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# September 1991 Radio-Electronics®

Vol. 62 No. 9

## BUILD THIS


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With a 100,000-volt peak output, this Tesla coil can create 8-inch sparks!
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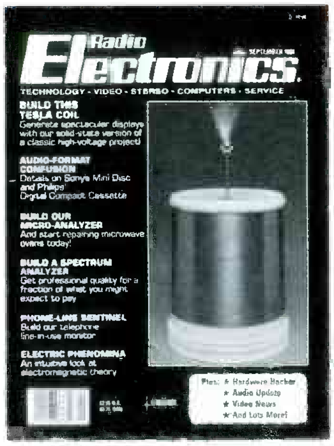


Ever since Nikola Tesla created the first one about a century ago, Tesla coils have been popular projects for electronics hobbyists and students. There are a couple of reasons for their continued popularity: One is that they create a dazzling electrical display, and the other is that there is much to be learned about electronics by building a Tesla coil. Our solid-state Tesla coil is different from the classic one in that the coupling to the secondary coil is by a direct electrical connection rather than by magnetic fields. It's the same in that it creates a spark as long as 8 inches and makes an excellent teaching tool. To find out how to build your own solid-state Tesla coil, turn to page 33.

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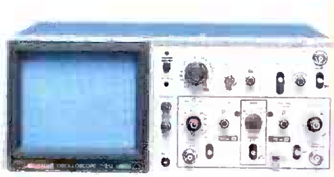

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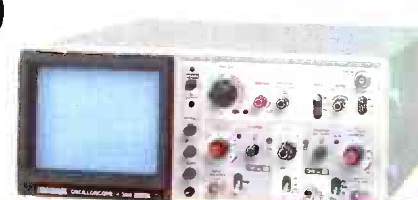

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# WHAT'S NEWS

*A review of the latest happenings in electronics.*

## ISCET certifies 30,000th technician

When Robert Bruce Bottoms, a computer technician and evening-school engineering major, achieved journeyman-level certification specializing in computers, he became the 30,000th electronics technician to be certified by the International Society of Certified Electronics Technicians (ISCET), Fort Worth, TX. The 28-year-old United Parcel Service employee has worked in information services, industrial engineering, weight and balance, and programming. Bottoms also served as project technician for the introduction of the delivery information acquisition device, a hand-held microcomputer that is replacing paperwork for UPS drivers.

The computer specialty exam covers the operation of computer systems with an emphasis on hardware. Subject areas include basic arithmetic and logic operations as related to computer theory, computer organization, input and output equipment, and memory and storage; knowledge of software, programming, and troubleshooting is also required. The computer exam, and others offered by ISCET, have become the standards by which dealers, manufacturers, and government agencies distinguish the most knowledgeable technician from the rest. To become a member of ISCET, technicians must pass the basic CET exam. Other certification exams are offered by ISCET in such specialty areas as consumer, industrial, communications, FCC Legal, computer, audio, medical, radar, and video electronics. Information about ISCET is available from ISCET, 2708 West Berry Street, Fort Worth, TX 76109.

•

## Semiconductor process precisely controls crystal growth

An experimental process developed by Bellcore (Red Bank, NJ) has produced aluminum gallium arsenide crystals that are compositionally ten times more precise than any previously reported. The process offers the first practical method to monitor and control the growth of compound semiconductor alloys—which could significantly increase a manufacturers' ability to mass produce compound semiconductor devices and, in turn, reduce prices.

Bellcore's approach uses optical signals to provide information about the chemical development of a crystal surface while the crystal is being grown, instead of analyzing crystal growth after the process is complete, as in current fabrication techniques. Ellipsometry, an optical technique that bounces light off a crystal's emerging surfaces, reveals intricate details. Findings are instantaneously fed into a computer and analyzed. Within seconds, the computer uses the information to regulate the flow of materials into the growth chamber, so that small errors in material compositions are corrected as they occur. The Bellcore research team calls the sustained precision level of 0.1% that they have achieved "an important milestone in the quest for consistently perfect' aluminum gallium arsenide crystal structures."

**BELLCORE RESEARCHER BILL QUINN grows aluminum gallium arsenide crystals for use in semiconductor materials and devices, using an experimental process that corrects small errors in material composition as they occur, resulting in the world's most precise crystals.**

## American technological edge over Japan?

According to the results of a Gallup survey reported in the April, 1991 issue of *IEEE Spectrum*, a sampling of U.S. electrical engineers believes that the United States holds a technological edge over Japan in many areas. The report summarizes a survey of a cross section of 150 IEEE (Institute of Electrical and Electronics Engineers) members consisting of 50 each from government, industry, and academia. The survey, commissioned by Japan's financial daily paper, *Nihon Keizai Shimbun*, asked the engineers questions regarding areas in which the United States holds the technological edge over Japan now and whether it is likely to in the future. The respondents perceived America to be currently ahead in nine out of twelve areas: space/aviation, medical/pharmaceutical, software, biotechnology, workstations, supercomputers, personal computers, semiconductor microprocessors, and new industrial material. Japan led in consumer electronics, semiconductor memory, and fifth-generation computers. A large majority of the engineers polled expected the U.S. to maintain its lead in those nine areas, despite some anticipated slipping in biotechnology and fifth-generation computers.

Those results contrast with recent studies by the U.S. Department of Commerce and the Council on Competitiveness, which suggest that the U.S.'s current lead in technologies will be usurped by Japan by the year 2001. However, the article points out that some of the discrepancies between studies can be explained by the fact that a technological lead "is not invariably the best indicator of marketplace success."

Asked where future technological priorities should be placed, the engineers supported the development of natural energy sources (91%), optical IC's (83%), anti-cancer medication (83%), medication for Alzheimer's disease (80%), one-billion-bit dynamic RAM chips (79%), and high-speed surface transportation (79%). **R-E**

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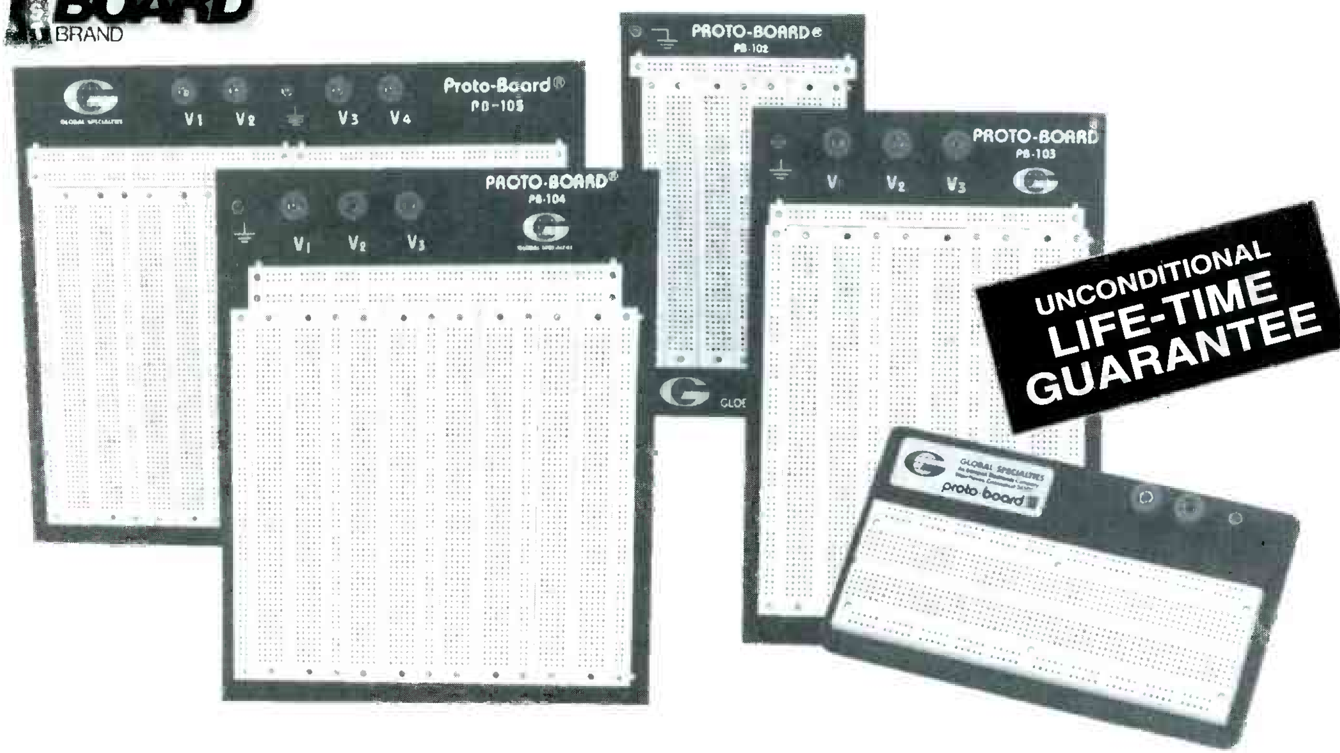


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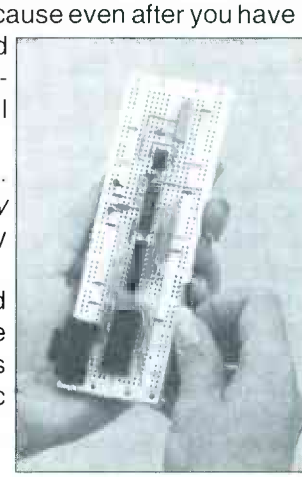

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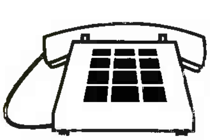

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# VIDEO NEWS

*What's new in the fast-changing video industry.*

DAVID LACHENBRUCH

**• Widescreen TV for U.S.** TV sets with the widescreen 16:9 ratio are on sale in Europe, with both Thomson and Philips introducing models (**Radio-Electronics**, June 1991), but both companies have been reluctant about committing themselves to introduce a similar product in the United States because of a lack of program material. Now it appears that the Japanese manufacturers have no such hesitancy, and we could see direct-view or projection sets—or both—with 16:9 pictures before the year is over.

The first company to commit to introducing a widescreen TV set here was JVC, which showed a prototype with a 34-inch tube at the Summer Consumer Electronics Show in Chicago. JVC didn't give any marketing date except "soon," but its officials stressed that they were showing an actual production model, not a prototype. Like the European widescreen sets, it will accommodate a number of picture modes and sources. For example, it will show a "letterboxed" movie from tape or disc full-screen and in proper dimension. With a conventional 4:3 picture source, it can magnify the image to full widescreen by cutting off a small portion of the top and bottom, or it can show it as a 4:3 picture leaving part of the screen blank. Under the latter arrangement, it can occupy the unused part of the screen with a group of pictures from other channels ("picture outside picture").

A race may be shaping up in Japan to introduce the first non-HDTV widescreen TV set, with Toshiba and Mitsubishi said to be ready to introduce sets with 16:9 ratio tubes and Hitachi planning a production model. The theory behind the industry's sudden interest in widescreen pictures with standard resolution is that even when HDTV comes it will be at least 10 years before it dominates the market, and in the meantime widescreen receivers will become popular as interim devices.

**• LCD projectors.** Projection TV sets using liquid crystal devices as shutters are getting better all the time. Sharp has introduced an industrial projector with about 650,000 pixel resolution (at an $8,000 list price) that finally appears to have achieved satisfactory picture quality.

No sooner had Sharp's model appeared than Philips announced its own model with about the same resolution but with many new features. It actually uses the same Sharp-made LCD's, but it will be priced around $6,000–$7,000 and aimed at commercial and industrial customers as well as high-end "home theater" buyers, according to Philips.

The Philips set, to be made in Holland and sold in the United States under the Magnavox brand, is a TV set complete with tuner—unlike other companies' monitor-only sets, which require VCR's or other outboard tuner systems. It employs a Philips-developed metal-halide lamp as its light source. The lamp is user-replaceable, and an extra lamp is packed in the projector. The lamp life is claimed to be 2,000 hours, and the on-screen graphics include a countdown telling the amount of life left in the lamp. When there are only 50 hours to go, a warning signal appears on the screen.

The picture projected by the Philips unit may be reversed or turned upside-down for incorporation in rear-projection systems. An interesting feature is the capability of pointing the wireless remote control at the screen instead of the projector, because of the light collector and amplifier built into the unit. The projector, weighing 38 pounds, has a built-in "convenience speaker" as well as a 10-watt-per-channel amplifier for remote stereo speakers which can be placed at either side of the screen. In the future, Philips plans a 16:9 widescreen version, and eventually the company predicts a set about the size of a VCR. Maximum picture size is about 100 inches diagonally.

**• Trumping Sony's ace.** Sony thought it had everything lined up. It was ready to introduce a new CD-ROM-based interactive multimedia format ("Super Disc") and had reached an agreement with Nintendo for Sony to supply hardware that would also be compatible with Nintendo's 16-bit Super Nintendo Entertainment System (SNES), and presumably Nintendo and its software licensees would support the Super Disc format with CD-ROM games. But Sony received a major surprise when Nintendo announced it had teamed up with Philips in a deal under which Nintendo will develop software based on the CD-ROM-XA format, which is compatible with Philips' Compact Disc-Interactive (CD-I) format, and Philips will develop a low-cost CD-ROM-XA drive for SNES. Sony was completely flabbergasted when Nintendo announced that it would not support the Sony system with software, and that "We will not cooperate with Sony." At our deadline, Sony, Nintendo, and Philips were in intensive negotiations to resolve the three-way dispute.

**• Dual-deck VCR setback.** Go-Video, the Phoenix, AZ company, which sells a dual-deck VCR and which sued many Japanese and Korean manufacturers alleging conspiracy not to supply it with parts or complete equipment, decisively lost its first round in federal court. Although most of the original defendants settled with Go-Video to avoid coming to court, Sony, JVC, and Matsushita refused to settle and precipitated a court battle involving a jury trial. Although the trial in Phoenix lasted two months, the eight-member jury took just three hours to decide that there had been no conspiracy to keep Go-Video out of the dual-deck VCR market. Go-Video, which had sought at least $500 million in damages, said that it would appeal the decision.

Meanwhile, the Go-Video VCR-2 dual-deck VCR was reduced in price from its original $1,000 to about $700, and its five-year warranty reduced to one year. Go-Video Chief Executive Officer Terren Dunlap testified that they sold about 16,000 decks in the first 11 months. **R-E**

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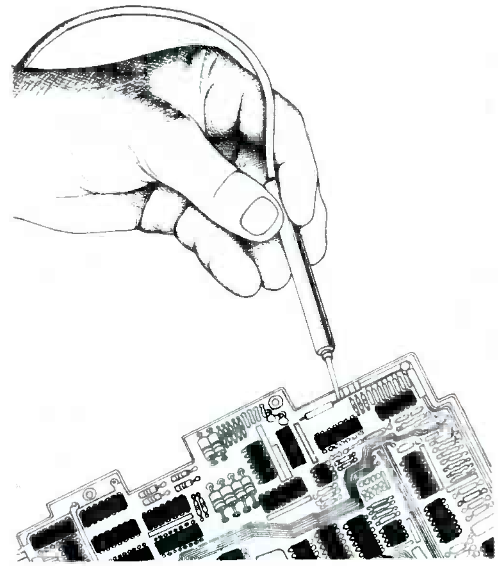


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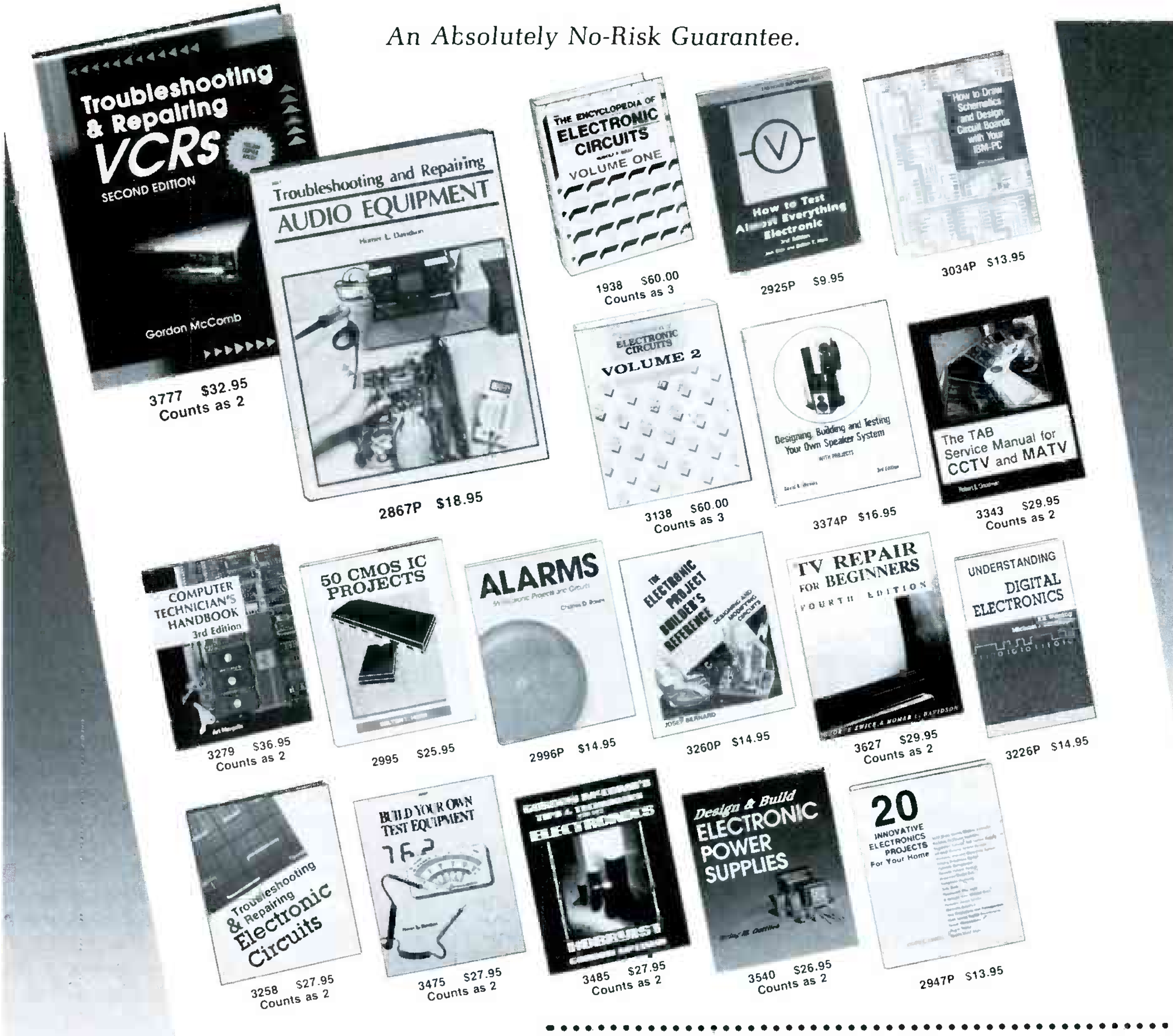


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### SOFTWARE SOLUTION

**A few months back you answered a letter from a reader named T. Waller who wanted a keyboard indicator to show that a Print Screen operation was in progress. Although he asked for a hardware solution, I think a software solution is better. At first, it would seem as though putting an indicator on the screen during a print-screen operation would mess up the very display you were trying to print. Fortunately IBM uses two bytes for each screen location (one for the displayed character and the other for the character's attribute) and only the first one is sent to the printer. I wrote a small program, PR_IND.COM, that modifies the print-screen handler by adding code to the hardware interrupt set up by the ROM BIOS. When my program is run, it goes resident and makes the two bytes in the upper-right corner of the screen go inverse video whenever a Print-Screen operation is taking place. It works on both color and monochrome screens and takes only 416 bytes of memory from DOS. Hardware is okay for a lot of stuff but bit twiddling is better for others.—J. Sprung, San Pedro, CA.**

I couldn't agree with you more, and 416 bytes is a cheap enough price to avoid having to screw around with hardware that's usually not only undocumented, but probably impossible to deal with as well. In these days of ASIC's (application-specific IC's) and custom silicon, the amount of hardware diddling you can do is pretty limited anyway.

I'm putting your source code and the COM file it produces on the RE-BBS (516-293-2283, 1200,2400, 8N1) in a ZIP file called PR_IND.ZIP. Your program works well and is the kind of utility that, after you've used it a bit, you feel should have been a part of the computer in the first place. Congratulations on a nice piece of work.

Any reader who wants to use the program (and that should be any reader with a DOS-based computer), can download the ZIP file from the bulletin board. For all those who don't have either a modem or the patience to deal with busy signals, the program can be created with any word processor that has the ability to save ASCII files. Type in the lines exactly as shown in Listing 1, end each line with a carriage return, and be sure to leave a blank line between the INT 27 and RCX near the end of the listing. Save the listing in a file named "IN."

**LISTING 1**

```
A
JMP    015C
PUSH   DS
PUSH   AX
CS:
MOV    DS,[0158]
XOR    BYTE PTR [809D],77
XOR    BYTE PTR [809F],77
MOV    AH,[009D]
MOV    AL,[009F]
CS:
MOV    [015A],AX
AND    AX,7777
CMP    AX,7070
JZ     0153
MOV AX,7070
MOV    [009D],AH
MOV    [009F],AL
PUSHF
CALL   0000:0000
CS:
MOV    DS,[0158]
XOR    BYTE PTR [809D],77
XOR    BYTE PTR [809F],77
CS:
MOV    AX,[015A]
MOV    [009D],AH
MOV    [009F],AL
POP    AX
POP    DS
IRET
MOV    AX,0707
JMP    0129
ADD    [BX+SI+0707],DH
MOV    AX,3505
INT    21
MOV    [0132],BX
MOV    [0134],ES
MOV    DX,0102
MOV    AX,2505
INT    21
MOV    DX,015C
INT    27

RCX
76
N PS_IND.COM
W
Q
```

When you've done that, you'll need a copy of the DEBUG program that came with DOS to turn the listing into a COM file. Put both the ASCII file you've called "IN" and DEBUG in the same directory and, at the DOS prompt, type "DEBUG" That will produce the program PR_IND.COM that you can then run at the DOS prompt or make a permanent part of your AUTOEXEC.BAT file.

If you get lots of error indications on the screen after you've run DEBUG the most likely source of the problem is the file produced by your word processor. In order for DEBUG to take commands from a file (in this case, the "IN" file you just created), each line has to be followed by a carriage return. When some word processors write an ASCII file, they include a line feed (0Ah) along with each carriage return (0Dh). If that's the way your word processor works, you'll have to use a different one to create the file.

The program is too down and dirty to check whether it's already resident, so make sure you don't load it more than once. Since it takes only 416 byte of DOS memory, the best way to deal with it all is to automate everything by putting it in your AUTOEXEC file and forgetting about the program entirely.

Remember that the program will work only on the text screen. If you have some TSR that enables you to do a screen dump of a graphics screen, chances are PR_IND won't give you an on screen indication that a Screen-Print operation is taking place.

