus 455 equals 2,000. That effectively subtracts the IF from the oscillator signal and any further reading will be equivalent to the incoming frequency. The FM is exactly the same, except that the reading would be 189.3 when set up for 10.7 MHz intermediate frequency.

It is now time to inject a signal from an AM radio's local oscillator into the AM input, pin 26. A reading (other than the 1540) should now be evident indicating that your counter is working properly. Tune the radio's tuning dial and the Digital Dial reading should coincide with the frequency indicated on the linear dial. When tuned to a station, the reading should be steady and accurate. If not, recheck your wiring and make sure that the IF selection and those used in the receiver agree. If so, you are ready to test the FM mode, using the same outline as above. Be sure to change the jumper lead that was added to pin 27 from ground to the +9-volt DC supply. Note that the FM oscillator frequency will be applied to pin 7 on U2.

(Continued on page 96)

## DIGITAL DIAL

(Continued from page 95)

There may be some experimenting to be done to find out the best point in the receiver at which to pick-off the oscillator voltage. Your choice should be at a point where the added lead has the least detuning effect on the receiver and also provides sufficient signal level to operate the counter IC's. In some cases, it has been the author's good fortune to place the input lead adjacent to the oscillator signal lead. Provided that some detuning does occur—and it would be impossible to prevent it in any case, after the Digital Dial has been installed—a slight touch-up of the trimmer capacitors can be made so that the receiver's dial tracks properly.

There are many uses for the Digital Dial, even if only for cosmetics or for a conversation piece. For anyone who collects, restores, or enjoys antique receivers, the dial, constructed around the prototype shown in the photos, can be attached to an old National Radio Company's HRO series receiver. That will allow the receiver to be used without a hard-to-read line graph to determine the frequency. Any collector will understand that advantage. The Digital Dial can be installed in any sort of a case and placed on top of the HRO. If that were to be considered for all-band sets such as HRO's, there would be a need to install a programmable divider ahead of the AM input pin to keep the oscillator frequency within the range of .5–2.2 MHz.

Pin 6 on the LED readout, DIS4, is used to illuminate the decimal point. (See Fig. 1 and 4.) When tuned to FM, it will be necessary to install a small wire from that pin to the FM band indicator lamp (LED1) connected to pin 15 of U1. That will cause the display to read the proper frequency (example 102.3, 95.5, etc.). When in the AM mode, LED2 will come on indicating AM operation.

Whatever use you may want to make of the Digital Dial, one thing is certain. The cost is very low compared to the enjoyment you will derive. ■

## COMPUTERIZED CAR

(Continued from page 70)

ing parameters to keep the car running until it can be serviced. Of course, fuel economy will suffer since those settings are much richer than normal, but the car will remain in operation. Also, timing will be advanced. Those settings are built into the firmware. The same is true of other key system failures, such as the throttle-positioning sensor.

### Anti-skid Braking

Finally,  $\mu$ P's will have an important role in vehicular safety. Not only are they likely to adjust your car's traction to take into account varying road conditions, but they will also help slow you down in other situations.

One safety function that is now controlled by a dedicated  $\mu$ P is anti-skid braking. With that system, the  $\mu$ P interfaces with a sensor on the brake pedal and sensors at each wheel.

In action, the  $\mu$ P senses a panic stop—the type which would require anti-skid braking—by the distance and force used to press the pedal down. If the sensor indicates that a panic stop has been initiated, the  $\mu$ P issues instructions to an electronic module on the braking system. It begins to modulate or engage the brakes to the point of lockup.

As the brakes near lockup, the sensor determines that the wheels will begin to stop rolling and instructs the system to release the brakes and begin the process over again. That can happen as many as 12 to 15 times per second. That constant pumping action not only stops the car in shorter distances, but also allows you to retain control because the wheels don't stop turning completely. When wheels do lock up, you lose control of the vehicle.

Automotive electronics have come a long way in a relatively short time. Twenty years ago, there were few solid-state devices; now cars are becoming more and more computer-controlled. It's an exciting prospect, one which will make the science-fiction writer's computerized car a reality. ■



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Shure's president, James H. Kogen said, "Dedication to our credo has resulted in two factors which directly under-



The ubiquitous and famed Shure Model 556 Unidyne microphone was the first single-unit cardioid dynamic type. It became an industry standard from 1938 to 1947.



If a microphone could become legendary, the Shure Model SM 58 cardioid dynamic microphone would head the list. It has been in continuous use from 1963 to the present.

score our worldwide reputation for quality. Those factors are (1) Shure's record of more industry firsts than any of our well-regarded competitors, and (2) Shure's record of more technical papers published in professional journals than any of our competitors."

In reflecting on the Company's past, present, and future, Kogen stated: "Through the years, Shure has been an audio pioneer in such diverse fields as mobile and fixed-station communications, stereo high-fidelity, public address

and sound reinforcement, recording, and broadcasting. Currently, we are in the forefront of teleconferencing, and already have become a recognized industry leader in this important new area of communications."

This editor is delighted to see the Shure people continuing their work pausing only slightly in deference to their accomplishments of the past—and then turn to the goals of the future. We look towards a steady stream of sophisticated yet practical products that will continue to make our lives more enjoyable. ■



In this age of rapid new model introductions, the Shure Model M3D Stereo-Dynetic phono cartridge has been contrary. It has seen use throughout the world for 25 years—1958-1983.

## CALLING ALL HAMS

(Continued from page 93)

application. Our version was built for operation in the sideband segment of each band. Again, the dimensions given in the table bring you near a preferred frequency. The antenna's actual length is influenced by height above ground of the antenna ends, as well as the apex angle between the two quarter-wave segments of each dipole.

In Table 1, dimensions are given for novice portions of the 10 and 15 meter bands. The umbrella configuration provides fine performance on each band with but a single transmission line. Add the 20-meter dipole. In so doing you can practice code reception and study operating techniques on the very active 20-meter DX band. In fact you can bring up your



Fig. 4—Coaxial cable exits at bottom of mast. It is coupled to the lead-in line to the receiver.

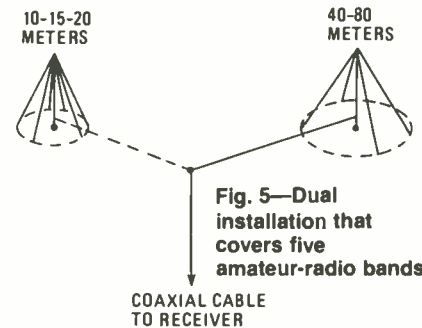
code speed at the same time that you develop an understanding of DX operating practices. There is always some DX activity on 20 meters, especially on the CW band. Also become familiar with sideband DX procedures by listening on the phone segment of the 20 meter band.

A similar construction can be used to erect a 40- to 80-meter novice umbrella. In that case, only two dipoles are required. Considerably more erection space is required because of the longer  $\lambda/4$  lengths of the lower-frequency bands. Refer to Table 2.

You might wish to space that second umbrella configuration a short distance from the higher-frequency one, Fig. 5. Perhaps you can arrange the positioning in such a manner that a single transmission line from the radio room can be ex-

TABLE 2—DIMENSION TABLE FOR 40- AND 80-METER DIPOLES

Band	kHz	$\lambda/4$ Length
40-Meters		
CW	7050	33' 2"
Novice	7125	32' 10"
Sideband	7250	32' 3"
80-Meters		
CW	3600	65' —
Novice	3725	62' 10"
Sideband	3900	60' —



changed between the base of one antenna mast and the other. You will then have a choice of using either the high-frequency umbrella dipole combination or the lower-frequency combination by making the changeover physically. Another possibility is to run the two coaxial transmission lines to the radio room and use a two-position coaxial switch to change over between the two antennas. Such a plan would give you operating capability on all five novice bands.