### LED TROUBLES

**I'm currently working on a project that pulses some bright LED's at a frequency of 300 Hz while they're rotating to create a**


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stroboscopic effect. The circuit is battery powered, remote controlled, and uses CMOS 567 tone decoders to toggle a latching relay that connects the 300-Hz CMOS 555 oscillator and the LED's to power. Everything works fine until the LED's are connected. As soon as they light, it causes a voltage spike that makes the 567's trigger wildly. I've tried using voltage regulators and different sized filter capacitors at various points in the circuit but haven't had any luck. The power source is limited to five AA's; is there an answer to this problem that won't cost more than a few milliamps?—D. Donofrio, Cleveland, OH**

The reason that you're having problems with the circuit is that the 567's, and other phase-locked loops as well, all use internal voltage-controlled oscillators (VCO's) to generate the signals they need for frequency detection. Although they're pretty immune to gradual shifts in the supply voltage, sudden swings usually cause them to lose lock and that plays havoc with their output states.

The only way to keep that from happening is to regulate the voltage supply to the chips themselves. The standard solution would be to run them at a lower voltage. Since you'll always have at least six volts available from your five-battery supply, you might try one of the small, "L" suffix regulators from National Semiconductor to provide a steady supply for the tone decoders. They're packaged in TO-92 type cases, use only a few milliamps, and can easily power the CMOS 567's.

Since the key to making your circuit work reliably is to isolate the tone decoders from the current demands of the LED's, you might be able to achieve that by using a resistor/capacitor combination on each of the 567 power inputs. As you can see in Fig. 1, the resistor isolates the power input to the 567 from the main supply rail. You'll be able to use a fairly large resistor since the CMOS 567's run on flea power. An initial value of about 150 ohms is a good starting point. The capacitor is there to provide an energy reserve when the LED's cause a voltage droop and a good starting value here would be somewhere around 100 μF.

If all this fails and the voltage fluctuations in the circuit still make the 567's go nuts, you'll have no choice but to try the ultimate solution. It takes some circuit design and a few extra components, but there's no doubt it'll solve your problem.

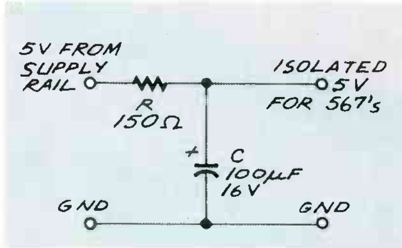


**FIG. 1—TO ISOLATE THE TONE decoders from the LED's you can use a resistor/capacitor combination on each of the 567 power inputs. The resistor isolates the power input to the 567 from the main supply rail and the capacitor provides an energy reserve when the LED's cause a voltage droop.**

Since the reason you're having the problem in the first place is that 567's are turned on at the same time the LED's are being turned on, you can make the circuit work properly by making sure that the two things never happen together. The 567's should be off when the LED's are on and on only when the LED's are off.

The idea of strobing power is a standard way of reducing the power requirements of a circuit. Basically it means you provide power only to the components you need. In your case, I would add circuitry that applies power only to the 567's when the output of the 555 oscillator is low. Since the rest state of your design shows that the 555 has a low output, the 567's would be constantly powered while the relay is open and intermittently powered on when the relay is closed (and the 555 is causing the LED's to light on and off).

All you need to make that happen is a single transistor switch with the base controlled by the output of the 555 and the power to the tone decoders taken from the collector. Since the current requirements of the 567 are so small, you can probably get by with one of the small-signal transistors like the 2N2222 or an equivalent PNP part.

Either of the two methods (isolating the 567 supply and strobing the power) may be the answer you're looking for. Try the resistor and capacitor first and, if that doesn't do the trick, try adding the transistor and rewiring the circuit. **R-E**

# LETTERS

*Write to Letters, Radio-Electronics, 500-B Bi-County Blvd., Farmingdale, NY 11735*

**MULTILAYER SOLUTION**

I am an electronics technician in the Navy, currently working as an instructor in the Navy's miniature/micro-miniature (2M) electronic repair program. I read the letter from V. Deeoh, titled "Multilayer Woes," that appeared in the *Ask R-E* column in the June issue of **Radio-Electronics**. The repair is possible. In fact, as I write this letter, I have five students in various stages of performing such a repair. It requires the use of various dental tools and a stereo-zoom microscope. It also requires a large amount of skill and patience. Of course, the damage would have to be isolated before the repair could be attempted.

ET1(SW) BRIAN K. FOWLER
*Norfolk, VA*

**ELECTRONIC COMPASS CORRECTIONS**

The "Electronic Compass" article (**Radio-Electronics**, June 1991) caught my attention, since I would like to build a device to measure magnetic field strengths in the order of Earth's and less. I thought that I might even use part of the compass circuitry—until I discovered what looks like a fatal flaw.

The article says that the Hall Effect sensors have a nominal 2.5-volt output that varies up or down about 1.3 mV per Gauss, depending on the field direction. Actually, that isn't stated clearly, but is implied and sounds reasonable. Thus, the inputs to resistors R1 and R2 will ideally be identical at 2.5 volts in the east-west orientation. By my concept of ideal op-amps, the voltage at pin 3 of IC2-a is entirely dependent upon the divider R4-R2, and the voltage from IC4 will be about 2.38 V. In an ideal op-amp, the voltage at pin 2 will be the same. The only way that can happen with both sensors at 2.5 volts is for pin 1 to be at zero volts, but the text says the voltage will be between 2 and 3 volts and the rest of the circuit depends upon it being in that range.

Next, I built that part of the circuit using adjustable supplies to replace the sensors. As my theory predicted, the output at pin 1 is near zero (actually 0.052 V) when equal voltages are applied to R1 and R2. I have found out from past tests of LM324's that they don't actually go to zero output. Mine are always 50 mV or so positive, and they are also quite nonlinear in gain in that region. I once attempted to use an LM324 as a differential amplifier with inputs quite similar to the compass circuit (differing by only millivolts). I gave it up primarily because of the nonlinear gain with near zero output voltage.

The text says that the gain of IC2-b is 100, but the resistors used with it give a gain of only 10. Also, the parts list is mixed up for the IC listing.

Something is seriously wrong. My lab tests agree with my theory, yet the published circuit apparently works. Please explain.

KENNETH E. STONE
*Cherryvale, KS*

*Mr. Stone's analysis of circuit operation is correct. The circuit will operate as published if the quiescent output voltage of IC4 is greater than that of IC3. That will cause pin 1 of IC2 to assume a positive value and operate with linear circuit gain.*

*In order to force the output of IC2 pin 1 to assume a voltage level between 2 and 3 volts, R4 should be deleted from the circuit. That will cause pins 3, 2, and 1 to assume a nominal voltage of 2.5 volts. The voltage gain of IC2-b is 10, as determined by the values of resistors R6 and R5. The identification of the IC's specified in the parts list is incorrect. IC2 is LM324N, while IC3 and IC4 are the Hall sensors.*

ANTHONY J. CARISTI

**PROFITS OR PROGRESS?**

Forty years ago, the first computer filled a large room, weighted 30 tons, and needed 19,000 vacuum tubes in order to function. Today, a desktop computer with silicon chips instead of tubes can do anything the 20-ton dinosaur did, and do it better. That's progress!

If we had the same kind of progress in the automobile industry, today we would be driving around in all-electric cars powered by super batteries or capacitors that can be charged in 10 minutes. Everything in the car would be controlled automatically by solid-state electronics.

However, there is not enough profit in trouble-free, non-polluting electric cars. The manufacturers prefer to give us the same old box on wheels that Grandpa drove, with the same old gasoline engine that needs oil changes and antifreeze, tuneups and lots of repairs. The more complicated they can make the car, the more money they make.

It's time for something better. Tell your congressman to outlaw the air-polluting, oil-dependent, gasoline-powered automobile, so the manufacturers will be forced to give us clean, modern electric cars. The sooner the better.

TOM ANDERSON
*The Electric Automobile Clubs of America*
*Valley Forge, PA*

**HIGH-END HOOPLA**

I've followed with interest the controversy that Larry Klein initiated in *Audio Update*, in the December 1990 issue of **Radio-Electronics** with his piece on "transfer functions." After reading John Atkinson's negative response to Klein's points in the March *Letters* column, I decided to read an issue of *Stereophile* to get a better handle on the fuss. After so doing, I think that magazine would be better titled (to borrow a phrase from Hunter Thompson) *Fear and Loathing on the High-End Trail*. A partial list of the things their staff doesn't like includes the following items: The Audio Engineering Society, *Stereo Review*, audio frequency modulation video recorders, CD players, and the Voice of Reason.

If there is one key issue that separates high-end aficionados from more sensible audiophiles, it is the importance of frequency response. Aside from such factors as amplifier power and speaker power-handling capacity, which determine how loud a system will play, much research has shown that frequency response alone determines the sonic character of any given component. In 1978, Mark Davis and his colleagues at M.I.T. reduced speaker differences to just two factors: frequency response and radiation pattern (*High Fidelity*, March 1980). All the while, high-end advocates skirted the matter of frequency response, emphasizing instead an endless panorama of strange, often unmeasurable, aura and electrical minutiae. (In addition, since speakers have the highest linear distortion of any component in the chain and since they determine the sound-radiation pattern, they have a much greater effect on a system's overall sonic quality than any other single component—another fact that high-end proponents seem to anxiously deny!)

I personally find it difficult to buy new and expensive components with the hope of obtaining more accurate sound reproduction because I know from experience that I'll be able to equalize the old equipment to sound so much like the new that any residual differences, usually in the bass region, won't justify the expense.

TOM GORDON
*Berkeley, CA*



### USING THE MAGNETIC FIELD METER

I was happy to see the "Magnetic Field Meter" project in the April issue of **Radio-Electronics**. The meter allows a quick (and inexpensive) assessment of home and business magnetic-field conditions for those of us who are unwilling to wait for U.S. standards to be established. I have some additional suggestions regarding the calibration use of such a coil-based meter.

For both calibration and use, the orientation of the coil is critical. The single-coil design is sensitive only to fields in one of three axes. The "right-hand rule" gives the relationship between the direction of field-producing current flow and the orientation of the coil axis for maximum sensitivity. For the calibration technique shown in Fig. 6 of the article, the meter pick-up coil should be at right angles to the current flow, hence parallel to the axis of the transmitting coil.

When conducting a survey, the meter coil axis should be oriented along each of three perpendicular axes and the strongest reading used for analysis. The external coil option would make that easier. The field strength due to monitors and due to unbalanced wiring usually has a strong maximum in one direction. The more expensive, professional meters typically use three perpendicular coils (or three Hall-effect devices) and electronically develop the true maximum field.

I would also like to provide some reference points of EMF field strengths to augment the values given in the article. The typical unbalanced current flow in the center-tap ground of a 240-volt drop to a house is 0–4 amps at 60 Hz. That corresponds to a magnetic field of 0–2 μT (0–20 milliGauss) at 1 inch from the current. The current usually flows down the outside wall of the house and through the cold water pipe along the basement ceiling. The quickest solution to such fields is to move furniture such as beds and cribs away from the area so that exposure time is reduced. The current could also be rerouted by an electrician with suitable copper ground strapping.

The new Swedish EMF guidelines for computer monitors (VDT's) are:

- 50 cm (20 in.), 5 Hz–2 kHz: 0.25 μT (2.5 mG)
- 50 cm (20 in.), 2 kHz–400kHz: 0.025 μT (0.25 mG)

Source: *VDT News*, Nov./Dec. 1990

Several manufacturers are now making low-radiation color monitors for the U.S. market, including all IBM's made since September 1989 and the new NEC 3Ds model. Many monitors exhibit low fields already, and can be tested with the Gaussmeter before purchase.

WILLIAM SNYDER
*Rochester, NY*

### NOBODY'S FOOL

I just finished reading the article on making a laser printer out of a monitor and a copier (**Radio-Electronics**, April 1991). It's a good idea in theory, but in practice you could have a problem. Some copiers will not run with the lamp removed. If you have that problem, you are going to have to create a path for the lamp voltage to "fool" the circuit.

RICK SCHWILL
*Phoenix, AZ* **R-E**

# EQUIPMENT REPORTS

## R.L. Drake R-8 World Band Shortwave Receiver

In our younger days, we never had the means to get the shortwave equipment that we really wanted. Our ham shack and shortwave monitoring setup were functional, and we did reasonably well, considering our non-existent budget. But every visit to a swap meet made our mouths water. And every magazine had advertisements of glorious equipment that we wanted. We knew that one day, we would own a communications receiver from R.L. Drake (P.O. Box 112, Miamisburg, OH 45342).

*R.L. Drake is back with a vengence!*



We never got a chance, though. In the early 1980's, Drake dropped communications receivers to pursue the satellite-TV business, where they've done quite well. But now they're back in business with the *R8*, a world band shortwave receiver re-engineered from the ground up.

They couldn't have picked a better time. Shortwave radio was undergoing healthy growth in the U.S. even before such dramatic events as the reunification of Germany, the revolution in Romania, and the Persian Gulf war. Even with the instant access to news that we can get through CNN and local all-news stations, people are tuning in to shortwave for something that is sometimes more difficult to find: a diversity of opinion. Although broadcast schedules and advanced taping of shows means that the news that you hear on the shortwave bands is often a few hours old, your chances of hearing a fresh perspective are still pretty good. And the chance of hearing stories not even covered in our news-saturated media is even better.

The *R8* offers continuous frequency coverage from 100 kHz to 30 MHz, which takes in the thirteen world-radio bands and everything in between. The table-top receiver measures roughly 13 × 5 × 13 inches, and weighs about 13 pounds. Although it's not designed for a mobile environment, the *R8* does offer a fused 12-volt DC input connector so that you can power the receiver, for example, from the cigarette lighter in your car. The AC input gives you plenty of options for world-wide operations: 100-, 120-, 200-, and 240-volt operation are supported at 50 or 60 Hz.

The front panel is dominated by a large, backlit liquid crystal display. We found it to be difficult to read at sharper angles. Head on, however, it's a delight. The seven-digit display provides a tuning resolution of 10 Hz.

The front panel isn't as cluttered with controls as many of its competitors. That doesn't mean, however, that the *R8* is short on features—features that really mean something when you're trying to capture the weak signals in crowded bands. Five receive bandwidths (6, 4, 2.3, 1.8 and 0.5 kHz) are provided. When you select one of the receiver's six modes (AM, FM, CW, RTTY, LSB, and USB) the *R8* automatically selects an appropriate bandwidth (1.8 kHz for RTTY, for example), but you are free to select another with the touch of a button. For example, if interference makes it difficult to intelligibly receive AM broadcasts using the 6-kHz bandwidth, you can reduce the setting to cut interference.

### Synchronous detector

One of the inherent "problems" with shortwave reception—regardless of the receiver—is signal fading due to propagation disturbances. To combat fading, the *R8* offers a switchable (slow, fast, or off) AGC or automatic gain control. In most cases, the AGC does a good job of keeping the signal listenable. But even with AGC, fading can cause distortion. That's where the *R8*'s synchronous detector comes in. A receiver-generated local oscillator, synchronized in frequency and phase to the carrier, is used in demodulating the signal. World-band listeners will really appreciate how it can enhance fidelity by reducing distortion.

A PASSBAND OFFSET control is another reception-enhancing feature that deserves mention. It allows you to electronically shift the receiver's IF frequency without disturbing the operating frequency! Thus, in many cases, you are able to move interfering signals out of the passband.

The synchronous detector and passband-offset capability—along with a tunable notch filter, dual-mode noise blanker, RF preamplifier for boosting signals over 5 MHz, and tone control—all help to dig the tough signals out of the crowded bands. In fact, there's not much more you could ask for. But the *R8* doesn't just offer superb reception capability. It also offers a host of other features.

One hundred memories store not only the frequency of a station, but also the complete receiver setup. Since the memory is stored in EEPROM, there's no need for battery backup. Tuning can be done by direct-frequency entry, tuning the large tuning dial (the faster you turn the dial, the faster the frequency shifts), or up and down keys that provide for larger

*continued on page 82*

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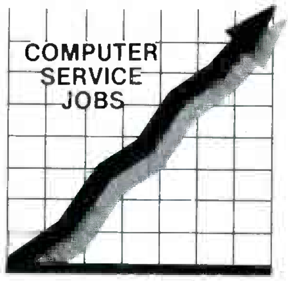


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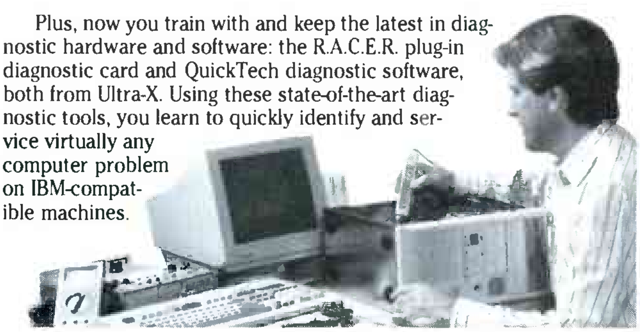

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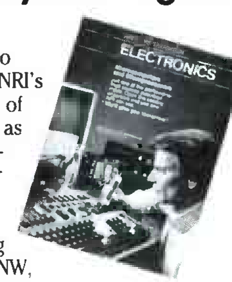


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# NEW PRODUCTS

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**PCXI BUS-EXPANSION CHASSIS.** PCXI is a modular, industrial PC, based on a 13-slot passive backplane. *Rapid Systems' PX1591* bus-expansion chassis includes a 13-slot ISA (industry standard architecture) standard backplane with a 200-watt modular power supply, a single-slot module, one bare expansion card, and front-end cabling needed to extend from the PCXI expansion chassis to any laptop or desktop PC. Using a standard PC with the *PX1591*, the PCXI chassis provides the benefits of EMI/RFI shielding, protection against vibration, and specified industrial cooling through a metal-shielded module cover with top and bottom cooling slots. Applications include field service, ATE development, factory automation, and industrial testing.

The *PX1591* bus-expansion chassis costs $2395.—**Rapid Systems, Inc.**, 433 North 34th Street, Seattle, WA 98103; Phone:206-548-0322; Fax: 206-547-8311.

CIRCLE 16 ON FREE INFORMATION CARD

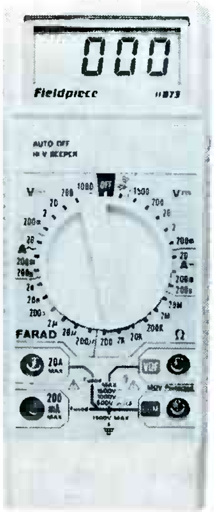
**AMATEUR-TV FILTER.** Designed for use in amateur televisions, the *FL-407 Vestigial Sideband Filter* from *International Crystal Mfg. Co.* is available in frequencies between 420 and 440 MHz. The 6-MHz nominal bandwidth and low-loss design are intended for transmitter or receiver use. Two filters can be used for repeater operation. The seven-pole, interdigital design provides excellent sideband suppression and filtering when used alone, or in pairs. Heavy-duty construction ensures stable operation and long life. The *FL-407* measures $2\frac{1}{8} \times 8\frac{13}{16} \times 20\frac{5}{8}$ inches. N-type connectors are standard.

The *FL-407* vestigial sideband filter costs $249.—**International Crystal Manufacturing Company, Inc.**, P.O. Box 26330, 701 West Sheridan, Oklahoma City, OK 73126-0330; Phone: 800-426-9825 or 405-236-3741; Fax: 405-235-1904.

CIRCLE 17 ON FREE INFORMATION CARD

**FIELD-SERVICE DMM.** Aimed specifically at field-service technicians, the *HB70 Series* digital multimeters from *Fieldpiece Instruments* look and function differently from others on the market. Two professional-grade, heavy-duty meters, which provide only those functions needed most by service technicians, feature a single easy-to-use rotary switch for function and range selection. Models *HB71* and *HB73* each have 24 ranges in AC and DC volts, AC and DC amps, and ohms. The model *HB73* (pictured) adds six capacitance ranges up to 200 µF. All voltage ranges withstand 1500VDC and 1000VAC; other ranges withstand 500 volts AC or DC. The manual-ranging meters include a dangerous-voltage warning indicator that causes an LCD icon to flash intermittently and a beeper to be activated when a voltage over 28V AC or DC is encountered. All of each meter's capabilities are displayed on the front of the instrument; the one dial is used to choose from the "menu" on the meter's face. The rugged design is shatter-resistant and features O-ring seals to protect against contaminants, full 600-volt fusing on all current jacks, and MOV's to protect against transients.

The models *HB71* and *HB73* digital multimeters have suggested list prices of $99 and $109, respectively.—**Fieldpiece Instruments, Inc.**, 8322B Artesia Blvd., Buena Park, CA 90621; Phone: 714-992-1239; Fax: 714-992-1239.




CIRCLE 18 ON FREE INFORMATION CARD

**SOLDERING IRON SPONGE.** The *Swiss Sponge* (named for the cheese, not the country) features multiple holes for improved tip cleaning. The holes trap the solder balls and drop them to the bottom of the sponge tray where they belong. *Virtual Industries' Swiss Sponge* is available in a variety of sizes to fit most makes of soldering-iron sponge trays. A "one-size-fits-all" sponge measures 3.5 × 4.8 inches and features patterns matching popular tray sizes so that

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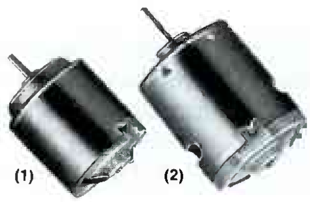
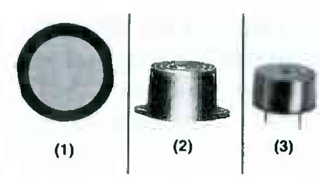
**Talking Multimeter.** Timesaving *speech* output! Take readings without having to glance over at the meter. Press a button on the probe and this meter calls out the reading in clear English while displaying it. Features full autoranging, autopolarity, liquid crystal display with low-battery and over-range indicators, continuity beeper, diode-check mode and 10-megohm input. With leads. #22-164 .......... **99.95**


**(1) Hobby Motor.** For robotics and projects. 1½ to 3VDC. About 1½" long. #273-223 .......... **99¢**
**(2) High-Speed 12VDC Motor.** Up to 15,200 RPM. About 2" long (with shaft). #273-255 ..... **2.99**


**(1) 4-in-1 Soldering Tool.** No cords or cylinders! Precision soldering wherever you need it. Operates anywhere on standard butane lighter fuel. Up to 60 minutes use per tank. Easy to use—refills in just seconds. #64-2161 .. **31.95**
**Optional Conversion Tips.** Available from CMC Special Order "Hotline".
**(2) Blow Torch.** Keeps a steady flame. #64-2169 .......... **9.95**
**(3) Hot Knife.** Ideal for design and repair. #64-2170 .......... **9.95**
**(4) Heat Blower.** Puts the heat on for quick drying. #64-2169 ..... **9.95**




**(1) Mini Piezo Speaker.** Only 1³¹⁄₃₂"-diameter. Use with IC drivers. #273-091 .......... **2.49**
**(2) "Ding-Dong" Chime.** Requires 6 to 18VDC. #273-071, **8.99**
**(3) Mini Buzzer.** Loud, yet only 7 mA at 12VDC. #273-074 ... **2.99**

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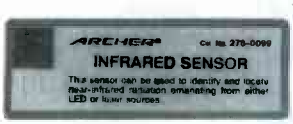
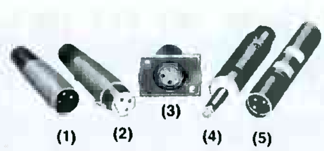
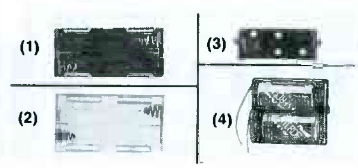



**NEW! TV/VCR Remote Control Tester.** Senses infrared light from remotes to tell you if they are working. Also locates near-infrared radiation emanating from either LED or laser sources. Pocket size. #276-0099 .......... **5.95**




**XLR Audio Connectors**

| Fig. | Type | Cat. No. | Each |
|---|---|---|---|
| 1 | Three-Pin Plug | 274-010 | 2.99 |
| 2 | Inline Socket | 274-011 | 2.99 |
| 3 | Panel Socket | 274-013 | 3.69 |
| 4 | XLR Plug Adapter | 274-016 | 11.99 |
| 5 | ¼"-Plug Adapter | 274-017 | 11.99 |




**Project Battery Holders.**
**(1) 2 "AAA".** #270-398 ..... **79¢**
**(2) 4 "D".** #270-389 ........ **1.59**
**(3) 1 "N".** #270-405 ........ **59¢**
**(4) 2 "C".** #270-385 ........ **1.29**

**Portable Shortwave Antenna.** Pulls in the DX! Great for traveling. Clips over telescoping rod antenna. Wire extends up to 23 ft. Dramatically improves reception on worldband portables. #278-1374 .......... **8.95**

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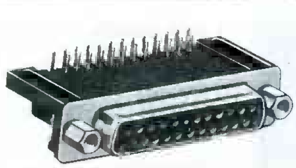
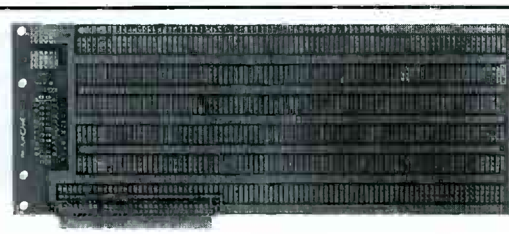
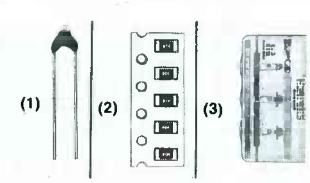


**NEW! 25-Pin Female D-Sub Connector.** Right-angle mounting, designed for Experimenter PC/XT Card-Edge Compatible Plug-In Card (at right) to provide standard 25-pin input/output port. #276-1504 .......... **2.39**



**NEW! Archer® Experimenter's Plug-In Card.** PC/XT compatible prototype card for breadboarding digital/analog circuits. Plated through holes, power and ground bus grids, 8-bit 31/62 plated-edge contacts, I/O mounting area for 25-pin d-sub connector (at left). #276-1598 .......... **29.95**




**(1) Hi-Precision 10K-ohm Thermistor.** #271-110 .......... **1.99**
**(2) 200 Surface-Mount Resistors.** 5% tol. #271-313, **Set 4.99**
**(3) Pocket Color Guide.** Finds resistor, capacitor, inductor values. #271-1210 .......... **79¢**

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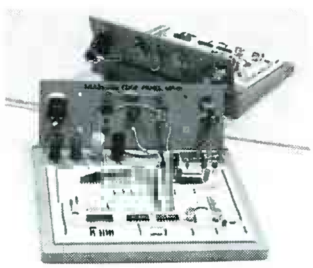
the user can cut it to fit using scissors.

Suggested list prices for the *Swiss Sponge* range from $.75 to $1.50 each.—Virtual Industries, Inc., 20 Mountview Lane, Unit E, Colorado Springs, CO 80907; Phone: 719-598-1369; Fax: 719-594-0147.

**SOLDERLESS BREADBOARDS.** Designed for use by students, hobbyists, and circuit-design engineers, the *X-tra Edge* solderless breadboards from *Chenesko Products* feature an extra multi-use edge panel for organizing and mounting components that do not fit into the normal DIP spacing of solderless breadboard socket connections. Available in four sizes, each contains a solderless breadboard area that contains both distribution and terminal strips to accommodate all DIP sizes, lead components (0.3–0.8mm lead diameter), and wire gauge of AWG 20–29 for interconnecting components. The breadboard contacts, spaced at 0.1-inch on center, are made of phosphor bronze nickel-plated for reliable low-resistance contacts. Initial contact resistance is less than 3 milliohms at 1 kHz (20°C) and the contacts are rated for a minimum of 10,000 in-out insertions. For easy connecting of external power supplies, four multi-purpose binding posts that accept both standard banana jacks and lead wires are standard on each model. The removable edge panel features a variety of geometric cutouts that allow the panel to hold transistors, stud rectifiers, triacs, SCR's, DIAC's, voltage regulators, heat sinks, rheostats, switches, buzzers, and fuse holders in a variety of package sizes.



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Models *NB-112P* (4.3 × 7.4 inches, 810 tie-points, 61 rows for DIP's), *NB-124P* (6.5 × 7.4 inches, 1620 tie-points, 122 rows for DIP's), *NB-134P* (7.9 × 7.4 inches, 2230 tie-points, 183 rows for DIP's), and *NB-145P* (9.7 × 7.4 inches, 2940 tie-points, 244 rows for DIP's) cost $7.50, $16, $21, and $27, respectively.—**Chenesko Products, Inc.**, 62 North Coleman Road, Centereach, NY 11720; Phone: 800-221-3516 or 516-736-7977; Fax: 516-732-4650.

**ELF METER.** To measure the strength of potentially harmful magnetic fields generated by AC electrical devices, *F.W. Bell* has introduced the model *4060* ELF (extremely low frequency) meter. Electromagnetic field (EMF) radiation, which is produced by power-transmission lines, computers, microwaves, and other electrical appliances, is under investigation by both private and governmental agencies for its possible link to cancer, leu-





CIRCLE 117 ON FREE INFORMATION CARD

kemia, and birth defects. The ELF meter can help the user to determine exposure levels. The com-


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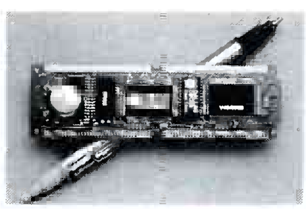
pact device features a 3½-digit LCD readout that indicates field strength in either milliGauss or Gauss (depending on the setting). A single control acts as both an on-off and a high/low range switch. Readings are taken simply by holding the meter near the source to be measured. The ELF meter has an accuracy of ±1% and a resolution of 1 mG or 10 mG.

The *4060* ELF meter has a suggested list price of $179.—**F.W. Bell, Inc.**, 6120 Hanging Moss Road, Orlando, FL; Phone: 407-678-7308.

**MINIATURE MICROCONTROLLER.** Called the *Flip Stik* because it functions as an expandable microprocessor when plugged in one way and a single-board microcontroller when plugged in the other way, *Dallas Semiconductor's DS2340* accepts software updates via its serial port while it is in the system, with no component removal required. The *Flip Stik* is roughly the size of a piece of chewing gum, and consumes very little power. It supports DOS-equivalent operating systems for diskless embedded systems, allowing application developments using standard DOS function calls. Thanks to its in-system reconfigurability, an embedded system that incorporates the *Flip Stik* can be configured with customized software just before shipping without opening its enclosure. Software upgrades can even be downloaded over the telephone line from a remote PC.

The *Flip Stik* incorporates a V40 microprocessor (software-compatible with the 8088), up to 256K bytes of non-volatile RAM, and a DS5340 "Softener" chip. That chip "crash-proofs" the microprocessor to safeguard data against power failure. Because the V40 executes the native instruction set of the PC, programmers can use the



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software base with which they are already familiar; they don't have to learn a new language or buy special development systems. They can write software for the *Flip Stik* on their desktop PC's and later port it to the embedded system. The V40 also provides a serial port, interrupt controller, timer-counters, and a DMA controller. The softener chip complements those functions with a clock oscillator, power monitor, watchdog timer, programmable address decoder, dual-port register file, and parallel I/O ports.

The *DS2340 Flip Stik* costs $54.30 in quantities of 1000.—**Dallas Semiconductor**, 4401 South Beltwood Parkway, Dallas, TX 75244; Phone: 214-450-0448. **R-E**

# NEW LIT

*Use The Free Information Card for fast response.*

**TONER CARTRIDGE RECHARGE CATALOG; from Chenesko Products Inc., 62 North Coleman Road, Centereach, NY 11720; Phone: 800-221-3516 or 516-736-7977; Fax: 516-732-4650; free.**

Anyone who owns a laser printer knows how costly replacement toner

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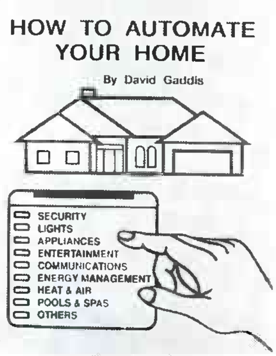
cartridges can be. This catalog explains alternatives to new cartridges, describing recharged cartridges—in do-it-yourself or full-service forms—that can be used with the HP LaserJet, LaserJet Plus, and LaserJet Series II, IID, IIP, and III; Apple LaserWriter, LaserWriter Plus, and LaserWriter IINT/IINTX; and many other models. When handled properly, the cartridges can be cleaned out, modified, and then recharged with new toner several times before the photoconductive drum in the toner cartridge wears out. This catalog describes three methods of recharge. For the handyman, six different kits are available with complete instructions on how to modify and recharge toner cartridges. For the person who wants to start a recharge business, a complete selection of toner-recharge products are offered at bulk prices. Those include generic toner, graphic toner, special replacement felt, new fixing rods, sealing strips, plugs labels, tools, clean air, wipes, and vacuums. Detailed assembly instructions are free with purchase. For those who lack the time or inclination to do the job themselves, the catalog also details Chenesko's mail-in service. The first time it is sent in, the cartridge is cleaned, modified, and recharged. The modification allows it to be easily refilled by the customer the second time, by purchasing the replacement toner and felt pad.

**HOW TO AUTOMATE YOUR HOME; by David Gaddis. Home Automation, USA, P.O. Box 22536, Oklahoma City, OK 73123; Phone: 405-840-4751; $29.95.**

Home automation, which promises better security, convenience, lower operating costs, safety, entertainment, and fun, is one of the fastest growing areas of consumer electronics. Encompassing home security, telephone



CIRCLE 338 ON FREE INFORMATION CARD

and communications systems, audio and video systems, lighting and appliance control, and environmental (heating, cooling, sprinklers, pools) control, automating a new or existing home requires quite a bit of information and forethought. This book contains valuable information on some of the most popular present and proposed automation concepts, including X-10, CEBus (The EIA's proposed standard, Consumer-Electronics Bus), Smart House, and Echelon.

Combining technical information with simple installation requirements and recommendations, step-by-step project directions, and 115 illustrations, the book serves as an installation guide as well as a reference source. Because there are so many variations and possibilities in home automation, the book is designed to provide the information required for readers to make decisions about their own requirements, based on cost, features, expandability, and goals.

Starting with an overall explanation of home automation, the book goes on to detail home wiring requirements. The remaining chapters each address a particular part of a home-automation system and include recommendations for basic and expanded systems and subsystems. Materials costs for the projects start as low as $28.00, and many cost less than $200 to install. The book includes $250 of coupons for discounts and free product offers.

**1991 TEST EQUIPMENT; from Amprobe Instrument, 630 Merrick Road, Lynbrook, NY 11563; Phone: 516-593-5600; Fax: 516-593-5682; free.**

Amprobe's full-line catalog contains complete specifications and describe the important features of its full line of electrical test equipment. Featured in its 48 pages are rotary scale clamp-ons with high-energy protection, digital mini clamp-ons, circuit tracers, true-RMS strip recorders, digital

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megohmmeters, ultrasonic detectors, analog clamp-ons, digital tachometers, pyrometers, and recorders. Convenient alphanumeric model listings are provided, as well as color photographs, illustrations, and helpful hints, and suggested accessories and replacements.

**AN INTRODUCTION TO AMATEUR COMMUNICATIONS SATELLITES; by A. Pickard. Electronics Technology Today Inc., P.O. Box 240, Massapequa Park, NY 11762-0240; $9.75, in-**

*(continued on page 30)*

# Radio Electronics® mini-ADS


**APPLIANCE REPAIR HANDBOOKS**—13 volumes by service experts; easy-to-understand diagrams, illustrations. For major appliances (air conditioners, refrigerators, washers, dryers, microwaves, etc.), elec. housewares, personal-care appliances. Basics of solid state, setting up shop, test instruments. **$2.65 to $7.90 each.** Free brochure. **APPLIANCE SERVICE, P.O. Box 789, Lombard, IL 60148. (708) 932-9550.**

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**THE MODEL WTT-20 IS ONLY THE SIZE OF A DIME,** yet transmits both sides of a telephone conversation to any FM radio with crystal clarity. Telephone line powered - never needs a battery! Up to ¼ mile range. Adjustable from 70-130 MHZ. Complete kit **$29.95** + **$1.50** S + H. Free Shipping on 2 or more! COD add **$4.** Call or send VISA, MC, MO. **DECO INDUSTRIES, Box 607, Bedford Hills, NY 10507. (914) 232-3878.**

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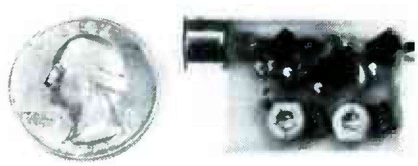

**SIMPLY SNAP THE WAT-50 MINIATURE FM TRANSMITTER** on top of a 9v battery and hear every sound in an entire house up to 1 mile away! Adjustable from 70-130 MHZ. Use with any FM radio. Complete kit **$29.95** + **$1.50** S + H. Free shipping on 2 or more! COD add **$4.** Call or send VISA, MC, MO. **DECO INDUSTRIES, Box 607, Bedford Hills, NY 10507. (914) 232-3878.**

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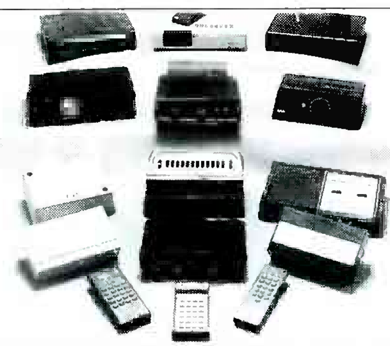

**CABLE TV CONVERTERS AND DESCRAMBLERS** SB-3 **$79.00** TRI-BI **$95.00** MLD-**$79.00** M35B **$69.00** DRZ-DIC **$149.00.** Special combos available. We ship COD. Quantity discounts. Call for pricing on other products. Dealers wanted. FREE CATALOG. We stand behind our products where others fail. One year warranty. **ACE PRODUCTS. P.O. Box 582, Saco, ME 04072 1 (800) 234-0726.**

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**$495 FOR A PROGRAMMABLE DC POWER SUPPLY IS NOW A REALITY!** • GPIB Interface Standard • Output Voltage/Current Programming & Readback • Local & Remote GPIB Operations • Remote Sense Function • Programmable Overvoltage and Overcurrent Protection • Software Calibration • Superior Line/Load Regulation • Output Enable/Disable • 3 Year Warranty. FREE Orientation Video available. For details, call: **AMERICAN RELIANCE INC. 800-654-9838 FAX: 818-575-0801.**

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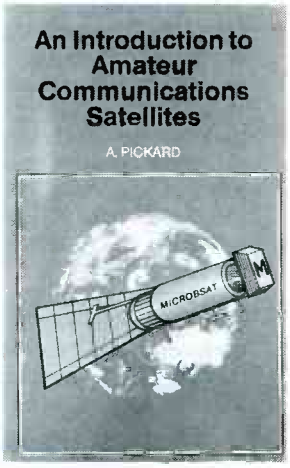
## NEW LIT

*continued from page 26*

**cluding shipping and handling (order No. BP290).**

Unless you work for a major telecommunications company, the space program, or the military, communications and broadcast satellites are normally off limits to you. Even if you own a satellite-TV receiver, you cannot participate in the technical aspects of those communications-satellite systems. There are, however, a large number of amateur communications satellites orbiting the earth. Those can be tracked, and their signals received, by ordinary people using relatively inexpensive equipment. This

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book describes several systems, how they can be connected to a computer, and how to use them. The decoded signals contain such information as telemetry data and weather pictures. The book is designed to encourage readers to become actively involved in receiving and decoding signals from amateur communications satellites, using aspects of electronics, engineering, and science. **R-E**

**Now, You Can Eavesdrop On The World.** Introducing the new Drake R8 Communications Receiver. It's world class, world band radio, made in the U.S.A. From Perth to the Persian Gulf, Moscow to Mozambique, local or global, you hear events *as they happen* with amazing clarity. Since 1943, Drake


has been setting the standards in electronic communications . . . and then raising them. Today, there's no better shortwave receiver than the Drake R8. **Out-Of-This-World Performance.** The new Drake R8 has more standard features than other shortwave radios. You get wide frequency range (100 KHz to 30,000 KHz), coverage of all world and local bands, and excellent dynamic range. But you also get important features you won't find on receivers costing hundreds of dollars more. A multi-voltage power supply. Pre-amp and attenuator. Five filter bandwidths and synchronous detector. Dual mode noise blanker and passband offset. Non-volatile 100 channel memory. All designed to give you the best reception with the least distortion. **Down-To-Earth Design.** The ergonomic design of the R8 gives you real ease of operation. You have convenient keypad entry, with large, legible controls. The face is bold. Uncluttered. And the liquid crystal display (LCD) is backlighted for easy reading. **Try The R8 . . . At Our Risk.** If you're not impressed by Drake's quality, performance and ease of operation, return the R8 Receiver within 15 days and we'll refund your money in full, less our original shipping charge. For more information, or to order, call **TOLL-FREE, 1-800-9-DRAKE-1.** Telephone orders may be placed on a major credit card. $979.00 (Shipping and handling $10 in continental U.S. Ohio residents add 6½% tax.) Call **TOLL-FREE, 1-800-9-DRAKE-1** today. You can't lose.

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## Hitachi RSO Series

(Portable Real-time Digital Storage Oscilloscopes)

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|---|---|
| VC-6023 - 20MHz, 20MS/s | $99/mo* |
| VC-6024 - 50MHz, 20MS/s | $120/mo* |
| VC-6025 - 50MHz, 20MS/s | $135/mo* |
| VC-6045 - 100MHz, 40MS/s | $125/mo* |
| VC-6145 - 100MHz, 100MS/s | $200/mo* |

RSO's from Hitachi feature roll mode, averaging, save memory, smoothing, interpolation, pretriggering, cursor measurements. These scopes enable more accurate, simplier observation of complex waveforms, in addition to such functions as hardcopy via a plotter interface and waveform transfer via the RS-232C interface. Enjoy the comfort of analog and the power fo digital.

**LEASING AVAILABLE**

**For all Hitachi Scopes - Call for details**

* Based on 24 months except V-1150, VC-6045, VC-6145 (36 months)

## Hitachi Portable Scopes

**DC to 50MHz, 2-Channel, DC offset function, Alternate magnifier function**

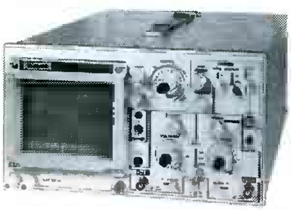
| | |
|---|---|
| V-525 - CRT Readout, Cursor Meas. | $1,025 |
| V-523 - Delayed Sweep | $995 |
| V-522 - Basic Model | $895 |
| V-422 - 40MHz | $795 |
| V-223 - 20Mhz delayed sweep | $695 |
| V-212 - 20MHz | $425 |

## HITACHI COMPACT SERIES SCOPES

This series provides many new functions such as CRT Readout, Cursor measurements (V-1085/1065/665), Frequency Ctr (V-1085), Sweeptime Autoranging, Delayed sweep and Tripper Lock using a 6-inch CRT. You don't feel the compactness in terms of performance and operation.

| | |
|---|---|
| V-660 - 60MHz, Dual Trace | $1,195 |
| V-665 - 60MHz, DT, w/cursor | $1,345 |
| V-1060 - 100MHz, Dual Trace | $1,425 |
| V-1065 - 100MHz, DT, w/cursor | $105/mo* |
| V-1085 - 100MHz, QT, w/cursor | $125/mo* |
| V-1100A - 100MHz, Quad Trace | $125/mo* |
| V-1150 - 150MHz, Quad Trace | $115/mo* |

## 20MHz Elenco Oscilloscope



**$375**

**MO-1251**

- Dual Trace Component Tester
- 6" CRT
- X-Y Operation
- TV Sync
- 2 P-1 Probes

**FREE DMM with purchase of ANY SCOPE**

**SCOPE PROBES**

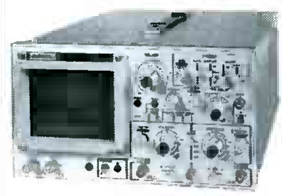
**P-1 65MHz, 1x, 10x $19.95**

**P-2 100MHz, 1x, 10x $26.95**

## Elenco 35MHz Dual Trace

Good to 50MHz **$495**

**MO-1252**



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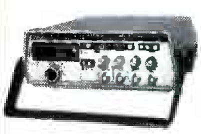

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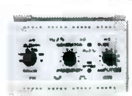

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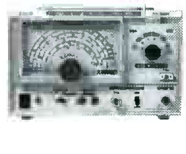

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*Our solid-state Tesla coil can produce sparks as long as 8 inches with a peak output of about 100,000 volts.*

# SOLID STATE TESLA COIL

DUANE A BYLUND

Tesla coils have been around for almost 100 years and, with the exception of vacuum-tube driven coils, not much has changed from the way Nikola Tesla invented them. This article describes a new type of Tesla coil; a true solid-state Tesla coil. One thing that makes our Tesla coil unusual is that the coupling to the secondary coil is by a direct electrical connection rather than by magnetic fields. Direct coupling is not new to Tesla coils but it is seldom seen.

The solid-state Tesla coil is by no means as spectacular as capacitive-discharge Tesla coils but it gives just as good, or better, performance as a vacuum-tube Tesla coil. Sparks as long as 8 inches are possible with a power-line consumption of 2 amps at 120 volts (see Fig. 1), and the output reaches a peak of about 100,000 volts. Although the average power input to the device is around 250 to 300 watts, the peak input power to the Tesla secondary coil is about 800 watts. The Tesla coil is an excellent teaching tool, as many interesting things may be learned with the aid of this device.