Keep tuned in. ■



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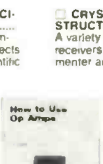
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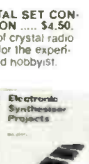
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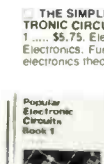
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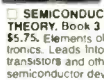
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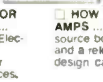
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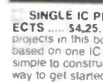
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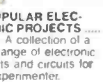
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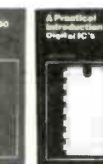
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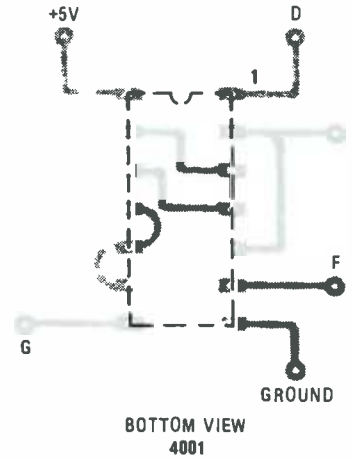
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# DIGITAL FUNDAMENTALS

(Continued from page 64)

9. The most popular form of TTL has high values of circuit resistors and uses diodes between the base and collectors of the transistors to prevent saturation. This kind of TTL is called \_\_\_\_\_.
10. The primary advantage of CMOS is:
- a. low cost
  - b. low-propagation delay
  - c. low-noise margin
  - d. low-power consumption

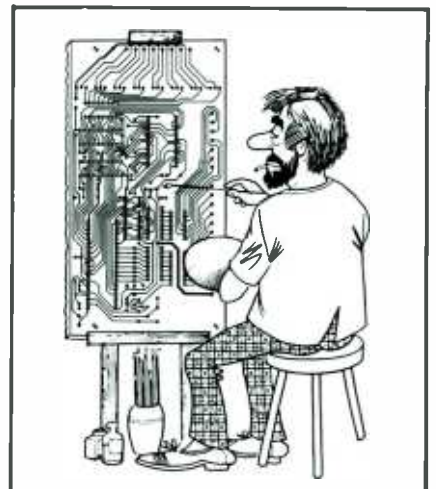
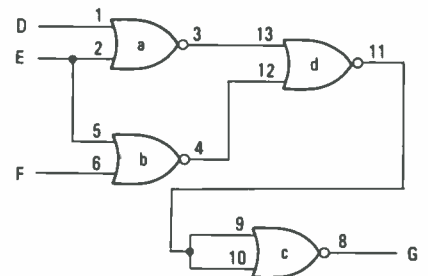
11. TTL is slower than CMOS.
- a. True
  - b. False
12. From the PC board wiring shown below, draw the logic diagram. Assume the use of the 4001 CMOS IC in Fig. 13A. Show all interconnections and pin numbers.



BOTTOM VIEW  
4001

## ANSWERS TO THE ABOVE QUESTIONS

1. c-switch
2. a short circuit (closed switch, etc.)
3. MOSFET (metal oxide semiconductor field-effect transistor)
4. b-NAND
5. b-binary 1
6. a-NMOS
7. complementary (which is the C in CMOS)
8. a-cut off
9. low-power Shottky
10. d-low-power consumption
11. b-False
12. See diagram below:



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# THE PLASMA MACHINE

(Continued from page 57)

WHEN USING THE CAPILLARY METHOD TUBING MUST BE CRIMPED BEFORE REMOVING FROM VACUUM SYSTEM. FLATTEN IN VISE & IMMEDIATELY SOLDER END FOR SECURING SEAL