**Circuit description**

The schematic for the solid-state Tesla coil is shown in Fig. 2. The secondary of the Tesla coil, when directly driven by a solid-state driver, appears like a series RLC circuit. That's due to the self-capacitance of the coil with respect to ground. The capacitance is normally very small with the inductance being fairly large. At the resonant frequency, the inductive reactance cancels the capacitive reactance. The effective impedance is limited by such losses as the DC resistance of the coil, AC skin effect of the wire, eddy currents induced in nearby objects by the field of the coil, and so on.

Series RLC circuits have relatively low impedances when operated at the resonant frequency. The coil used in this project, when operated at its resonant frequency, looks like a 450-ohm resistive load to the solid-state driver. Series RLC circuits produce high voltages on the inductor and capacitor at the resonant frequency. The high voltage is due to a high current flowing through a high reactance (remember that the inductance is large and the capacitance is small, creating large reactances in each component at a given frequency). That is what produces the corona discharge at the end of the secondary coil.

The heart of the driver is IC1, the SG3524 pulse-width modulator. The duty cycle is fixed at about 45% for best efficiency. The frequency is controlled by the resistance on pin 6 and the capacitance on pin 7. With the values shown, the frequency has a range from 200 to 240 kHz. A flip-flop inside the chip divides that by 2 so that the effective output of the driver has a range from 100 to 120 kHz.

The outputs on pins 12 and 13 are 180 degrees out of phase with each other, and drive the gates of MOSFET's Q1 and Q2, which, in turn, drive the primary of transformer T1. Transformer T1 drives the bases of switching-transistors Q3 and Q4. The components in the base circuitry are used to increase the switching speed of the transistors. Transistors Q3 and Q4 switch the line voltage across the primary of T2, which increases the voltage and drives the end of the secondary coil directly. Note that the line voltage delivered to T2 is half-wave rectified by D1. That is important to the operation of the Tesla coil because a pulsating voltage is needed to produce the best effects.

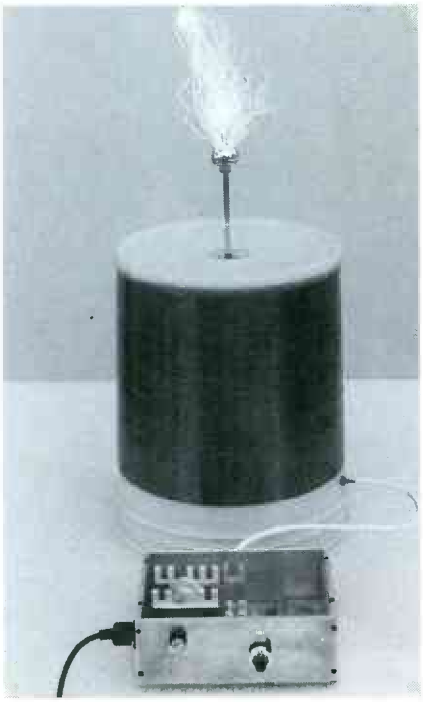
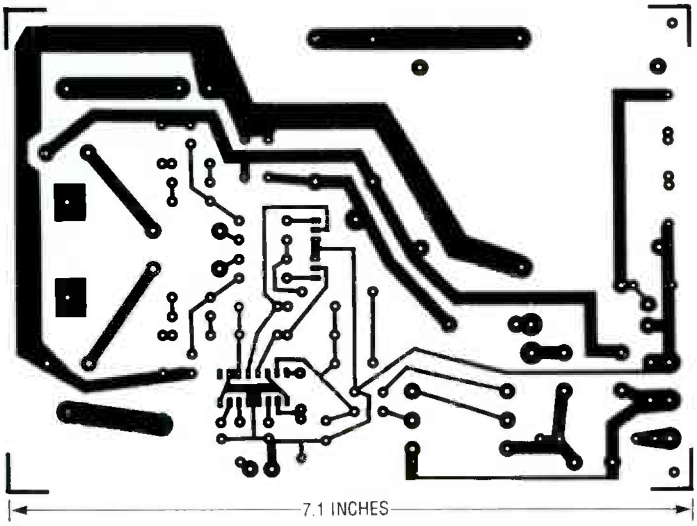


FIG. 1—THE SOLID-STATE TESLA COIL can produce sparks as long as 8 inches. The output reaches a peak of about 100,000 volts.

> Warning!! This article deals with and involves subject matter and the use of materials and substances that may be hazardous to health and life. Do not attempt to implement or use the information contained herein, unless you are experienced and skilled with respect to such subject matter, materials, and substances. Neither the publisher nor the author make any representation as for the completeness or accuracy of the information contained herein, and disclaim any liability for damages or injuries, whether caused by or arising from the lack of completeness, inaccuracies of the information, misrepresentations of the directions, misapplication of the information, or otherwise.

When the device is plugged into a wall receptacle it will be in its standby mode. That is, the 21-volt power supply will be operational and the FET's will be driving the primary of T1. The standby mode produces enough power to "tune" the driver to the coil's resonant frequency before full power is applied. (Remember that the resonant frequency can be affected by nearby objects.) The current supplied to the secondary coil is indicated by LED1. Tuning is accomplished by adjusting the frequency via R1 and observing LED1. When resonance is achieved, the secondary coil will have a low impedance which will produce maximum current, lighting the LED. Diodes D3–D6 limit the forward and reverse voltages on LED1 when in the high-power mode. (Note that you must use an LED that lights at 1.5 volts—some LED's, including most green ones, need 2.1 volts or higher.

When the device is switched into the operating mode (or the high-power mode), half-wave line-voltage pulses will be applied to the primary of T2. As the half-wave voltage increases, the current in the secondary coil increases and the energy stored in the inductance and capacitance of the secondary coil will increase. During this time there is no corona from the secondary coil (if the coil is constructed as shown in this article). Sometime before the half-wave line voltage reaches its peak, the corona will appear on the secondary coil, which will dissipate the stored energy very quickly. During the remainder of the half-wave line voltage, the coil will produce corona but the energy level will not be as great as the initial discharge. The coil will produce sixty individual corona discharges every second, although you'll see a continuous discharge.




USE THIS FOIL PATTERN, shown half-size, to etch your own PC board.

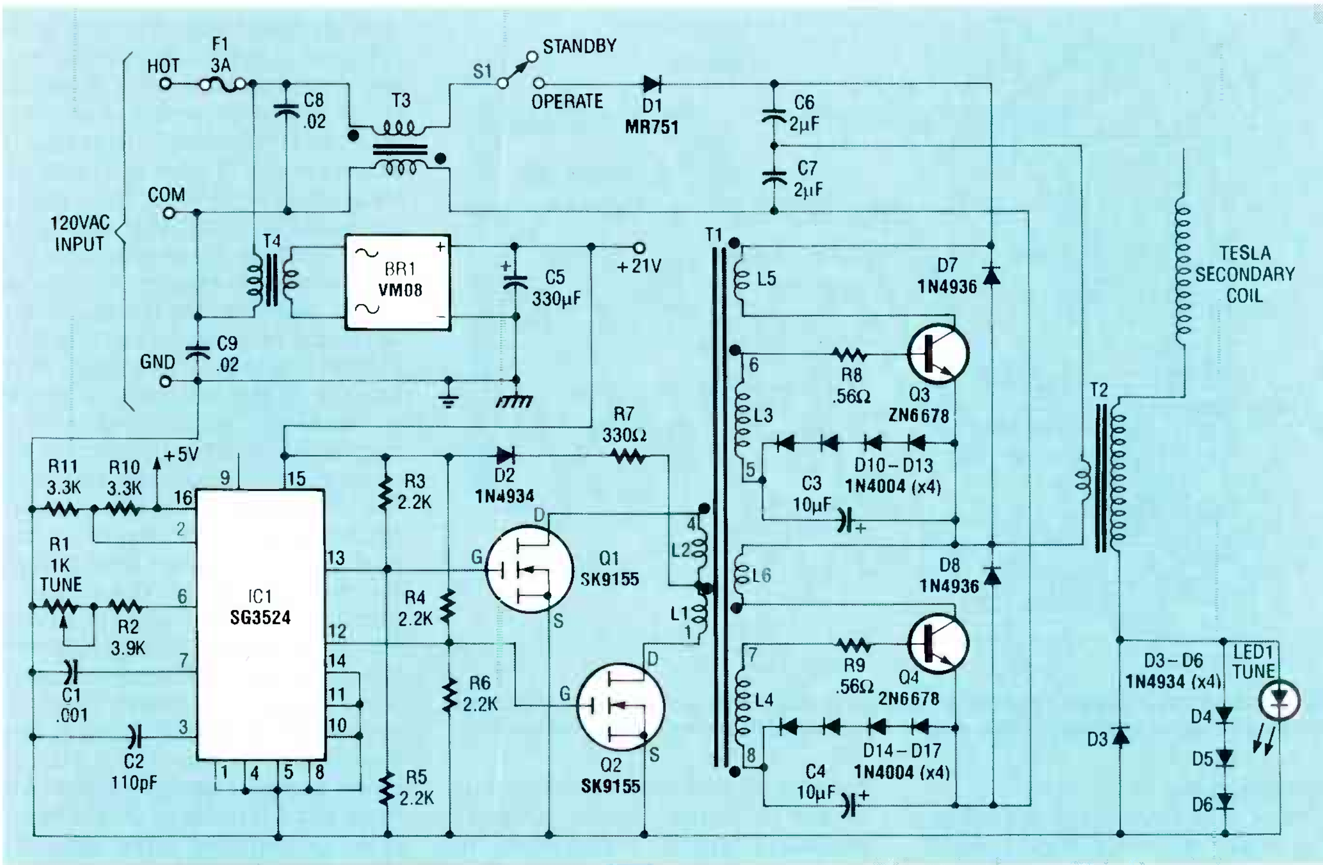



**FIG. 2—SCHEMATIC FOR THE SOLID-STATE TESLA COIL.** The secondary of the Tesla coil appears like a series RLC circuit due to the self-capacitance of the coil with respect to ground.

## PARTS LIST

**All resistors are ¼-watt, 5%, unless otherwise indicated.**
R1—1000 ohms, 10-turn potentiometer
R2—3900 ohms
R3, R4—2200 ohms, ½ watt
R5, R6—2200 ohms
R7—330 ohms, 1 watt
R8, R9—0.56 ohms, 2 watts, flameproof
R10, R11—3300 ohms

**Capacitors**
C1—0.001 µF, 50 volts, 5%, polyester
C2—110 pF, 50 volts, polyester
C3, C4—10 µF, 35 volts, tantalum
C5—330 µF, 35 volts, electrolytic
C6, C7—2 µF, 200 volts, nonpolar film-type
C8, C9—0.02 µF, 1000 volts, ceramic disc

**Semiconductors**
IC1—SG3524 pulse-width modulator
D1—MR751 diode
D2–D6—1N4934 diode
D7, D8—1N4936 diode
D9—not used
D10–D17—1N4004 diode
Q1, Q2—SK9155 power MOSFET
Q3, Q4—2N6678 or SK9140 NPN transistor
LED1—red LED. See text

**Other components**
F1—3-amp, 250-volt, fast-blow fuse
BR1—VM08 bridge rectifier, Varo
T1—hand-made transformer (the core is TDK # PC30EER25.5-Z and the bobbin is TDK # BEER-25.5-118CP)
T2—hand-made transformer (the core is TDK # PC30EC70-Z and the bobbin is TDK # BEC-70-5116)
T3—hand-made transformer (the core is TDK # PC30EER25.5-Z and the bobbin is TDK # BEER-25.5-118CP)
T4—115VAC/15VAC center-tapped transformer (Triad F-132P)
S1—SPST key switch

**Miscellaneous:** enclosure, aluminum angle bracket, high-voltage wire (to connect main unit to Tesla secondary), 30-gauge magnet wire for Tesla secondary and L1 and L2, 24-gauge magnet wire for L3 and L4, 18-gauge stranded hook-up wire for L5 and L6, 15-gauge magnet wire for T2 primary, 26-gauge hook-up wire for T2 secondary, 18-gauge magnet wire for both windings of T3, brass rod, discharge ball, hardware, AC linecord, etc.

**Note: TDK ferrite cores and bobbins are available from MH&W International, 14 Leighton Place, Mahwah, NJ 07430, (201) 891-8800. The following items are available from Corona Coil, PO Box 474, Riverton, UT 84065:**
- **T1—$15.00**
- **T2—$38.00**
- **T3—$12.00**
- **T4—$14.00**
- **Tesla secondary coil—$50.00**
- **PC board—$15.00**
- **Aluminum angle bracket (heatsink and PC-board mount)—$5.00**

**A 124-page book by the author, *Modern Tesla Coil Theory,* is available for $16.**

**Please add $15 S&H for the Tesla secondary, and 10% S&H for all other items.**

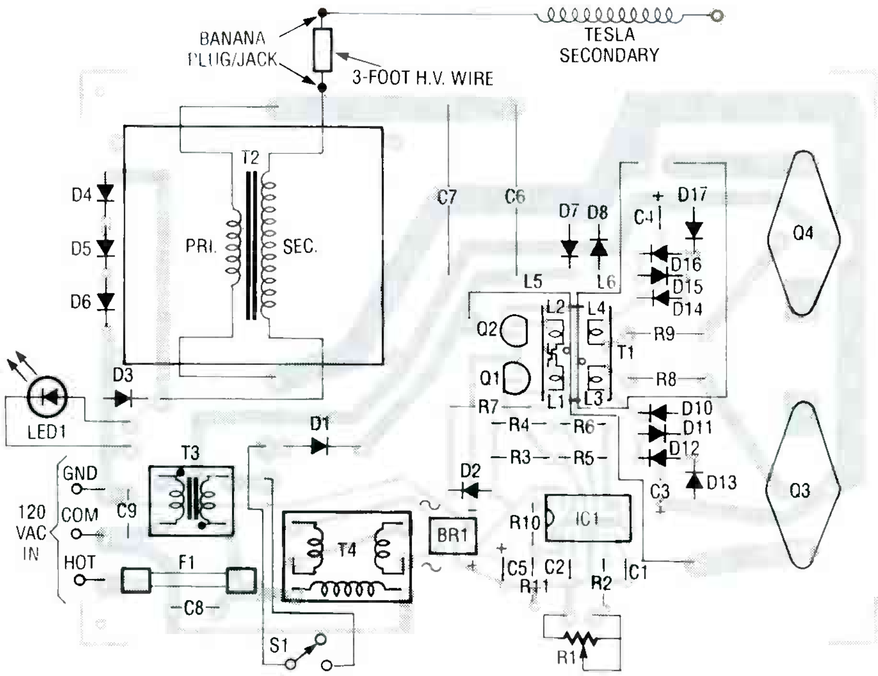



FIG. 3—PARTS-PLACEMENT DIAGRAM. It's best to play it safe and use the PC board for this project; we've provided the foil pattern if you would like to etch your own board.

## Construction

Most of the construction is fairly simple if the printed circuit board is used. A parts-placement diagram is shown in Fig. 3. and we've provided the foil pattern if you would like to etch your own board. Figure 4 shows the completed prototype board housed in its aluminum enclosure.

The most difficult item to construct will be the Tesla secondary coil, followed by T1 and T2. The secondary coil may take an hour or so to make if you prepare ahead of time. Preparation includes making some device that will easily rotate the coil form while winding the wire. The author used a small lathe and it took about 15 minutes of actual winding time and 30 minutes to get set up.

Do not deviate at all from the following parameters of the secondary coil! Any deviation will change the characteristics of the coil and it may not operate with the driver unless modifications in the driver are made. Any change in physical dimensions or wire size will alter the resonant frequency and effective impedance of the coil. Any change to the discharge electrode will effect the maximum energy obtainable.

The coil form for the secondary winding is a standard 5-gallon plastic container 10 inches in diameter at the bottom, 12 inches in diameter at the top, and 14 inches long. The bottom of the container becomes the top of the coil. To make winding easier you should drill a hole about an inch in diameter through the center of the bottom of the container. A similar hole should be drilled through a removable lid and then the complete coil form can be rotated easily on a dowel. Start the secondary winding 1 inch from the small-diameter end and close-wind 30-gauge magnet wire for a total length of 10 inches. It does not matter what direction the wire is wound in.

When winding the original coil for this article, shellac was used to lubricate the wire as it was wound and also to act as a sealant afterwards. It was difficult to wind the coil because the coil form was very slick and had a slight taper to it and, as a result, the wire kept slipping. It may be easier to spray the container with adhesive before winding the wire to make it stay in place. A couple of coats of shellac should be applied to the finished winding. You also must put 3 or 4 beads of silicone sealant around the end of the winding at the top of the coil to keep corona discharges away from the area. If corona discharges appear along the coil at the top it will limit the maximum energy and destroy the coil form.

The discharge ball, or electrode, is a brass-plated metal doorknob, 1-inch in diameter, that can be found in hardware stores (see Fig. 5). The ball is mounted on a 4-inch brass rod; you can drill and tap the ends of the brass rod with a 6-32 tap (or whatever matches the threading on the doorknob) to make mounting easier. The brass rod is connected to the coil form by two pieces of plastic, one on each side of the coil form, over the ½-inch

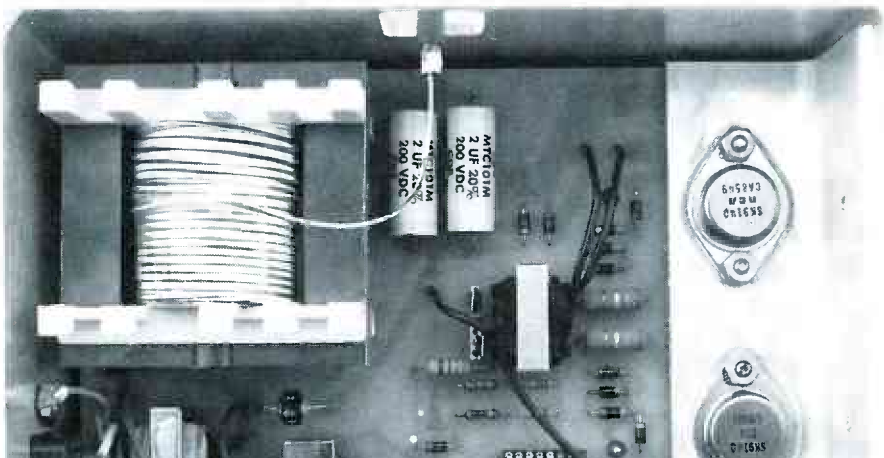



FIG. 4—HERE'S THE AUTHOR'S COMPLETED PROTOTYPE housed in its aluminum enclosure. It's important that the case be properly grounded.

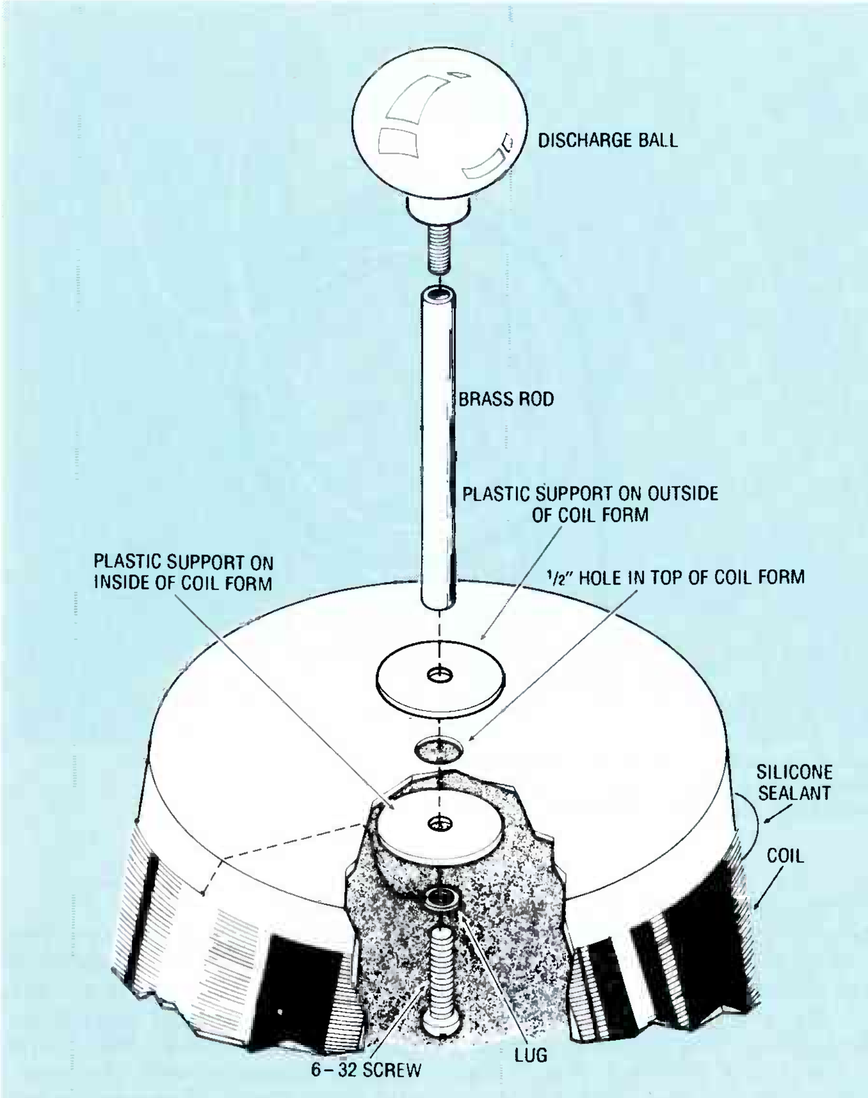



**FIG. 5—THE DISCHARGE BALL is a brass-plated metal doorknob, 1-inch in diameter. The ball is mounted on a 4-inch brass rod that's been tapped to make mounting the ball easier.**

hole. A 6-32 screw passes through the pieces of plastic and into the brass rod to hold the assembly together. The wire is soldered to a lug held in place by the 6-32 screw.

A banana jack is used to make connections at the bottom of the coil. Locate the jack about ¾-inch from the edge of the wire on the coil. Silicone should be used to insulate the connections between the magnet wire and the brass rod and banana jack. The finished coil, when built exactly as we've shown, will have a resonant frequency of about 110 kHz.

Transformer T1 is made with a ferrite core and bobbin from TDK (see the parts list). Coils L1 and L2 are wound first with 30-gauge magnet wire, 16 turns each, making one layer on the bobbin. The two windings are bifilar wound, as shown in Fig. 6-*a*: L1 starts on pin 3 and L2 starts on pin 4. Wind both in a counterclockwise direction while looking at the top of the bobbin. Terminate L1 on pin 1 and terminate L2 on pin 2. Put a layer of cellophane tape on top of the winding to insulate it from L3 and L4.

Coils L3 and L4 are made with 5 turns each of 24-gauge magnet wire and are also bifilar wound, on top of L1 and L2, and in the same direction. Coil L3 starts on pin 6 and L4 starts on pin 8. Terminate L3 on pin 5 and terminate L4 on pin 7. This completes the transformer until it is mounted on the PC board.