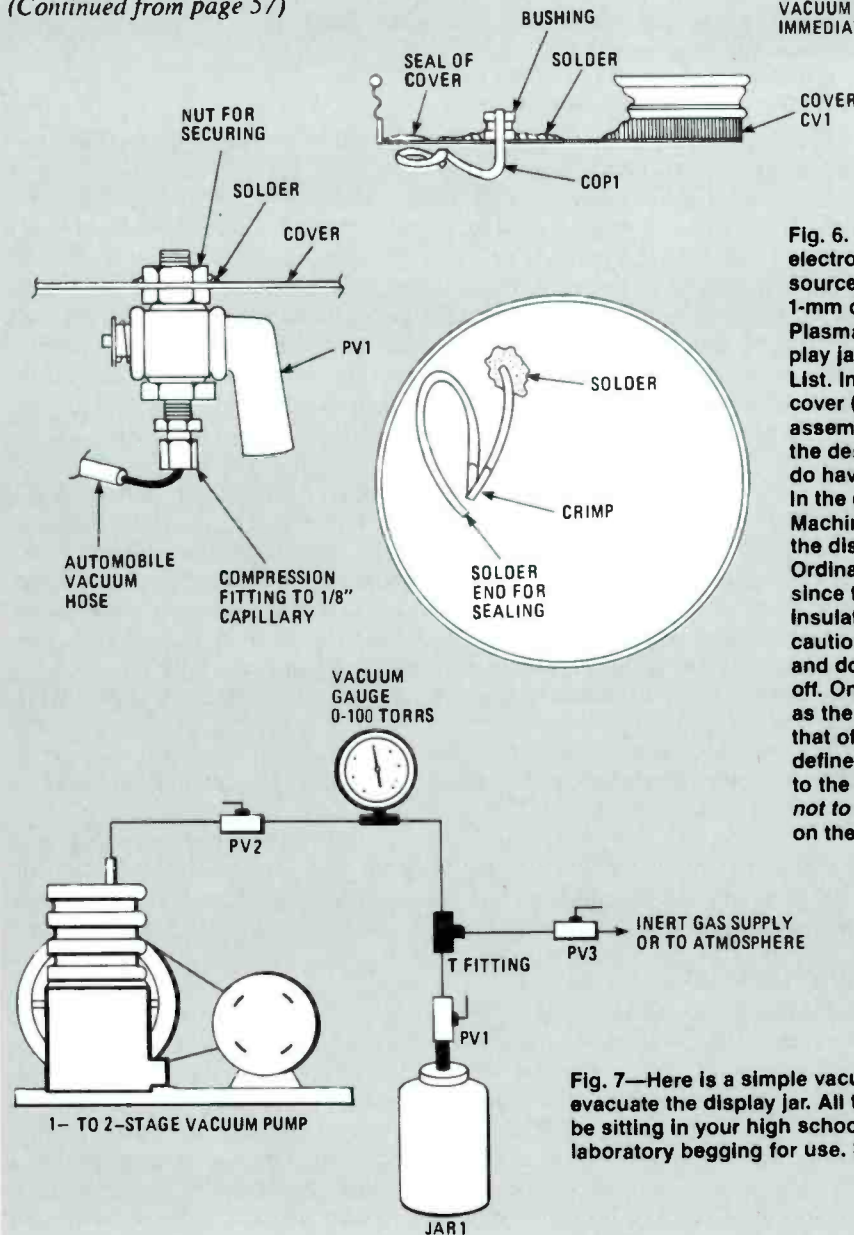


Fig. 6. It is reasonable to assume that most electronics hobbyists do not have a vacuum source or pump at home that can go down to 1-mm of mercury (approximately 1 torr). Most Plasma Machine builders will obtain the display jar direct from the supplier in the Parts List. In that case the display jar (JAR1), cover (CV1), and pet cock (PV1) come as an assembled unit with the interior evacuated to the desired vacuum. However, for those few who do have a vacuum source available, the details in the drawings are important. The Plasma Machine may be powered with high voltage as the display jar is evacuated to 1 to 2 torrs. Ordinary automotive vacuum hoses may be used since they will provide adequate electrical insulation. Nevertheless, observe extreme caution in the vicinity of the Plasma Machine, and do not touch unless the power is turned off. Once the plasma tornado comes into view as the pressure drops, select the vacuum level that offers the brightest display with a well defined plasma column. Whenever you apply heat to the cover for soldering purposes, be sure not to damage the rubber or plastic seal on the covers' inside-top edge.

Fig. 7—Here is a simple vacuum setup that can be used to evacuate the display jar. All the items for this setup may be sitting in your high school's or college's physics laboratory begging for use. Speak to the instructor in charge.

## Powering Up

Plug the AC line cord into an outlet and set S1 to on. Power is applied to step-down transformer (T1). An electrical arc of nearly 1-inch may be drawn from the high-voltage lead of transformer T2. Use a long, clean glass rod to bring a grounded wire to the alligator clip (CL1). Have a second person ride the power switch so that power would be disconnected immediately in case of smoke, overheating, or other disaster. Once an arc is drawn and proven to be stable, remove the lead and glass rod. Leave the power on for several minutes, then turn it off. Immediately check for excessive heating of the transistors. If continuous use is anticipated, it will be necessary to cool the heat sink and components with a fan (FAN1) as shown in Figs. 4 and 5. The circuit does have a tendency to run hot.

The human body acts as an antenna when in contact with any metal part of the Plasma Machine and an annoying

burning sensation will occur. To avoid that effect, cover any and all metal parts including the toggle lever of switch S1 with a piece of plastic tubing. Cover any exposed screw heads with high-voltage putty, or a dab of RTV cement.

Fabricate the plastic enclosure (EN1) as shown in Fig. 5 to mate with power-supply assembly diagrammed in Fig. 4. Also shown is a method of mounting an optional muffin fan (FAN1) for cooling. Note: About ten 3/8-inch-diameter ventilation holes are punched or drilled in the lower base area. Another method to increase air circulation by the fan is to raise the base with rubber feet, keeping the housing about one inch above the tabletop.

The enclosure shown and supplied with the kit is a large plastic planter available through most garden and florist shops. Obtain a #10 standard plastic pot, or equivalent.

Positioning of the high-voltage transformer is important  
(Continued on page 102)

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(Continued from page 101)

for proper operation as the display jar (JAR1). That is why the 7-inch length of PVC extender tube (EXT1) is important. When the alligator clip (CL1) connects to the cover (CV1), the high-voltage transformer (T2) should hang about one inch above the mounting bracket (BK1).

## Assembly of Display Container

Proceed with the following steps very carefully. Read them carefully from beginning to end before beginning.

1. Obtain a 1-gallon, clear glass jar (JAR1) with a metal cover (CV1) with rubber seal. Those are similar to jars used for pickles, peanut butter, etc., and will hold a medium vacuum when properly sealed.

2. Fabricate the metal cap (CV1) as shown in Fig. 6. Note that two approaches are shown with a choice of the sealed capillary tubing (COPI) or the pet cock (PV1). The sealed capillary technique limits the builder from readily changing pressure and gas mixtures. That technique is suggested as an approach, once the desired pressure and mixtures are determined. A more flexible technique requires the use of a pet cock, which allows more convenient control of pressure and gas mixtures.

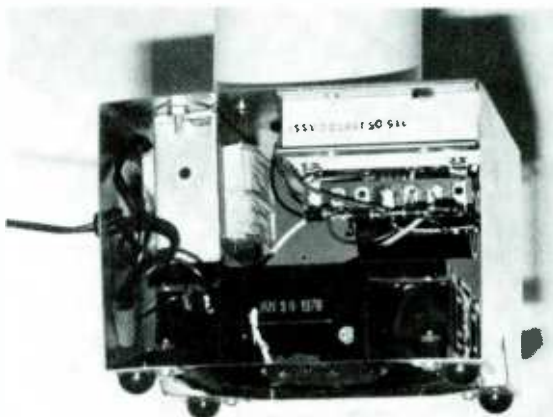
3. Very carefully punch or drill an appropriate hole in the metal cap (CV1) without distorting it. When using the capillary tubing (COPI), the hole should be off center. When using the valve, the hole may be in the center. You will note a back up bushing or nut to provide surface area for soldering to the thin metal cap. Solder as shown (Fig. 6) and be careful not to burn the rubber or plastic seal. Solder must flow evenly and provide a vacuum-perfect seal. The kit listed in the Parts List is supplied with the more versatile pet cock. It also is necessary for the builder to provide the vacuum extension tubing and any compression fitting as shown in Fig. 6.

4. Connect to vacuum system (Fig. 7) and proceed to charge the display jar for desired effect. Experiment using various safe gases. **Do not use explosive or poisonous gases!**

5. A very satisfactory plasma display can be obtained by simply pumping down to between 1-3mm (torrs) and sealing the display jar. That provides an excellent display of a plasma tornado. That is the method used to prepare assembled display jar that is purchased assembled, evacuated, and tested.

## Now Have Fun

All that work demands that you have a lot of fun demonstrating the Plasma Machine. First, assemble a group of friends and family. Act in a mystical style, indicating you have discovered a new physical phenomena that you can control. Keep them guessing and on their toes. Demonstrate the device in a darkened room in front of a large mirror. The plasma reflections will make the presentation eerier. Having practiced with the device before the demonstration, you will be able to go through a presentation that will be exciting to those assembled. Have the audience participate. When their interest is at its peak, tell them exactly what you have, and then see if you can get through the pack to play with your Plasma Machine. You may have to practice some crowd-control tactics. If that's your problem, we made your day! ■



Realizing the amount of metal work that goes into this project, consider following the author's layout to the letter. In fact, it is suggested that you obtain the parts in kit form. Refer to the Parts List.