Put the two core halves through the bobbin and put tape around them to hold them in place. As shown in Fig. 6, L5 and L6 are wound after the transformer is mounted on the board; L5 and L6 are wound with 18-gauge stranded hook-up wire with one turn each. Solder the collector (Q4) end of L6 to the PC board. Go one turn in a counterclockwise direction around the core of T1 and then terminate the other end of L6 at the primary of T2. Solder the collector (Q3) end of L5 to the PC board and go in a clockwise direction around the core of T1 for one turn, terminating the winding at the cathode of D1.

Transformer T2 is also made from a ferrite core and bobbin from TDK (again, see the parts list). The primary is 10 turns of 15-gauge magnet wire, although a smaller gauge, say 18, can probably be used. It does not matter what direction the wire is wound in but the turns should be equally spaced across one layer of the bobbin. Put several layers of cellophane tape on top of the primary to insulate it from the secondary and to provide a smooth surface on which to wind the secondary. The secondary is made with 280 turns (the exact number is not critical) of 26-gauge hook-up wire. The direction is unimportant. You can use magnet wire if you desire but you should put cellophane tape between each layer. The low-voltage end of the secondary is the one that is the closest to the primary winding. When the windings are complete, put the core halves through the bobbin and hold them in place with tape wrapped around them.

Transformer T3 is made with the same core and bobbin as T1. Both windings are bifilar with 18-gauge magnet wire for as many turns as possible. The start of both windings are polarized as indicated by a dot in the schematic diagram (Fig. 2). The pins on the bobbin are not used and should therefore be cut off, and the 18-gauge wires are then soldered directly to the PC board as indicated.

An aluminum angle bracket is used when mounting switching-transistors Q3 and Q4. The bracket provides the physical support between the PC board and enclosure and also provides good heat sinking for the transistors. The transistors should

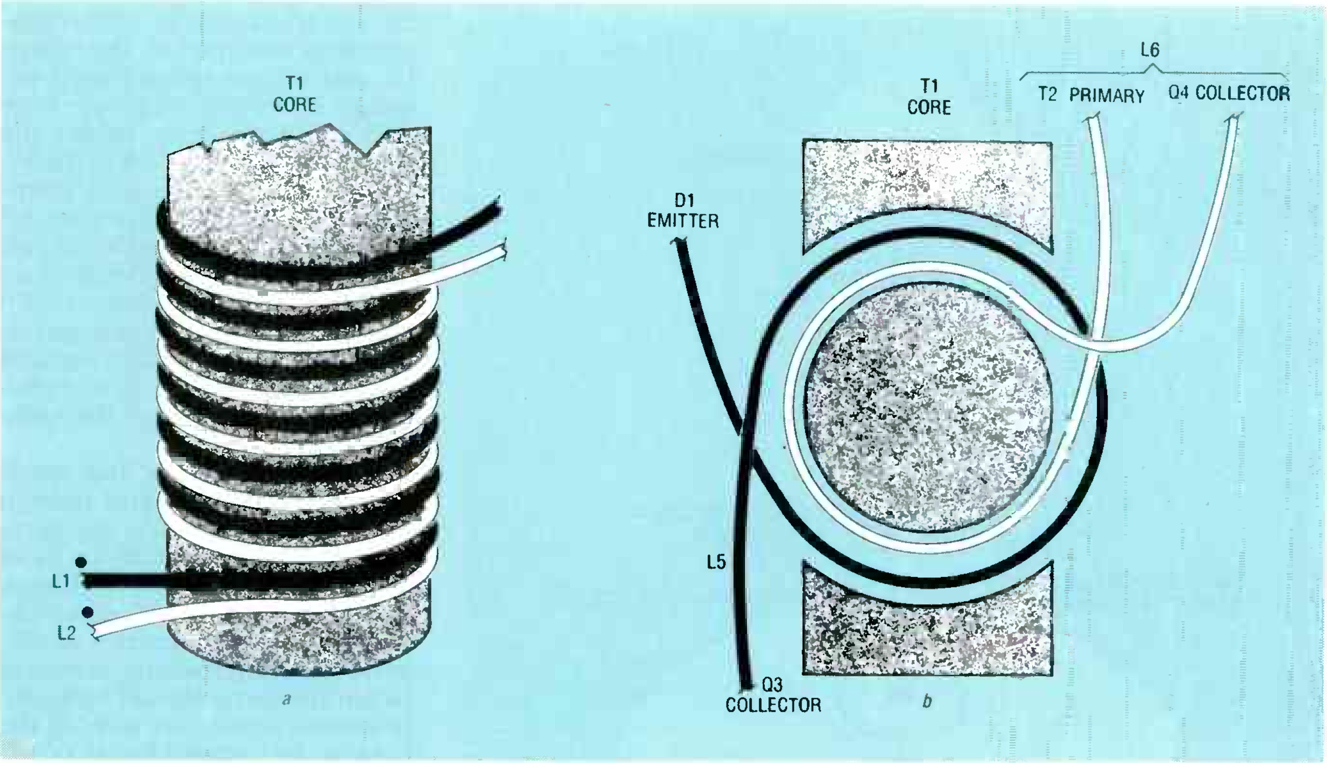



**FIG. 6—TRANSFORMER T1 IS MADE by winding coils L1 and L2 first (*a*). After putting a layer of cellophane tape on top of the first windings, coils L3 and L4 are wound on top of L1 and L2. Coils L5 and L6 are wound after the transformer is mounted on the board (*b*). See text for detailed instructions.**

be insulated from the aluminum; insulating hardware is normally included when you purchase the transistors. Use the PC board as a template for drilling holes for the transistors in the aluminum bracket. The angle bracket is mounted to the enclosure by drilling holes and taping them with a 6-32 tap. Thermal conductive compound is used between the transistors and angle bracket and between the angle bracket and the enclosure.

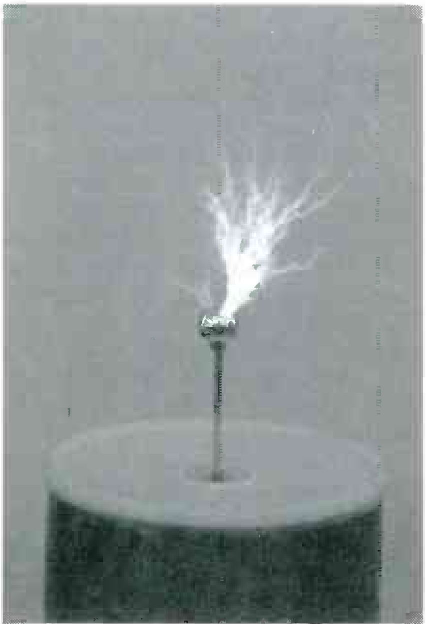


**FIG. 7—SEEN HERE IS THE DISCHARGE from the ball electrode into the air.**

A banana jack is mounted in the back of the enclosure to make connections between the Tesla secondary coil and the high-voltage ferrite transformer. The output voltage from the ferrite transformer may reach 5000 volts peak with no load so it is wise to use extra insulation for the banana jack. Mount a piece of plastic, 1½-inch square, to the back of the enclosure over a 1-inch square hole, and mount the banana jack in the center of the plastic. That will space the banana jack at least ½-inch from the metal enclosure.

The prototype used a 10-turn potentiometer for R1 to make frequency adjustments easier and this allowed the use of a 10-turn dial to mark the frequency settings for different purposes. You can use a regular potentiometer but the 10-turn unit is superior.

An enclosure was fabricated out of ⅛-inch aluminum with a plexiglass top, but any metal enclosure would be suitable. Just be absolutely sure that you ground the metal enclosure.

## Operation

**Warning:** The power output from the Tesla coil is dangerous! Make sure no one comes in contact with the output voltage directly from the driver. Make sure nobody tampers with the unit, and keep it out of reach of children. Make sure you use a key

**FIG. 8—THE SPARKS WILL JUMP even farther if a grounded electrode is placed near the discharge ball.**

switch to turn power on and off to prevent someone from getting injured, and keep the key in a safe place.

**Caution:** All components on the secondary of T1 are not isolated from the power line. Use caution when measuring values in this area. You must isolate an oscilloscope from ground if measuring in this area. Make sure you use a three-prong power cord and that the case of the driver is well grounded. Also, make sure you plug the unit into a well-grounded electrical outlet.

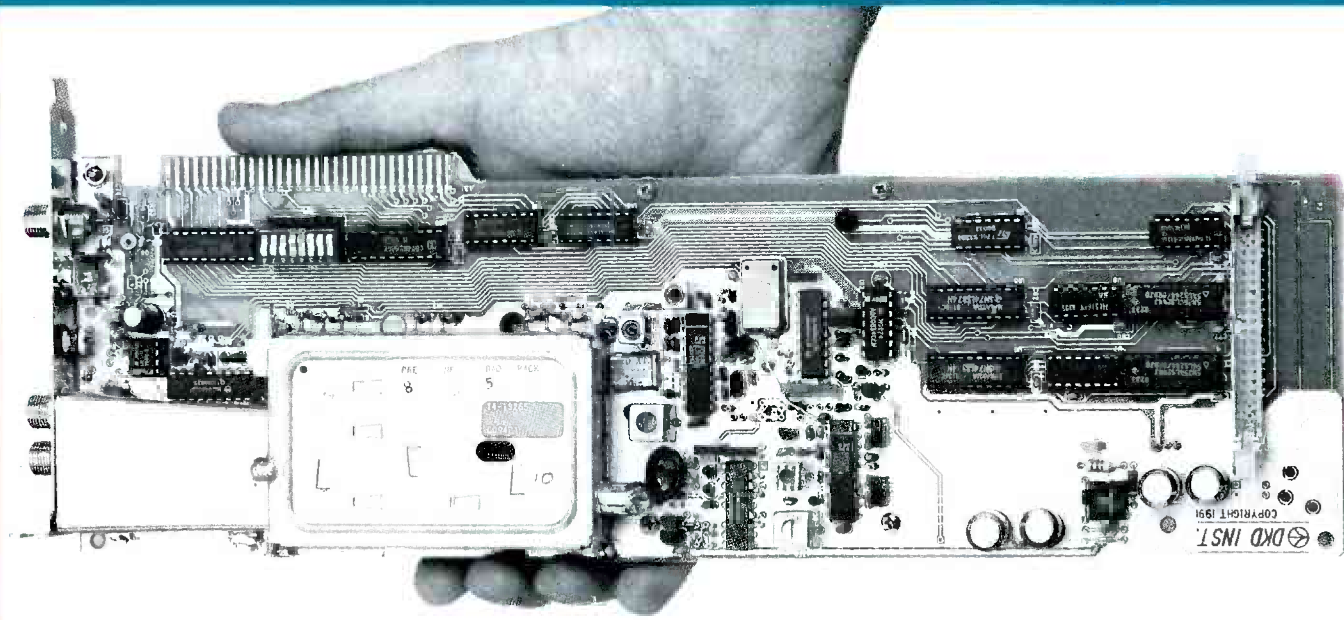
Double check all wiring to make sure it is correct. Make sure the operate switch is in the standby position (line voltage disconnected from D1). Using a digital voltmeter isolated from ground, measure the voltage across C3 and C4. If everything is working correctly in the low-voltage circuitry, there should be about 2.5 volts across those capacitors. If that voltage is not present you should check the 21-volt power supply. Make sure that 5 volts is on pin 16 of IC1. If the oscillator is working correctly you should have about 3.6 volts on pin 6 of IC1.

Connect the Tesla secondary coil to the driver with a 3-foot insulated wire (it is a good idea to keep at least 3 feet from the secondary coil). You should always unplug the driver when you are making connections between the driver and secondary coil to be absolutely safe. The wire connecting the coil and driver carries a dangerous amount of power so be certain the wire is well insulated. In a dimly lit room you should be able to adjust the tune control to set the driver at the coil's resonant frequency. Observe the LED and watch for one place in the tuning control's adjustment where the LED glows brighter than anywhere else. Never apply full power to the driver unless you can obtain resonance first. Damage to the driver will most likely occur if resonance is not maintained.

Once you obtain resonance you can switch to the full-power mode; the LED will glow very brightly. With no objects around the coil you should observe a snappy brush discharge 5 to 6 inches in length emanating from the discharge electrode (see Fig. 7). It might be somewhat louder than you would expect. Very slight adjustments in the tune control may improve the discharge. You should be able to get 7-inch streamers with a grounded electrode above the coil (see Fig. 8). Be aware that any change of the physical surroundings around the coil will change its resonant frequency and the tune control will need to be adjusted to maintain resonance. When operating the Tesla coil, be aware of the temperature of the enclosure where the aluminum angle bracket is mounted. Shut off the power if the area gets too warm. The prototype was operated for 2 full minutes, and you could just start to feel some warmth on the enclosure. However, you should operate the Tesla coil only for short periods of time.

Once you have a working unit you can start to experiment with different things. Try removing the discharge ball and use a point instead. Try changing the distance of the ball electrode from the coil. Try holding an incandescent lamp a short distance from the coil—but be very careful. Different lamps will produce different discharges. **R-E**






# Spectrum Analyzer

DAN DOBERSTEIN AND JOHN CARDONE

LAST MONTH WE DISCUSSED THE theory behind our PC-based 810-MHz spectrum analyzer. This month, we'll show you how to build it and discuss the software used to operate the instrument. Before we get into the construction, let's start off with a description of the setup and operating software. All executable files we mention here can be downloaded from the **Radio-Electronics** BBS (516-293-2283, 1200/2400, 8N1, file SPEC-AN.ZIP). Even before you build the analyzer, we would recommend that you download and run the software. (It will run even without the board installed.) Even though you won't get any meaningful data, it will help you to understand exactly how the software operates.

## Software and operation

Before you can use the spectrum analyzer, some software settings must be initialized so that the host computer will know at what address the analyzer resides, which printer port will be used, and the type of printer that will be used. The initialization is performed with SETUP.EXE, which is a stand alone program that must be executed outside of the main program menu. The details of using SETUP are covered in the README.DOC file. SETUP stores your system configuration and needs to be re-executed only if something changes.

The two main programs are 810EGA.EXE and 810CGA.EXE. One is used for EGA systems, the other for CGA. Both programs operate the same way. The EGA version supports VGA/EGA monitors and has color capabilities if your monitor supports color. The CGA version has reduced graphics resolution and the sweep display will be monochrome. All the photos presented here are from the EGA version. The CGA version was included primarily to support low-end laptop computers using the parallel-printer interface.

When the software is executed, a copyright message will be displayed while it is loading the calibration files. After a few moments the sweep display will come up. Figure 11 shows a typical sweep display. The display is continually updated as the local oscillators's (LO's) are swept and new data is gathered. The box on the left side of the screen contains the list of function keys that are currently active. All user interactions from the sweep display are initiated by function keys, arrow keys, or the ESC key. Function key F1 is always used to bring up the Instrument Setup menu. The user can change all the settings of the spectrum analyzer from the menu. That will be covered in more detail later.

Function key F10 activates the marker function. When the marker is on, the sweep is interrupted until a return to sweep mode is commanded (ESC key). Once the Marker is up, the user can do a peak search, or by using function key F7 toggle the delta marker on and off. The marker is moved using the arrow keys with the power and frequency (or delta power and delta frequency) displayed in the lower left corner of the screen. Another feature of the marker is to tune the spectrum analyzer as you move it, enabling the marker to act as a station indicator for the FM demodulator.

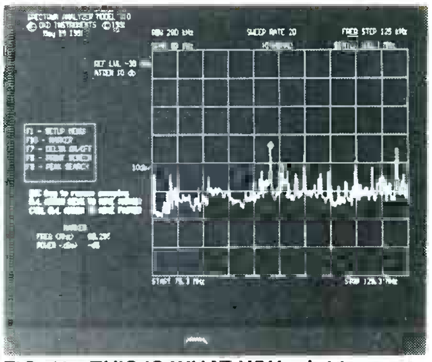


FIG. 11—THIS IS WHAT YOU might see on a typical sweep display.

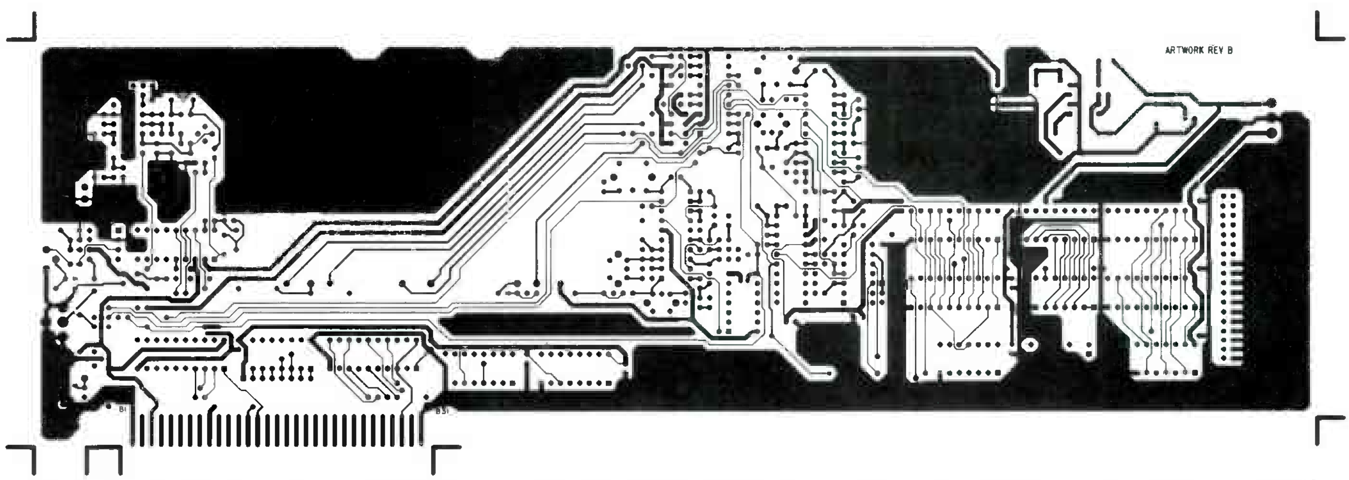
Using an external speaker and an antenna on the input you can "scan" the bandwidth of the analyzer, listening for different FM broadcasts.

Function key F8 activates a screen dump. Your printer must be selected using SETUP for this to work. A large number of printers are supported, ranging from Laserjets to low-end dot matrix types. When you return to active sweeping the marker turns off and the functions associated with it (FM tuning, screen dump, and so on) are not accessible to you.

When you're in the sweep mode, you can save and recall all the settings of the analyzer using the function keys preceded by the ALT key for saving states, and the CNTRL key for recalling states. Ten states are available: one for each ALT/CNTRL function key pair. The states are numbered 0 through 9 and are stored on the disk as STATEx.DAT. STATE0 is special because it is used as the wake up state of the machine. You can modify the wake up state of the analyzer by just saving a new STATE0 using the ALT F1 keys.

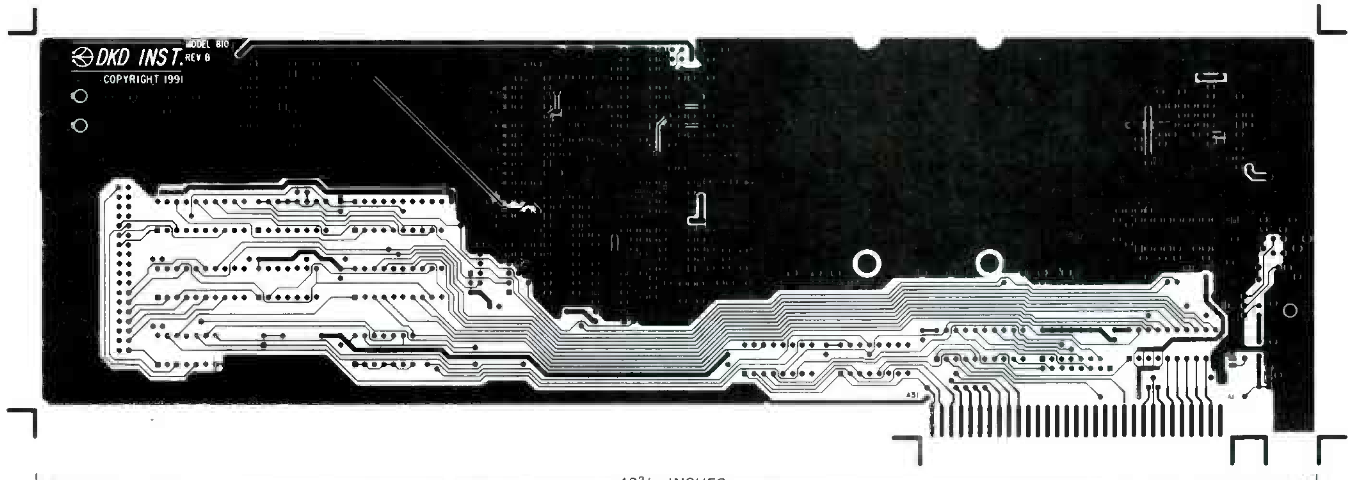
**Instrument setup menu**

By using the up/down arrow keys of the setup menu you can move to the item you wish to change or execute by hitting return. Start frequency, center frequency, and span determine the portion of the spectrum analyzer's bandwidth you wish to examine. Center and start frequencies cannot be independently chosen. In other words, you can only specify start and span or center and span frequencies. That's due to the fixed-span table approach used in the analyzer. The fixed spans are: 800, 600, 500, 400, 300, 200, 100, 50, 25, 12.5, 10.5, 2.5, 1.25, and 0.625 MHz. When the span is less than 12.5 MHz, the resolution bandwidth (RBW) is automatically switched from 280 kHz to 10 kHz. No direct user control is provided for the RBW setting.




13 3/16 INCHES

THE SOLDER SIDE of the foil pattern is shown here.




13 3/16 INCHES

THIS IS THE COMPONENT side of the foil pattern.

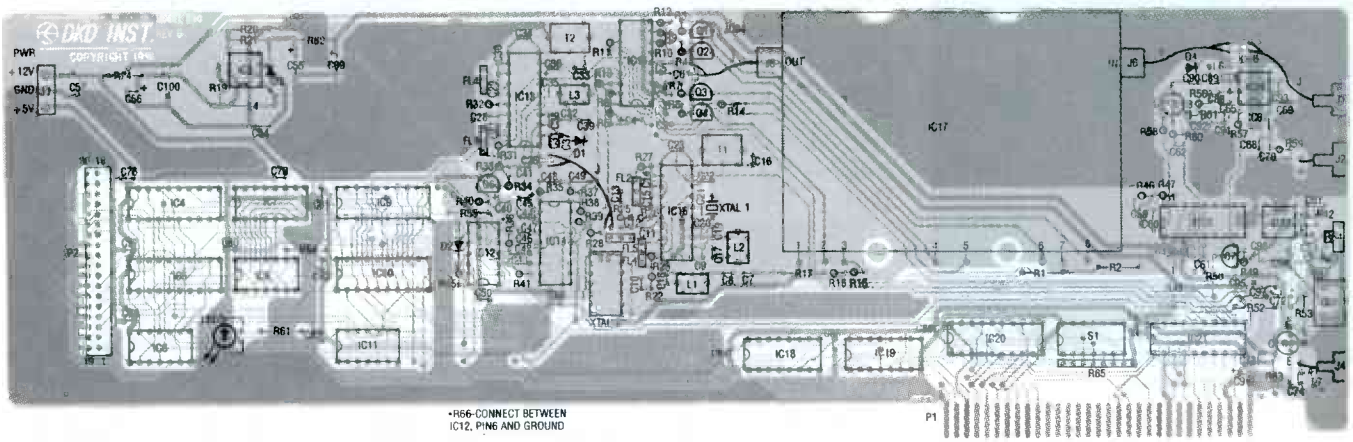


FIG. 12—PARTS PLACEMENT DIAGRAM. Note the location of the four coax runs. Make sure you install all chip capacitors first because of their small size.

## PARTS LIST

**All resistors are ⅛-watt, 5%, unless otherwise noted.**
R1, R33—3300 ohms
R2, R31, R32, R43—5600 ohms
R3–R12, R37, R38, R46, R47, R49, R50, R66—22,000 ohms
R13, R22, R23, R27, R39, R40, R48, R53, R54, R57, R61—470 ohms
R14, R56, R60—1000 ohms
R15, R28–R30—not used
R16, R17, R24—18 ohms
R18, R45, R59, R62—68 ohms
R19—180 ohms, ¼-watt
R20, R52—1800 ohms
R21—47,000 ohms
R25—240 ohms
R26—180 ohms
R34, R35, R51, R55, R58—56,000 ohms
R36, R41, R42—100,000 ohms
R44, R64—10,000 ohms
R63—390,000 ohms
R65—10,000 ohms × 7 SIP resistor

**Capacitors**
C1, C2, C22, C36, C40, C44, C45, C53, C56, C63, C64, C91—1 µF, 50 volts, tantalum
C3, C48, C60—0.1 µF polyester
C4, C42, C49, C59—47,000 pF, polyester
C5, C6, C9–C18, C32, C46, C47, C61, C88–C90—0.001 µF, ceramic disc
C7, C62—330 pF, ceramic disc
C8, C68, C69—100 pF, ceramic disc
C19, C38, C66—22pF, ceramic disc
C20, C26, C34, C37, C41—10 pF, ceramic disc
C21, C35, C67, C73—1000 pF, chip
C23, C71, C74—2.7 pF, ceramic disc
C24, C25, C97—not used
C27–C31, C33, C50, C70, C72, C75–C87, C92–C95—0.01 µF, ceramic disc
C39—200 pF, ceramic disc
C43, C51—0.01 µF, polyester
C52, C54—1000 pF, polyester
C55, C57, C99, C100—220 µF, 35 volts, electrolytic
C58—220 µF, 16 volts, electrolytic
C65—5 pF, ceramic disc
C96—10 µF, 16 volts, tantalum
C98—10 µF, 16 volts, tantalum

**Semiconductors**
IC1, IC2—Not used
IC3—MC34063, step-up voltage regulator, Motorola
IC4, IC5—74LS244, three-state octal driver
IC6—74LS04, hex inverter
IC7–AD558, 8-bit A/D converter, Analog Devices
IC8—74LS164, 8-bit par out shift register
IC9, IC10—74LS374, three-state octal driver
IC11—74LS32, quad OR gate
IC12—ADC0834, A/D converter, National Semiconductor
IC13, IC16—NE615, receiver, Signetics
IC14, IC15, IC23—MC44802, PLL, Motorola
IC17—OE-175-14, tuner, Zenith
IC18, IC19—74LS138, decoder
IC20—74LS688, address decoder
IC21—74LS245, bus transfer
IC22—LM386, audio amp, National Semiconductor
IC24—NE602, oscillator/mixer, Signetics
Q1–Q4, Q7—2N3906, PNP transistor
Q5, Q8—MRF901, double emitter NPN transistor, Motorola
Q6—2N3904, NPN transistor
D1, D4—MV209 or MV2105, varactor diode, Motorola
D2—IN5229B, 4.3 volts, Zener
D3—1N4003, diode
LED1—Any red light emitting diode

**Other components**
L1—T10307, 0.15 mH, 7-mm can type, Toko
L2—T10407, 1.0 mH, 7-mm can type Toko
L3—421F224, 5.8 to 3.7 mH, 7-mm can type, Mouser
L4—220 mH coil, Mouser
L5—3 turns of #30 AWG wire on #23 drill, LS = 0.138″
L6—5 turns of #30 AWG wire on #42 drill, LS = 0.2″
L7—3 turns of #30 AWG wire on #42 drill, LS = 0.138″
T1—421F128, 10-mm can type, Mouser
T2—421F102, 10-mm can type, Mouser
FL1, FL2, FL5—SK M1, 10.7-MHz ceramic filter, Toko or Murata Erie
FL3, FL4—CFM2-455E, 455-kHz ceramic filter, Toko
XTAL1—34.3000-MHz standard crystal
XTAL2—XTAL107, 4.00-MHZ TTL oscillator
S1—7-position DIP switch

**Connectors**
J1, J2, J4—Female F-type bulkhead connector
J3—RCA audio jack, PC board mounted (90°)
J5, J6—F-type connectors are part of tuning assemble (IC17)
J7—3-pin type, Molex, 0.156″ O.C. power connector
P2—36-pin DIP header
Two RCA male connectors for coax to tuner connection

**Miscellaneous**
- Bottom shield—3-7/8″ × 3-7/8″ single-sided PC board with glass epoxy, copper side facing away from board. Four ½-long screws, four 4-40 nuts and bolts, four lock washers and insulating washers.
- Lowband shield—2-1/4″ × 2-1/2″ sheet metal.
- Rear panel with mounting screws.
- 3 inches of 0.047 miniture coax.
- 16 inches of RG174 coax.

**Note: The following items are available from DKD Instruments, 1406 Parkhurst, Simi Valley, CA 93065; (805) 581-5771: A complete kit including executable and data files on a 5-1/4 inch disk with manual, $255.00; Centronics interface cable, $13.00; power cable, $4.00; an assembled, tested, and calibrated unit, $500.00. Send check or US postal money order. Allow 3 to 5 weeks for delivery. California residents add 6% sales tax.**

The reference level and attenuation settings determine the power level of the top line of the sweep grid. That is a user-entered number that can take on any floating-point value. The user has a choice of three settings for internal attenuation: 0, 10, and 20 dB. The attenuation is implemented by reducing the gain, not by the use of attenuation pads. That's a subtle yet significant difference from high-end analyzers that use switched attenuators for gain reduction. User attenuation is located in the input path, which is convenient for automatically calculating in the effects of inline attenuations. Since that's a floating point entry, negative attenuations (or gains) can also be entered in the signal path. There are three choices for the vertical power scale units using the dB/div entry: 2, 5, and 10 dB. Reference level, attenuation, and dB/div affect the placement of the power data on the sweep grid. It's best to experiment with different settings to get a feel for how they interact.

**Sweep rate**

The sweep rate determines how fast the display is updated and how long it takes to go through one sweep. It is directly affected by the CPU clock speed. For a given sweep rate, a faster PC will finish the sweep in less time than a slower PC. Sweep speed increases with higher values of sweep rate. The sweep rate and power accuracy are interrelated; longer sweep times usually result in more accurate power measurements. That has to do with the video bandwidth and PLL settling time. A fixed number of sweep rates are provided in the analyzer: 1, 3, 5, 10, 15, 20, and 30. A more complete discussion of the sweep rate and power accuracy relationship is given in the README.DOC file.

**Band select**

The band select menu item allows the user to select which input is going to be used: highband or lowband. The user must select the band of operation and connect to the appropriate input because autoswitching is not provided. The highband input should not be terminated when using the lowband input. That

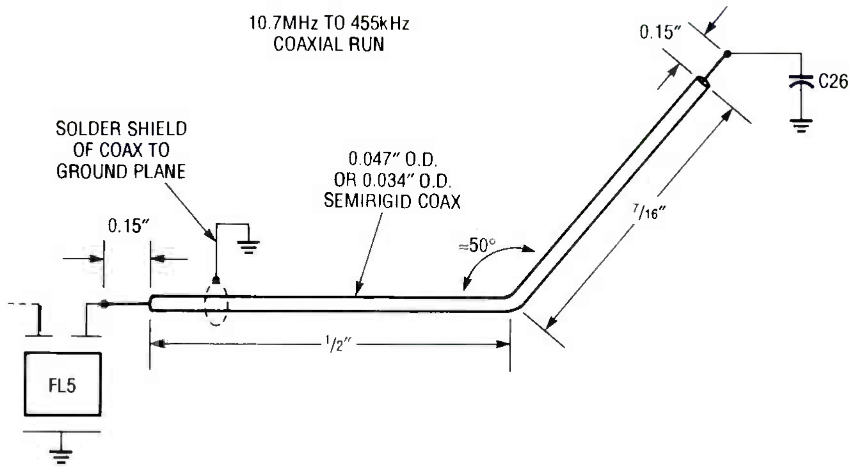



**FIG. 13—THE 10.7 MHz TO 455 kHz COAXIAL RUN reduces spurious pickup from the 455-kHz IF.**

would result in erroneous power measurements.

The exit to sweep menu item returns the user to the sweep display. Hitting the ESC key while on the menu bar does the same thing. Exit to Dos returns control of PC to DOS.

**Calibration**

Three power related calibration files are used by the spectrum analyzer: one for the automatic gain control (AGC), one for the received-signal strength indicator (RSSI), and a user-generated error table. The AGC calibration tables correct any variations in gain using the DAC input to the AGC pin of the tuner. Most of the variations are in the tuner. One table for each value of internal attenuation is provided.

A set of six data files are also used for the lowband and highband modes; namely the AGC*.DAT files. The RSSICAL*.DAT calibration files are used to "linearize" and map the RSSI voltages to an absolute power level. Two RSSI files are used; one for each RBW. Two user-generated files, POWERRH.DAT and POWERRL.DAT, can be used by kit builders to improve the accuracy of their power readings if they can get their hands on the equipment needed. The details of using the program USERCAL.EXE are covered in README.DOC. That error table is optional, and for factory calibrated units it is zeroed out.

If you build a kit, you'll have to live with the generic calibration files which, as mentioned above, result in degraded power accuracy. Most of the power errors come from variations in the gain of individual tuner modules, which are approximately ± 2 to 3 dB over the entire bandwidth. The RSSI data tends to change very little. Because of that, the largest errors will be at the band-switching points. The averaged generic calibration files are provided with the kit, and are posted on the **Radio-Electronics** bulletin board.

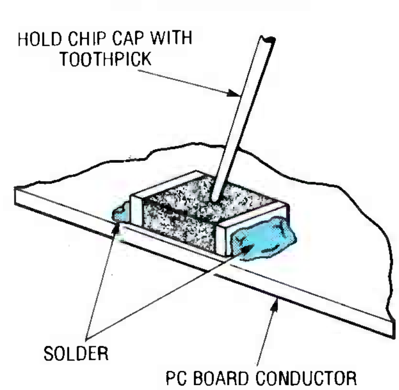



**FIG. 14—USE THIS DIAGRAM as a guide to installing the chip capacitors.**

**Construction**

The entire circuit of the spectrum analyzer is mounted on one double-sided PC board. We have provided foil patterns of the component side and the solder side of the PC board if you wish to make it yourself. Before mounting any components, you should visually inspect the board for shorts and solder bridges, especially around the pads that are surrounded by the ground plane. That can be done by putting a bright light behind the board, which really

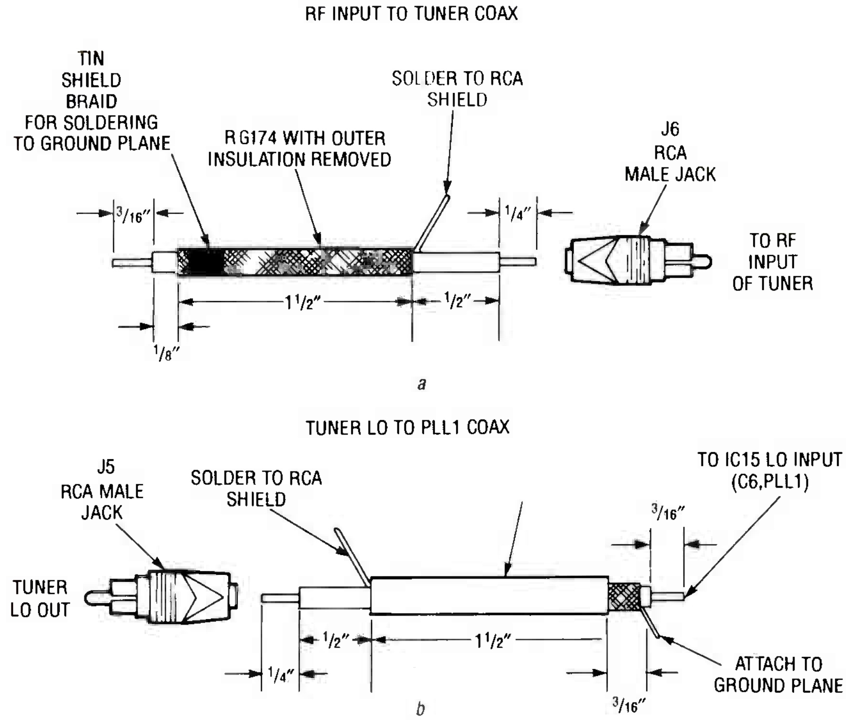



**FIG. 15—TWO RG-174 COAX RUNS ARE SHOWN for the RF input to tuner (*a*) and the tuner LO to the PLL1 (*b*).**

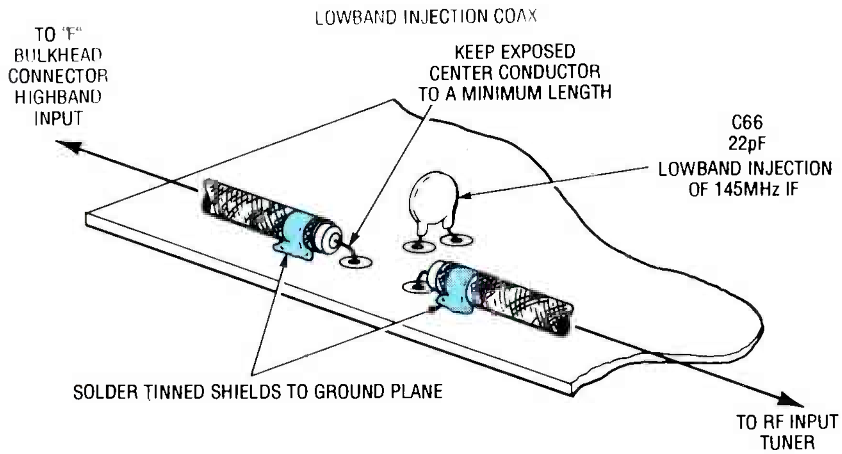



**FIG. 16—THE RF FEED FOR the lowband injection coax. Make sure your center conductor is as short as possible.**

makes the pads standout. After careful visual inspection, check the +5-, +12-, and +33.3-volt power buses for shorts to ground.

Figure 12 shows the component placement, as well as the locations for all coax runs. Before mounting any components, a short coax run must be installed on the top side of the board. A small piece of semirigid coax is used to connect the 10.7-MHz IF from FL5 to the input from the 455-kHz IF mixer (IC13, pin 1). The coax reduces the spurious pickup for the 455-kHz IF. Cut, strip, and bend the coax as shown in Fig. 13. Using an ohmmeter, check to make sure the inner conductor is not shorted to ground. RG174 type coax, with the external insulation removed, can be used but it's a tight fit.

You're now ready to start soldering in the components. Install chip capacitors C21, C35, C67, C72, and C73 first, using Fig. 14 as a guide. Because of their small size they can be very difficult to install with the board fully stuffed. Solder in all remaining capacitors. Check them off on the parts list as you install them, then recheck the power buses with an ohmmeter. You should read infinite resistance, as before. If you read a short or very low resistance, look for solder bridges.

Now solder in the resistors according to the component layout. Again, check the power buses for shorts using the ohmmeter. Install the inductors and coils next. If you buy a kit, L5, L6, and L7 are already made. Install all filters and crystals. Their leads can go in either direction. Lay XTAL1 down flat and solder its case to ground. The case of XTAL2 should also be tied to ground using a small piece of wire. Solder in the diodes, being careful to observe the correct polarity. Do the same for transistors Q1–Q8. Q5 and Q8 are surface-mount types from Motorola; "M" marked on the top indicates the collector. Using the ohmmeter again, check for shorts on the power buses.

When installing the IC's, use sockets for all the chips except the NE615's, MC44802's, and the NE602. Those chips need a close connection to the ground plane to ensure proper operation. Check for shorts again. After you install IC3 (the MC34063 step-up voltage regulator), make sure you have 33.3 volts DC between R62 and ground. That is where the 33.3-volt power line comes from. If you really want to be thorough, use an ohmmeter to check every IC pin for shorts to ground and verify that the pins that should be grounded are grounded. Now install the mechanical parts: the RCA jack, 3-pin Molex connector, 36-pin dual header (for the parallel interface), DIP switch S1, and R64.

## Tuner installation

Before the tuner can be installed, two RG-174 coax runs to the RF input and the LO output must be connected, as shown in Figs. 15-*a* and -*b*. If you don't get the lowband option, the RF input is just a direct feed using RG59 cable to a female/female F-type connector on the rear panel plate. After the cables are made, connect the LO cable to the board and solder the coax shield to the ground plane. Now make the RF feed. (If you have the lowband option, Fig. 16 shows you how to connect the coaxial cable to the board.)

Using the outer shield of the

lowband coax as a gauge, put the tuner on the board, top side up, by tacking the corners down with solder. Don't solder the lowband shield on yet, that goes on after tuning L6. Two holes are provided for using tie wraps to hold down the tuner if you desire. Cut small pieces of wire to connect tuner pins 1–8 on the bottom edge to the appropriate holes on the board. Make sure the IF OUT jumper is as short as possible. Now connect the two RCA jacks for the LO OUT and the RF IN coax runs.

### Terminal panel and shield

Before you mount the terminal panel to the board, connect the highband coax run as shown in Fig. 17. Connect the coax to the board first, then connect the lowband and comb F connectors to the terminal panel. Now connect the highband F connector to the terminal panel and secure the panel to the board using two 4-40 screws and nuts. Solder jumpers from the plated holes in the printed-circuit board to the center conductor lowband and comb F connectors.

Figure 18 shows the mounting details of the bottom shield, which is made of a single-sided PC board and is mounted, with the copper side facing away from the main board, using four 4-40 bolts. This shield should be in place before you perform any final tuning as it effects signal levels.

### Coil pretune

We're almost ready to power the unit up, but first we need to pretune the coils. Most of coil adjustments are noncritical. Use the following initial settings just to get you started:

- L1—Slug is 1½ turns from the bottom (fine adjust later).
- L2—Slug is 1½ turns from the top (± 1 turn).
- L3—Slug is all the way to the bottom.
- L5—Close wound.
- L6—Close wound.
- L7—Close wound.
- T1—Slug is 1½ turns from the top.
- T2—Slug is 1½ turns from the top.

The spectrum analyzer should work with those settings. All adjustments from here on for fine tuning.

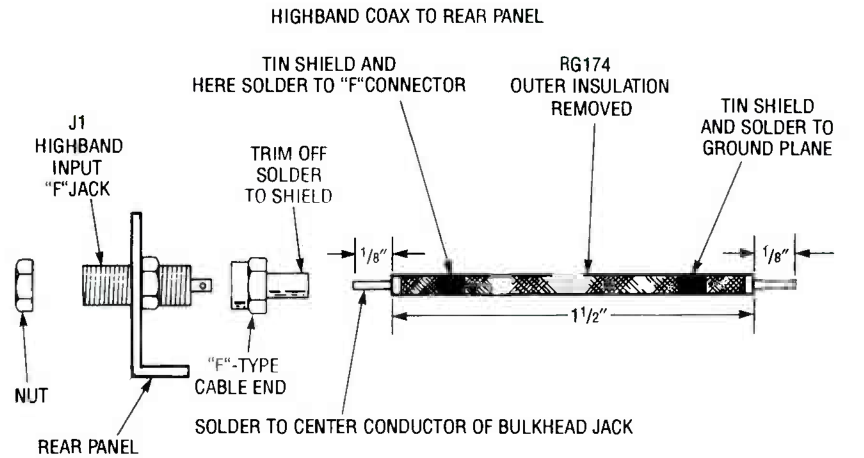



**FIG. 17—THE HIGHBAND COAX RUN is shown here. This coax connection must be made before the terminal panel is installed on the PC board.**

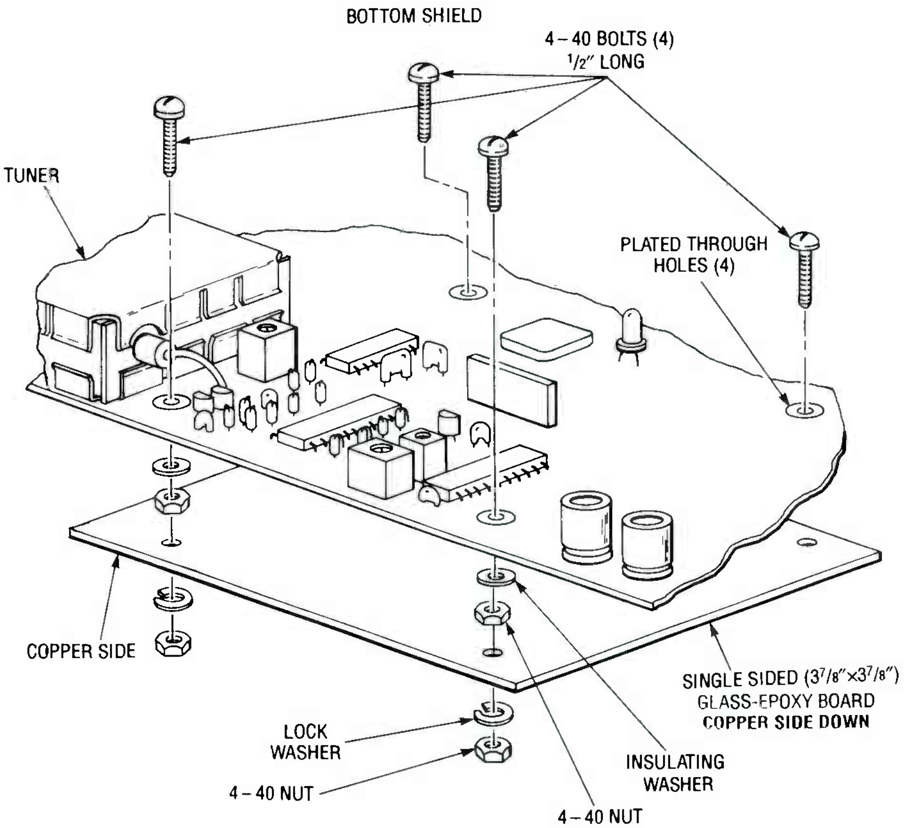



**FIG. 18—THE BOTTOM SHIELD ASSEMBLY is shown here. Make sure the copper side of the shield is installed away from the PC board.**

### First power up

Put the card in the computer or, for external use, connect it to a parallel port and external power supply. Connect the comb output to the highband input and turn it on. Check the +5-, +12-, and +33-volt levels to make sure they are correct. Run either 810EGA or 810CGA program, depending on your video adapter. The supplied wake-up state is a span of 400 MHz with a start frequency of 100 MHz. Assuming everything goes well, you should see a series of lines 4 MHz apart slowly rolling off in amplitude. If you don't, go to the "Troubleshooting" section.