## TELEPHONE HOLD

(Continued from page 75)

diode D1 has a normal voltage drop—called the *breakover voltage*—of 0.7 volts, and the LED has a forward drop of 2.0 volts. Excluding the voltage drop across R1 there is a maximum of 2.3 volts available for SCR1, which is too low to maintain conduction; so SCR1 automatically opens the Telephone Hold circuit when any telephone goes off-hook.

## Construction

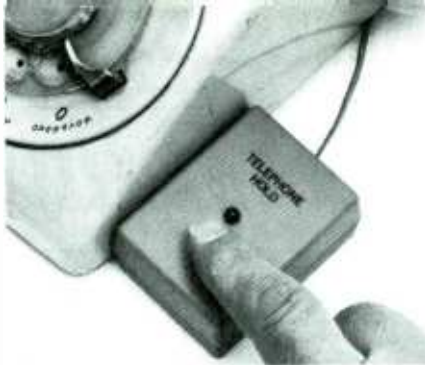
The Telephone Hold is assembled on a small printed-circuit board for which a full-scale template is provided (see Fig. 2). The project could just as easily be built on a small piece of perforated board, or even *air wired* and encapsulated in plastic or silicon rubber. The printed-circuit board assembly is recommended, because it provides an easy way to mount the device using a single nut threaded on S1's shaft.

Take extreme care that SCR1 is installed correctly. The flat side of its case should face the nearest edge of the printed-circuit board. Refer to Fig. 3. Install S1 and the light-emitting diode, LED1, after all other components have been soldered to the printed-circuit board.

Switch S1 is a subminiature type whose terminals exactly fit the holes in the printed-circuit board if they are fanned outward slightly. But be careful; the switch terminals are delicate until soldered to the printed-circuit foils. Don't force the terminals with your fingers or a screwdriver; use longnose pliers to bend them outward slowly and gently. Similarly, use longnose pliers to slightly fan LED1's leads.

Solder only one lead of switch S1. Make certain that S1 is at a right angle to the printed-circuit board, and then solder the remaining lead. Then install LED1 in a similar manner, but position it above the printed-circuit board so that the top of the LED just sticks up above the threaded shaft of the switch. For best viewing, LED1 should be a round, diffused lens type, the kind that's packaged 10 or 20-for-\$1. Do not use miniature or subminiature light-emitting diodes. Keep in mind that the light-emitting diode must be rated for at least 20 mA of current.

Switch S1 and LED1 are spaced exactly 1/2-in. apart. To install the device in a telephone or in a cabinet, drill two 1/4-in. holes a half-inch apart, slide the



The project is shown attached to the side of a phone. If you do not own the phone, do not mount the project on the instrument so that it can damage the cover.

switch and LED through the holes, then secure the assembly with S1's mounting nut. If the cabinet is plastic, the threaded shaft probably won't pass through the plastic panel if you attempt to use the lockwasher supplied with the switch; so simply discard the lockwasher.

## Checkout and Use

Connect the Telephone Hold across the telephone's red-green wires, taking extra care to connect diode D1's free end to the green wire. Press S1. The LED should turn on. If it doesn't, use a DC voltmeter to check the polarity of the red-green wires, because it's possible that the telephone installer reversed the red-green wires and your telephone's green wire is negative. The Telephone Hold won't work if the red-green polarity is reversed.

If the line's polarity and unit's assembly is correct, pressing S1 will cause LED1 to light. Lifting the phone or an extension off-hook will cause LED1 to go out. If the hold action is somewhat *hairy*, if LED1 is very dim or flickers, change R1 to 1000 ohms. Changing the value of R1 normally isn't necessary, but there are unusual variations in telephone wiring which might require it to be done. ■

### PARTS LIST FOR TELEPHONE HOLD

D1—1N4002 through 1N4005 silicon rectifier, 100-PIV or higher  
 LED1—Light-emitting diode, 20–30 mA rating, diffused lens (see text)  
 R1—1500-ohm, 1/2-watt, 10% resistor  
 R2—1000-ohm, 1/2-watt, 10% resistor  
 S1—Pushbutton switch, normally open (Radio Shack 275-1571)  
 SCR1—Silicon controlled rectifier, 100-PIV (RCA SK3638, GE-246, or equivalent)  
 Misc.—Printed-circuit materials, wire, plastic case (optional), solder, etc.