### Tuning the unit

The spectrum analyzer can be used to fine tune L1, L6, T1, and T2; L2, L3, L5, and L7 should need no further adjustment. Adjusting the coils is easier with the card outside of the PC case, for instance if you use the parallel

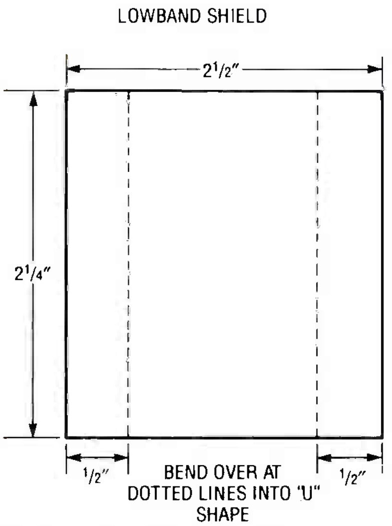



**FIG. 19—THE LOWBAND SHIELD is soldered on the top side of the PC board.**

**CORRECTIONS**

**There may have been some confusion where the DAC output from IC7 (Fig. 10) goes to from our Part I article. Just to clarify those connections, we have redrawn the correct DAC outputs in Fig. 20. Two other corrections are noted below.**

- **The power-supply line to Pin 2 of IC15, IC23, and IC14 is 33.3 volts DC.**
- **Two signal labels, $LO_{IN}$ and $V_{TUNE}$, should be reversed in IC23 of the signal-processing block diagram (Fig. 6).**

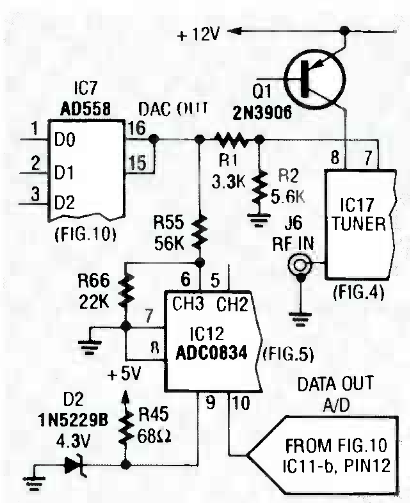



**FIG. 20—THE DAC OUTPUT from IC7 goes to IC17 and IC12 as shown here.**

interface. Allow about 5 minutes for warm up and then tune the coils in the following sequence.

The maximum span available from the lowband is affected by L6. It is tuned by spreading, or closing, its turns. Connect the comb out to the lowband input and set the spectrum analyzer as follows:

- Bandselect—lowband
- Span—100 MHz
- Start freq—5 MHz
- Inter atten—10 dB
- Ref level— −40 dBm

The sweep display should show lines every 4 MHz. If the upper end lines are missing, open up L6 a little and the upper lines should start appearing. You should be able to see the line at 104 MHz when L6 is adjusted properly. Once L6 is adjusted and you're confident that the lowband circuit is working properly, install the shield over the circuit. Figure 19 shows the details of that shield.

Set L1 by observing the power level of the noise floor. Terminate the highband input in 50 to 75 ohms and set the band select to highband. Use the following settings to make a measurement:

- Span—12.5 MHz
- Center frequency—120 MHz
- Sweep rate—3
- Inter. atten—10 dB
- Ref level— −40 dBm

The sweep display should show almost a flat line. Turn the slug of L1 until the noise floor reads −100 dBm. An alternative and more accurate method requires a crystal source of known power level. For best results, the frequency of the source should be between 100 to 500 MHz. Set the spectrum analyzer to display your line using the 12.5-MHz span and a sweep rate of 1. Now adjust L1 so that the power level of your line is correct.

T1 is tuned by using the spectrum analyzer as an FM radio. The setup settings are:

- Span—25 MHz
- Start freq—85 MHz
- Band select—highband
- Volume potentiometer (R64)—centered

Connect an antenna up to the highband input. You may have to use an outside antenna. You can make a simple antenna by attaching a 2- to 3-foot piece of wire to the center conductor of the input. Connect a speaker to the audio out RCA jack. Now let the analyzer make a few sweeps. You should be able to hear FM broadcasts as the analyzer sweeps by them. Now activate the marker and find a strong station. Put the marker at the peak of the signal, even if the audio drops out. Adjust T1 now for the best sound. T2 can be adjusted the same way, but you'll have to pick off the audio and amplify it as it is not connected to an amplifier. You will also need a narrowband FM broadcast for proper adjustment. With a little hunting you should be able to find one. (Try your local National Weather Service broadcast station in the 162.4–162.6 MHz band.) The adjustments of T1 and T2 only effect the FM demodulation and do not effect the accuracy of the instrument.

## Troubleshooting

Typical symptoms indicating a problem are a flat or "pegged" sweep display and no response to inputs. Two programs are available to help in the troubleshooting process; BLINK.EXE and ADCDAC.EXE. BLINK is used to give a simple visual indication that the host PC has some communication with the card. With the card plugged into the PC or parallel cable, run BLINK. The LED on the card should blink at approximately 1-second intervals. If no blinking at all occurs, you have a communication problem with the PC. Double check the interface settings using SETUP; if those are wrong the card won't respond. If wiggling cables, checking power-supply voltages, and every permutation of interface selections does not result in a successful BLINK, you most likely have a hardware problem.

ADCDAC.EXE is a more extensive test in that both reading and writing to the card are involved. There is little chance that this test will be successful if BLINK fails. ADCDAC sends a voltage level to the DAC, then reads that voltage using the ADC. If the read voltages are within the tolerances, the test is declared a success. ADCDAC returns a pass/fail verdict upon completion. If you fail, it could be an interface problem or a problem with the ADC or DAC. Passing does not guarantee that all systems are go, just that the interface and ADC/DAC seem to be working.

If you still can't find the problem, see README.DOC for more things to try, or call DKD Instruments at (805) 581-5771. They'll be happy to help you. **R-E**

DAVID T. MIGA, CET


# BUILD THE MICROANALYZER

***Repair microwave ovens the easy way with the Microanalyzer.***

DID YOU KNOW THAT MICROWAVE ovens were invented more than a quarter century ago using technology more than half a century old? Even so, many electronic technicians are reluctant to service them because they do not understand them. That's a shame, considering the fact that there are millions of them in use. True, there is enough power in even the smallest microwave oven's power supply to kill a person, yet most technicians repair television receivers with many times more voltage without giving it another thought. The point is that a technician with the proper knowledge, who follows safe, intelligent procedures will never have a bad experience, and can make lots of money. This article explains how microwave ovens work, and shows you how to check all of the critical parts using the Microanalyzer project that we'll show you how to build.

## How they work

A microwave oven is similar to an RF linear amplifier that has been purposely tuned to be unstable, and therefore to oscillate. The oscillator/amplifier tube is called a magnetron, and its schematic is similar to an ordinary tube rectifier (see Fig. 1). However, instead of the electrons having free space to boil off of the filament/cathode to be grabbed by the plate, the electrons are purposely frustrated by placing a powerful circular magnet around the cathode, causing the electrons to rotate around the cathode on their way to the plate. There are cavities in this section of a critical diameter that will cause the oscillations to be of a certain frequency, usually 2450 MHz. Because the plate of the tube does not operate at a high voltage, but instead is at ground potential, the cathode, therefore, is powered by a very high negative voltage, usually between three and four thousand volts. The filament of the tube is directly heated, so it must be capable of handling the high negative voltage as well as passing a 3-volt AC filament current of about 10 amps. In most microwave ovens, a single power transformer has both high-voltage and low-voltage secondaries.

The magnetron tube has a wire in the plate cavity that intercepts the swirling electrons and passes the energy to the top of the tube where the energy is transmitted by a small antenna tuned to the proper wavelength. The energy therefore transmits horizontally, similar to the ripples in a pond caused by a dropped pebble. The microwaves are routed by a square metal tube, or duct, called a waveguide, whose cross dimensions are tuned to the same wavelength as the magnetron. The waveguide directs the microwaves to the inside of the oven through a plastic or mica panel called a waveguide cover. The cover keeps food particles, grease, and steam from entering the waveguide, yet passes the magnetic energy.

Most microwave ovens have a stirrer, which can be motor activated, or in many ovens may be blown propeller style by the air forced through the cooling fins of the magnetron. The stirrer is in the top of the oven, and it reflects the microwaves all around the oven cavity.

All microwave ovens have safety features to prevent unsafe microwave emissions. A series of micro-switches operate in a certain sequence, and are in series with one or more thermal switches, so as to assure that the power supply will operate only when all of the switches are in their correct positions. There's even a switch designed to short out the AC line, blowing the fuse, if any of the switches malfunction (see Fig. 2).

In operation, a mechanical timer or an electronic control unit will cause a relay or triac to pass 120-volts AC to the primary of the power transformer. The transformer has a 3-volt secondary for heating the magnetron's filament, and a 1500- to 2500-volt secondary for the high-voltage power supply. To keep the windings count low, a voltage-doubler circuit is used (see Fig. 3). During one half of the 60-cycle current, the transformer charges a high-voltage capacitor to ground through a high-voltage diode, cathode to ground. When the polarity reverses, the capacitor is free to discharge through the high-voltage winding. Since the voltages are in series, the voltage is doubled, although the current is reduced to what the capacitor can supply during its discharge. Therefore, the size of the capacitor controls the wattage, and the magnetron actually transmits energy in 60-Hz pulses. Note that the capacitor may remain charged for hours after using the oven, so it must be properly discharged before any components in the oven are checked.

When a microwave oven is operated, the magnetron usually takes about 3 seconds to fire up, because the filament must come up to temperature. If one listens, the firing up is audible; the magnetron emits a 1-second buzz immediately after the filament heats up. In most ovens with several power settings, the actual power delivered to the magnetron does not vary, but instead is cycled on and off by the controlling circuitry. The fan and light stay on, but the primary of the power transformer is energized or de-energized by a relay or triac, as shown in Fig. 4.

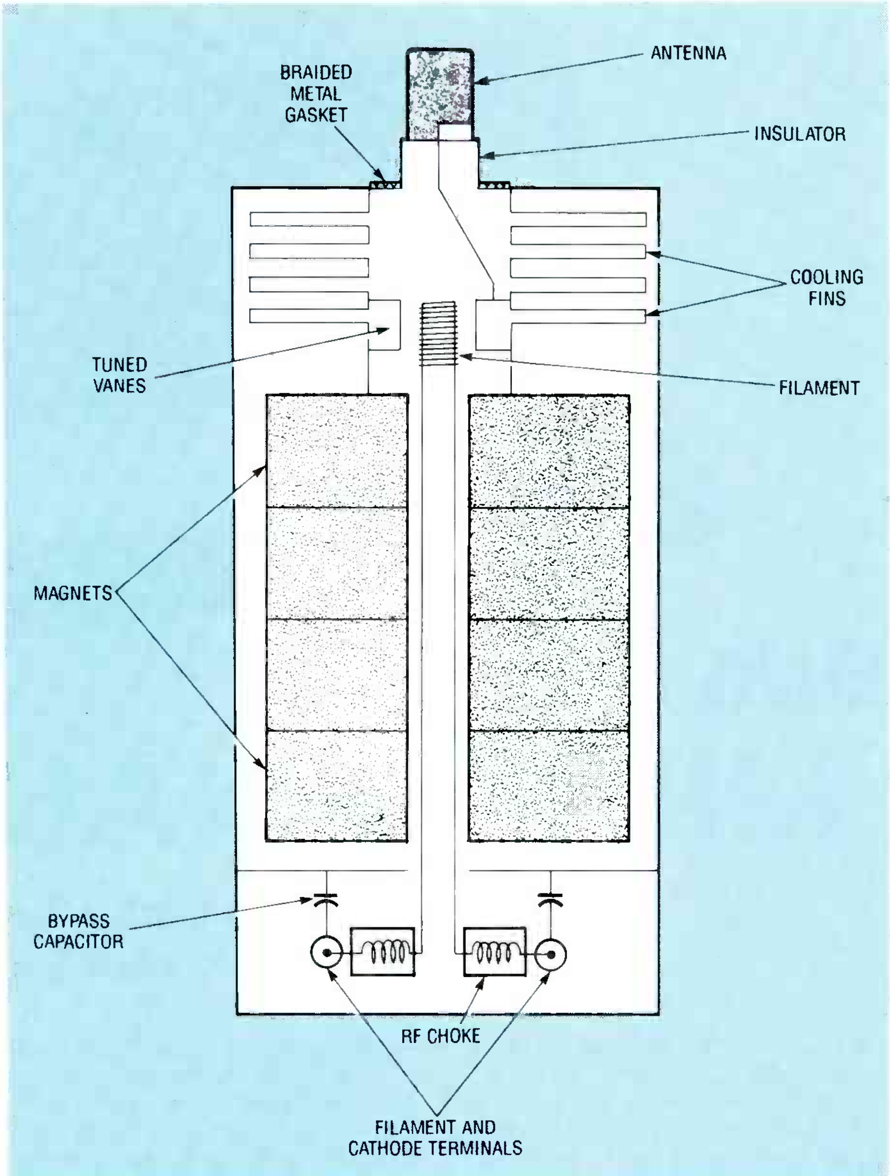



**FIG. 1—A MICROWAVE OVEN'S oscillator/amplifier tube is called a magnetron. The electrons are purposely frustrated by placing a powerful circular magnet around the cathode, causing the electrons to rotate around the cathode on their way to the plate. There are cavities in this section of a critical diameter that will cause the oscillations to be of a certain frequency, usually 2450 MHz.**

More sophisticated ovens may use a temperature probe, or even a heated tin-oxide gas-vapor sensor to determine when the food is cooked. The thermistor's resistance in the probe, or the voltage output of the gas sensor, is routed to a microprocessor, which has been programmed with the proper values to turn off power when the food is fully cooked, or "smells" done.

## The Microanalyzer

The Microanalyzer is actually several pieces of test equipment rolled into one easy-to-carry cabinet. First, a 3½ digit DVM is incorporated to measure up to 500-volts AC or DC, with a high-voltage input that allows up to 5000-volts AC or DC. Second, a high-voltage supply is wired to a circuit that allows the testing in-circuit of the high-voltage diode and capacitor, with test voltages as high as 700 volts peak-to-peak. The results are plainly displayed by four neon indicators. Third, a semiconductor checker allows the testing of devices such as triacs, silicon controlled rectifiers, bipolar transistors, diodes, and MOSFET's.

Figure 5 is the schematic of the Microanalyzer. Power transformer T1 has a low-voltage sec-

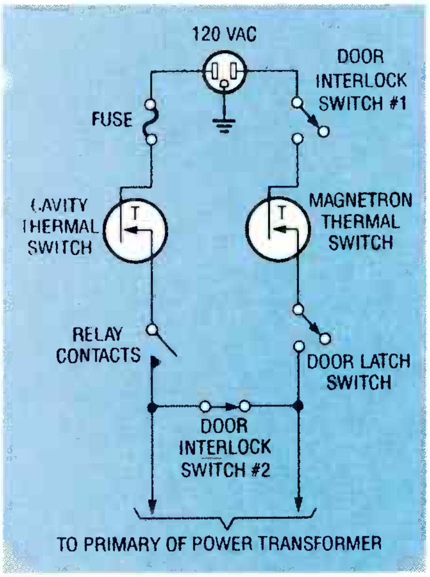



**FIG. 2—ALL MICROWAVE OVENS have safety features to prevent harmful emissions. A series of micro-switches and thermal switches assure that the power supply will operate only when all of the switches are in their correct positions.**

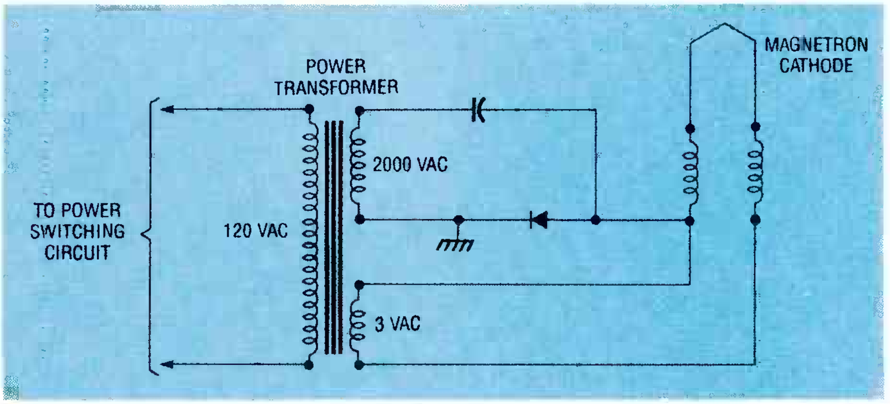



**FIG. 3—TO KEEP THE POWER TRANSFORMER's windings count low, a voltage-doubler circuit is used to generate high voltages.**

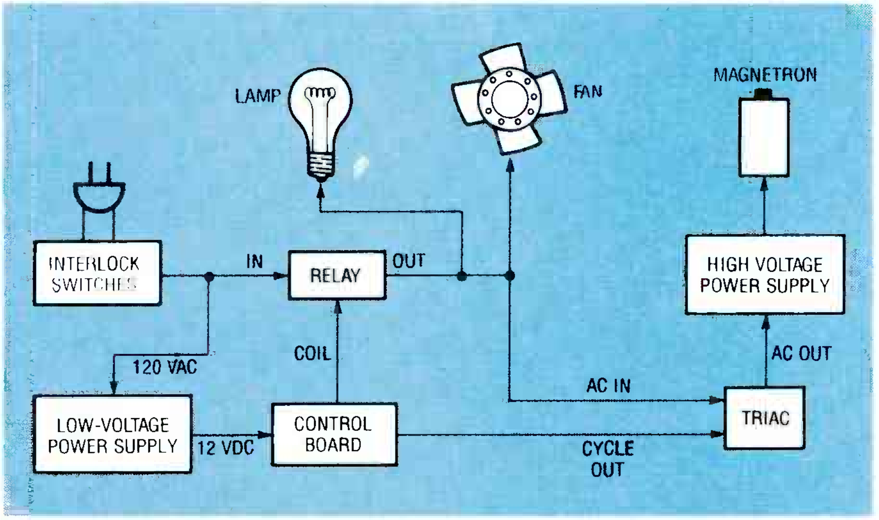



**FIG. 4—IN OVENS WITH SEVERAL POWER SETTINGS, the magnetron is cycled on and off by the controlling circuitry. The fan and light stay on, but the primary of the power transformer is energized or de-energized by a relay or triac.**

ondary that provides power to the DVM chip, IC2, via diode bridge BR1 and regulator IC1, as well as AC power to the semiconductor tester. The high-voltage secondary provides 250-volts AC for the high-voltage diode and capacitor tester. A small sample voltage is taken from the secondary's center tap via R30, D12, and D9 for the negative voltage required by IC2.

Selection between the DVM, the capacitor tester, and the diode tester is done by three-pole, three-position switch S2. In the "capacitor-test" and "diode-test" positions, one pole of S2 connects the internal high-voltage source to banana jack J2; a second pole turns off the DVM display via D8, R25, and Q3; the third pole selects either high-voltage AC for testing diodes, or DC for testing capacitors. If the selector is placed in the "diode-test" position, a 250-volt RMS potential is placed through current-limiter R1 to the diode under test between J1 and J2.

Across R1 is neon-indicator NE3, which will light only if the AC current flow is in the wrong direction; if the diode is shorted, for example. Diode D5 will keep NE3 off if the diode under test is good. The diode-OK neon indicator (NE1) will illuminate only with DC, since AC will be bypassed across NE1 by C1 and C2. The diode-open neon indicator (NE2) cannot light if the diode under test is good, since the diode will keep the positive voltage across R5, D6, and NE2 under 8 volts, which is the forward-bias potential of a good high-voltage diode. Diode D6 will keep NE2 off during negative flow; however, if the diode under test is open, there is sufficient positive voltage to light NE2.

Flipping S2 to the "cap-test" position switches D1 in line which causes a pulsating negative DC voltage to appear across R1. With an open circuit, NE1 and NE3 will be off because there is insufficient voltage across R1 to illuminate either one. Indicator NE2 will be off because only a positive voltage can light it, and NE4 will be off because the 250-volt DC signal is not high enough to break down the reverse junctions of diodes D3 and D4 in series with NE4 and R2.

If the capacitor under test is 0.1 μF or higher, the negative current flow will charge it through D1; however, when the current flow reverts to positive, D1 blocks the flow, which now is the combined voltage of T1's secondary in series with the charged capacitor. The combined voltage is now enough to break down the reversed junctions of D3 and D4, protected by current-limiter R2, and NE4 glows. A value below 0.1 μF will create a voltage lower than NE4 usually requires to conduct, so C14 is placed across NE4 to charge up to NE4's ionization point. Because of that, any capacitor that is below the normal value found in most microwave ovens will cause the NE4 to flash, due to the relaxation oscillator circuit. Capacitor values of 0.5 μF or higher will illuminate NE4 continuously, while smaller and smaller values will cause NE4 to flash slower and slower.