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## MIND MASTER

(Continued from page 91)

If DISPI shows the wrong number, the adding circuits are malfunctioning. To correct the problem, you'll have to check the wiring for correctness, including connections to the inputs of U22. Once you've debugged the circuit and have the unit working, move on to the power supply.

Mount the power-supply components on a small piece of perfboard and wire according to the Fig. 3. Be sure to heat-sink the regulator, U25. After that, power-up the circuit and check for the presence of +5 volts at the output.

## Cabinet Preparations

Now that everything's working, prepare the chassis for the circuit. The author used a sloping-front cabinet with a base measurement of 10½ × 8 inches. Before drilling any holes, measure the diameter of the chassis-mounted components to determine the necessary bit size.

Armed with that information, drill the holes, according to the layout in the photos. The rectangular hole for DISPI can be made either by drilling successive holes and using tin snips or using a nibbling tool. Another, less favorable, method is to drill a hole and with a small file shape and increase the size of the hole as needed. Make the hole slightly smaller than DISPI, but not so much so that it shorts the pins of the display. If deburring is needed, a larger bit or a small file may be used. After that, carefully paint the cover to hide any nicks or abrasions.

Now wire the circuit board to the chassis components. Glue (or clip-mount) the light-emitting diodes to the cover. When complete, the cover and circuit board will be an integral unit. Now mount the power board with the transformer and power cord to the base as seen in the photo. Join the cover and main board to the base and secure. Wire the power-supply board to the main board and connect S9 to the power board. Now secure the cover to the base, and again power-up and verify that everything is working.

The final step is the front-panel labeling. Dry rub-on transfers may be used to label switches and indicators and to enhance the appearance of the project.

## Playing the Game

Plug the Mind Master into a wall outlet and flip on the power. Turn S4 off

so that the Combination light-emitting diodes are unlighted. Press and release the RESET switch. Now press and hold down the RANDOM switch for a few seconds. Using S5-S8, select a combination and then press TEST. The CORRECT display, DISPI, will show how many you've guess correctly (as long as the TEST switch is held).

Release TEST and you'll see the TURN advance one count. Keep trying until you either win or lose. After your game, flip S4 to DISPLAY and see what the secret code was. And oh yes—Have fun! ■

## TESTBENCH IDEAS

(Continued from page 92)

### Sharpie Idea

In time the paper labels pasted on my computer cables begin to fall off. I now get a truly permanent marking by writing directly on ribbon cable with a "Sharpie" marking pen. The ink actually dissolves into the plastic and becomes part of the insulation itself; water causes the markings to neither smear nor wash off. Try it!

—James Vaar



## ADVERTISING INDEX

HANDS-ON ELECTRONICS magazine does not assume any responsibility for errors that may appear in the index below.

Free information No.	Page	
—	Active Electronics	22
519	AF Publishers	12
522	All Electronics	18
518	AMC Sales	105
521	American Design Components	106
511	Bishop Graphics	22
520	Caudill, Inc.	8
—	C.I.E.	29-31
—	Command Productions	8
515	Deltax	16
—	Dick Smith Electronics	4-5, 6-7
527	Diehl Engineering	17
514	Digi-Key	15
—	Electronic Book Club	24
—	ETT	98
513	Fluke	C4
526	Information Unlimited	103
510	Jameco	13
517	Keypro Circuit Systems	12
516	Mouser	105
—	NRI	19-21
—	NTS	10
512	Oregon Microwave	103
523	OWI, Inc.	3
—	RE Bookstore	100
—	RF Parts Co.	102
—	Tektronix	C2
—	Windjammer	C3

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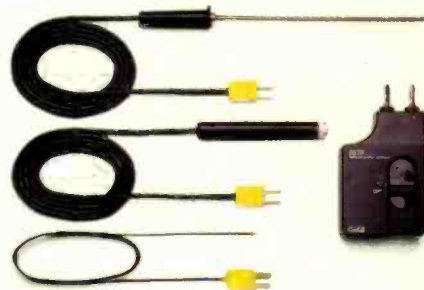
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