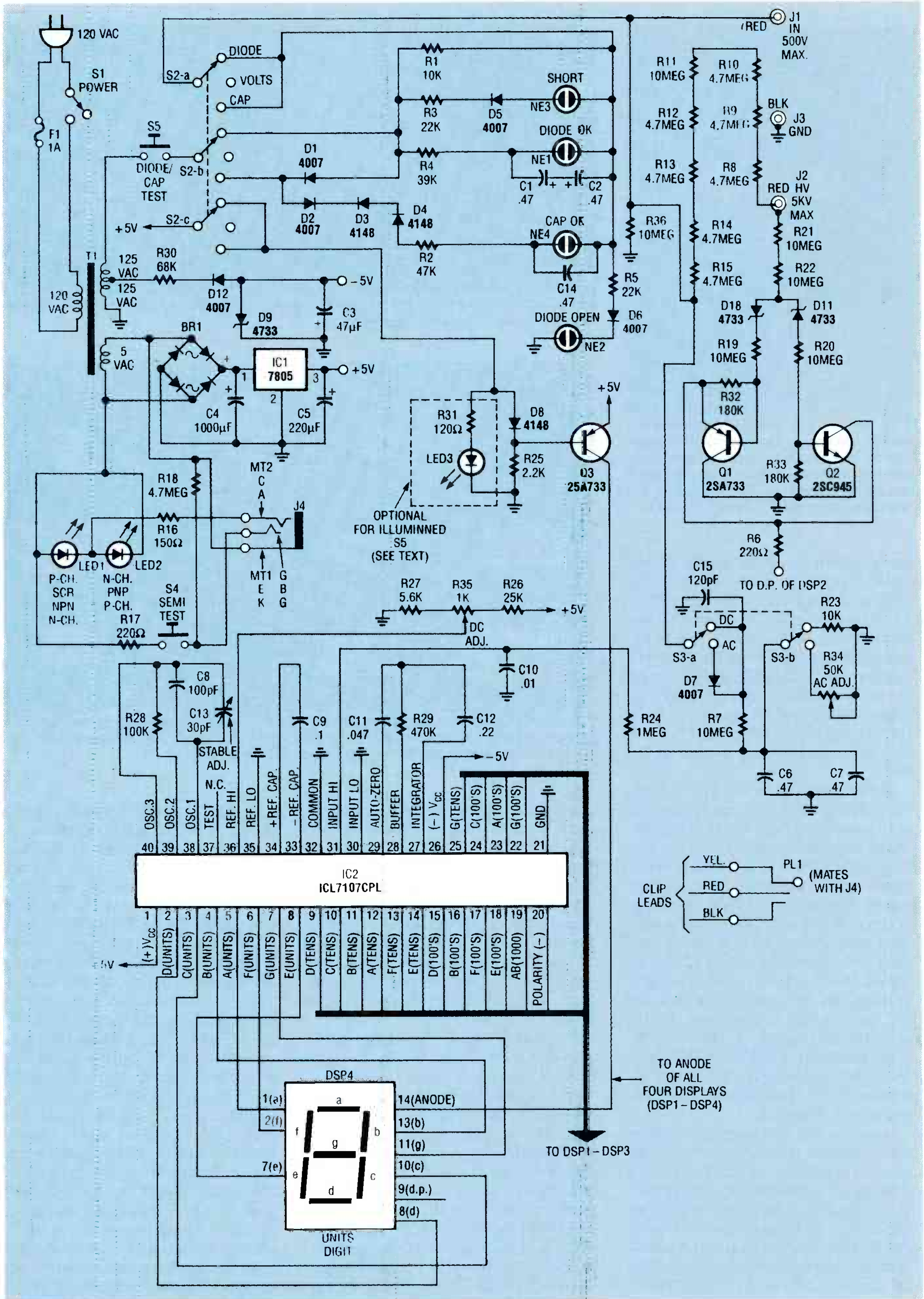


FIG. 5—POWER TRANSFORMER T1 has a low-voltage secondary that provides power for the Microanalyzer's circuitry. The high-voltage secondary provides 250-volts AC for the high-voltage diode and capacitor tester.

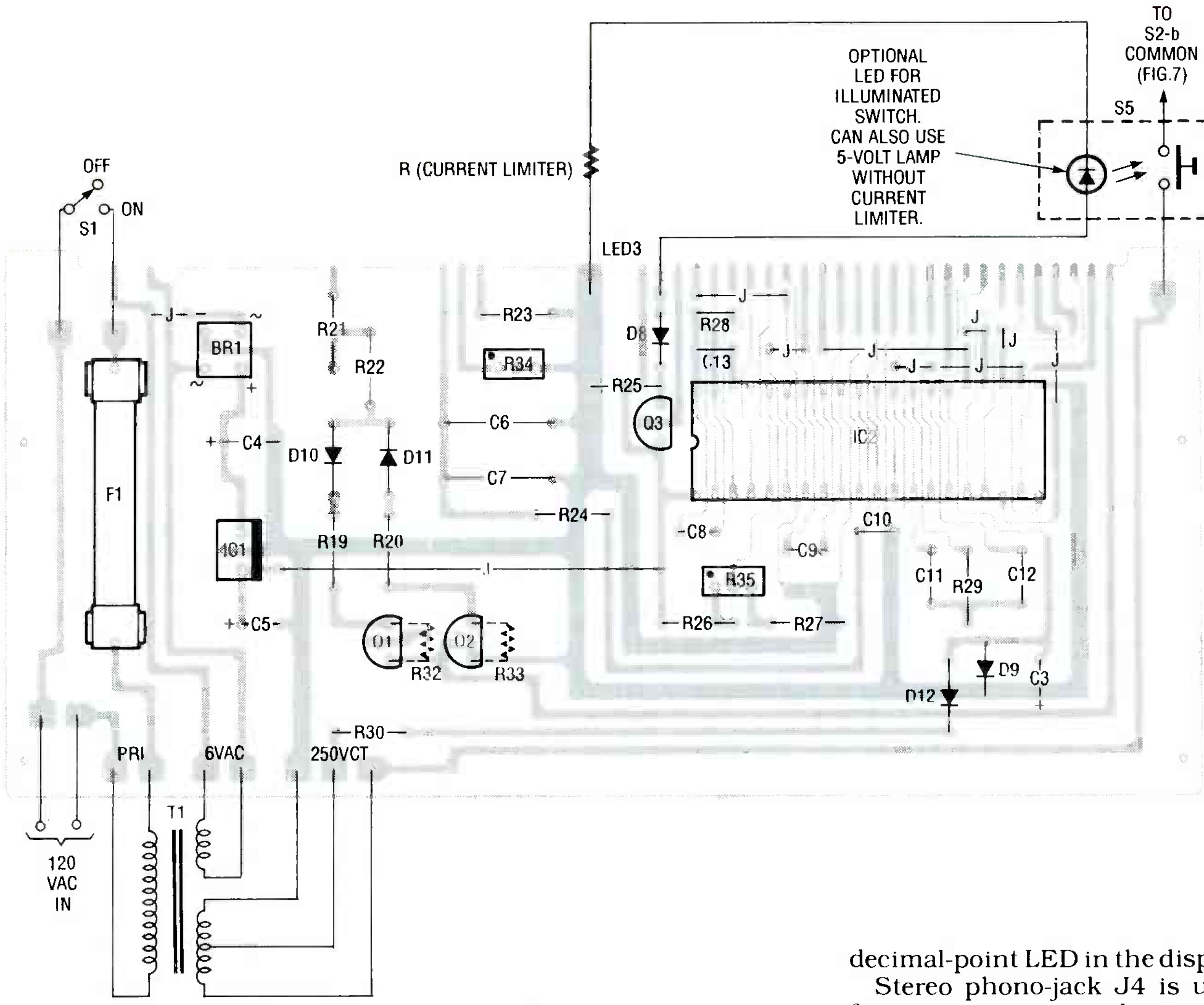



**FIG. 6—ALL COMPONENTS ON THE MAIN BOARD are mounted on the component side except for R32 and R33 which must be tack-soldered to the solder side of the board.**

One quirk of this circuit is that if the capacitor under test is shorted, not only will short-indicator NE3 glow, but so will NE1, the diode-OK indicator. Since a capacitor is under test here, the user can simply ignore the diode-OK lamp. If that is bothersome to the user, a 4-pole switch may be used for S2, with the fourth pole used to switch in NE1 in the "diode-test" position only.

The voltmeter circuit uses the popular 7107 DVM chip (IC2). The AC/DC switch (S3) switches D7 in or out so that IC2 always sees either positive or negative voltage, but never AC. Because the single diode is a half-wave rectifier, normally the reading will be only a small portion of the true RMS voltage; therefore, a second pole of S3 switches from R23 to a trimmer, R34, so that the meter can be adjusted to read the correct RMS voltage in the "AC" position. Because IC2 uses an on-board oscillator for the dual-slope integrating analog-to-digital converter, trimmer-capacitor C13 has been added across C8 so that the sampling frequency can be varied. If the trimmer capacitor is left out, any AC voltage readings may be unstable; therefore, the chip's sampling frequency can be adjusted to an exact multiple of the 60-Hz AC voltage to be measured.

Trimmer R35 is the basic reference-voltage adjustment used to calibrate the DVM on the lower scale DC measurement. The values of R7 and R23 or R34 will correctly divide the input voltage up to 500 volts AC or DC down to 2 volts for the DVM chip (IC2), but if anything up to 5000 volts must be measured, the voltage is passed through banana-jack J2 which uses R8–R15 for an additional 43 megohms to reduce the voltage to a compatible level.

The circuit containing Q1 and Q2 constantly measures the voltage at J2. If any AC or DC voltage appears at J2, one or both transistors are biased to turn on the decimal-point LED in the display.

Stereo phono-jack J4 is used for testing semiconductors. A matching phono plug, PL1, with a black lead on the outer conductor, a red lead on the middle conductor, and a yellow lead on the tip conductor, plugs into J4 and provides test clips to attach to components. The 5-volt AC source from T1 is passed through LED1 and LED2 through current-limiter R16. Both LED's will remain off when the test leads at J4 remain unconnected, but both will illuminate when the red and black leads are shorted. To test a semiconductor, connect the red lead to the collector of a transistor, the anode of an SCR, MT2 of a triac, or the drain of a MOSFET; connect the black lead to a transistor emitter, SCR cathode, triac MT1, or MOSFET source; and connect the yellow lead to a transistor base or gate of any other part. Pushing test button S4 will forward-bias the device and, depending on whether either, both, or neither LED lights, a semiconductor device can be tested for proper conductance. More details on the testing will be given later.

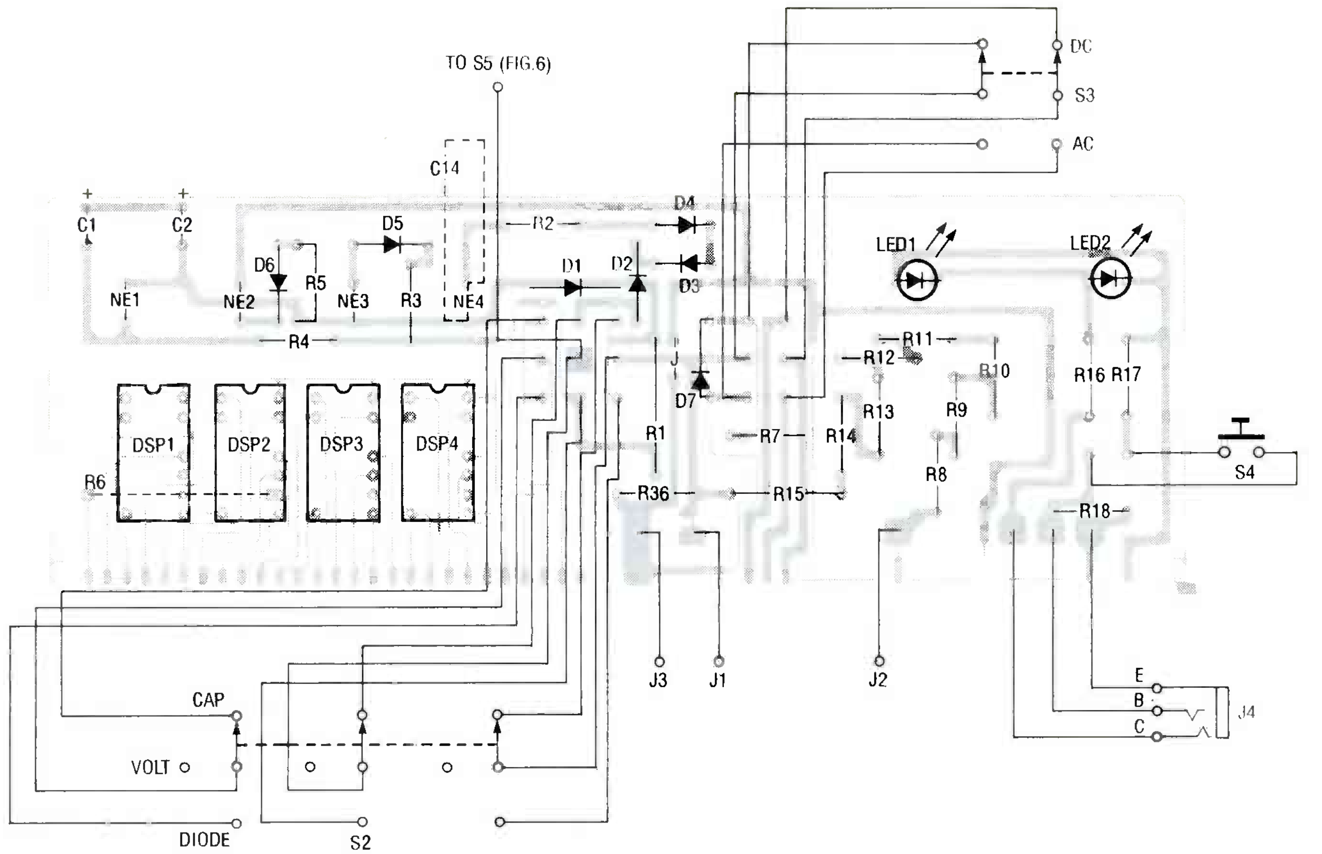



**FIG. 7—MOUNT THE PARTS ON THE DISPLAY BOARD as shown here. Note that R6 and C14 are soldered to the back of the board.**

## Construction

The Microanalyzer consists of two single-sided PC boards: a main board containing the power supply and the DVM chip with auto decimal-point circuitry, and a display board containing the indicators, displays, switches, and test jacks. The display board is joined to the front of the main board by soldering interconnecting foils at their edges. We've provided the foil patterns in case you'd like to make your own boards. Alternatively, the boards, as well as complete kits, are available from the source mentioned in the parts list.

Almost all components, except the power transformer and switches S1 and S5, are mounted on the PC boards. Follow the parts layouts for the main and display boards, Figs. 6 and 7, respectively. Solder all jumpers on both boards first, followed by the fuse, resistors, trimmers, diodes, capacitors, transistors, regulator IC1, and sockets for the 7-segment displays and IC2, in that order; do not put IC2 in its socket just yet. Prepare switches S2–S4 by soldering 1-inch lengths of solid wire to the terminals to make them PC-mountable. Do not put too much solder on S2 or else it may not fit between the display board and front panel.

Mount, but do not solder the neons, LED's, and prepared switches in the display board. Insert the digital displays in their sockets. As indicated by the dashed lines in the parts-placement diagrams, tack-solder R32 and R33 to the back (the solder side) of the main board, and R6 and C14 to the back of the display board. Hold the display board in position next to the main board using the slots and bosses in both boards, and solder all of the foil connections, making sure that the boards are exactly perpendicular. Check all connections for solder bridges.

Solder the power-transformer wires to the main board, and solder three 4-inch wires in the holes marked for both switches S1 and S5. If you are using an illuminated switch for S5, install 6-inch wires in the holes marked LED3. Solder the power switch (S1) to its wires.

Assuming you have purchased a ready-made front panel and case (see the parts list), you can mount all of the jacks and indicator lenses on the front panel just like the prototype, and slip four ⅝-inch heat-shrink tubes over the neons. Otherwise you can make your own front panel in a similar fasion. Remove all hardware from S2–S4, but leave one nut on S3. Mount the front panel and the PC-board assembly in the bottom shell of the cabinet. The neons, LED's, and switches can now be extended to reach the panel to be mounted. Adjust the nut on S3 to match the shaft length of S2, and install and tighten the remaining hardware for all three switches. Solder the components after they have been mounted. Also mount S1 and S5 in the panel and wire them up; note that the other side of S5 is connected to the rear of the display board on the center contact of S2 (S2-b common).

Remove the assembly from the cabinet, turn it over, and wire up jacks J1–J4 to the holes marked on the display board using the shortest possible lengths of very thin solid wire. Remember to wire the LED3 wires to the indicator inside S5 only if a 5-volt bulb or LED is installed; the indicator will light only when the

## PARTS LIST

**All resistors are ¼-watt, 5%, unless otherwise indicated.**
R1—10,000 ohms
R2—47,000 ohms
R3, R5—22,000 ohms
R4—39,000 ohms
R6, R17—220 ohms
R7, R11, R19–R22, R36—10 megohms
R8–R10, R12–R15, R18—4.7 megohms
R16—150 ohms
R23—10,000 ohms
R24—1 megohm
R25—2200 ohms
R26—25,000 ohms, metal, 1%
R27—5600 ohms
R28—100,000 ohms
R29—470,000 ohms
R30—68,000 ohms
R31—120 ohms (optional for illuminated S5, see text)
R32, R33—180,000 ohms
R34—50,000 ohms, 10-turn trimmer
R35—1000 ohms, 10-turn trimmer

**Capacitors**
C1, C2—0.47 µF, 350 volts, electrolytic
C3—47 µF, 16 volts, electrolytic
C4—1000 µF, 25 volts, electrolytic
C5—220 µF, 16 volts, electrolytic
C6, C7—0.47 µF, 100 volts, Mylar
C8—100 pF, polystyrene
C9—0.1 µF, 100 volts, Mylar
C10—0.01 µF, 100 volts, Mylar
C11—0.047 µF, 100 volts, Mylar
C12—0.22 µF, 100 volts, Mylar
C13—30 pF, ceramic micro trimmer
C14—0.47 µF, 200 volts, Mylar
C15—120 pF, 500 volts, silver mica

**Semiconductors**
IC1—7805 5-volt regulator
IC2— ICL7107CPL 3½-digit DVM chip
D1, D2, D5–D7, D12—1N4007 diode
D3, D4, D8—1N4148 diode
D9–D11—1N4733 5-volt Zener diode
BR1—ECG5304 400-PIV 1.5-amp bridge rectifier
Q1, Q3—2SA733PNP transistor
Q2—2SC945 NPN transistor
LED1, LED2—orange light-emitting diode
LED3—light-emitting diode or 5-volt lamp (optional for illuminated S5)
DSP1–DSP4—MAN 4710A common-anode 7-segment LED display

**Other components**
S1—SPST pushbutton switch
S2—3PDT C.O. switch
S3—DPDT switch
S4—SPST pushbutton switch
S5—SPST pushbutton switch (illuminated optional)
T1—120 VAC primary, 250 VAC C.T. 25 mA secondary, 6 VAC, 1 amp secondary
J1, J2—red banana jack, ½-inch
J3—black banana jack, ½-inch
J4—stereo mini phono jack
PL1—stereo mini phono plug
F1—1A, 250V pigtail fuse, Littlefuse 318.500
NE1–NE4—NE-2H neon indicators
**Miscellaneous:** Amerex 570 black cabinet, hardware, AC line cord, 3.5mm lamp lenses, wire, solder, etc.

**Note: The following parts are available from EDS, Inc., 275 Rock Island Road, N. Lauderdale, FL 33068: Set of drilled and screened main and display PC boards for $25; kit of all parts and boards for $199; complete kit including Amerex cabinet with screened and machined front panel for $249. Please include $4 shipping for boards only, or $8 for kits. Florida residents must include 6% sales tax.**

diode or capacitor functions are selected, while the digital display will illuminate only when the selector is in the "volt" position. Mount transformer T1 to the center floor of the cabinet using #8 bolts and nuts. Run the AC line-cord through the hole in the back of the cabinet and solder the leads to the main board. Install the line-cord strain relief; you may have to melt it to the inside of the cabinet for added strength. Finally, mount the assembly to the bottom shell of the cabinet and proceed with making of the test leads. Figure 8 shows the inside of the completed unit.

Because the unit will be used to measure potentials up to 5000 volts, it is important to use wire intended for use as test leads, such as the rubber-insulated variety. Solder fully insulated banana plugs to one end of the wires, and fully insulated alligator clips to the other end. The semiconductor test wire is made from an ordinary piece of 4-conductor telephone wire, with only the red, black, and yellow wires used. Solder a 3.5-mm stereo phono plug (PL1) to one end, being sure that the pin-out matches the jack (J4), and solder small IC clips or micro alligator clips to the remaining end.

After you have checked for solder bridges, bad connections, and proper component polarities and values, you can apply power. Measure the voltage at the positive terminal of C5; it should be +5-volts DC measured to ground. The anode of D9 should measure −5-volts DC, and the S5 pad on the main board should be 250-volts AC. If the voltages appear to be normal, turn off power and install IC2 in its socket. Turn on power and cycle S2 to be sure that the digital display and LED3 work properly. If everything looks good, plug in the high-voltage test leads and put S2 in the "diode test" position. Press S5 and verify that NE2 (open diode) illuminates. Short the test leads and press S5 again to see that NE3 (short) lights. Now, connect a high-voltage test diode with red at anode and black at cathode, and check that NE1 (diode OK) lights. Note that if the diode is connected backwards, all three diode-test lamps will illuminate simultaneously.

Check the capacitor-test functions with high-voltage capacitors rated between 0.01 and 1.0 µF and verify the correct functions of NE3 and NE4. Remember that voltages across the test leads can be as high as 700 volts p-p when S5 is pressed, so please be careful. Since the test voltages are fully isolated from the power line, and one hand is needed to push the test button, it would require a three-handed person to get a shock, but the warning is given anyway.

Next check the semiconductor tester. Plug in the 3-conductor test cord and connect the ends to an NPN transistor using red for the collector, yellow for the base, and black for the emitter. Without pressing S4, LED2 may be dark or slightly lit. That is normal reverse leakage for an NPN transistor, and will be brighter when testing low-voltage, high-frequency transistors. Pushing S4 will darken LED2 and brightly illuminate LED1, showing transconductance. Testing a PNP transistor should yield reversed indicators.

## Test and calibration

To test and calibrate the voltmeter, you will need to construct a test jig using an actual microwave oven's power transformer. You will not have to remove the transformer, but just remember that during these tests that you will be exposing yourself to potentially lethal voltages. Use rubber gloves and have someone else nearby to supervise. Construct a string of five 1-megohm, ½-watt, 2% resistors from the transformer's high-voltage output to ground, with a 1N4007 diode and 0.01-µF/1kV ceramic capacitor connected as shown in Fig. 9. Disconnect the lead from the high-voltage output of the transformer to the high-voltage capacitor to keep the oven's magnetron from firing.

Connect a DMM (set to its highest DC voltage range) in parallel with the Microanalyzer's test leads, with red to the DC test point of the test jig, and black to ground. Be sure that both meters are set to DC and, after checking and covering all exposed connections, plug in and turn on the microwave oven. Using your DMM as a reference, adjust R35 for the same reading. Turn off and unplug the oven, and switch to the AC test point. Set both meters to AC, then turn on the oven again. If the digital display seems to be unstable or hunts up and down, adjust C13 with an insulated alignment tool until the readings settle down. After that has been done, adjust R34 for the same reading as your DMM. Turn off and unplug the oven, then move the red banana plug to the high-voltage test jack J2. Turn on the oven again and verify that the decimal point illuminates when voltage is present, and the reading of the display is shifted one digit to the left so that the display reads kilovolts to the nearest 120 volts. If the accuracy is poor, you can replace R11 (10 megohms) on the display board with different values from zero to 10 megohms. This completes all testing and calibration.

## Use

Since we have learned that microwave ovens are simple devices with a high-voltage power supply, magnetron tube, and some type of control circuit, troubleshooting is usually straightforward unless the oven has an intermittent problem. If an oven is "dead," check and replace, if necessary, the fuse with the correct type; most ovens use a ceramic self-quenching type fuse. Put a cup of water in the oven and fire it up. If there is still no function, or if it lights but doesn't heat, unplug the oven and discharge the capacitor by connecting a test clip to ground, touch one, then the other capacitor terminal to ground. Now using the clip, short across the terminals. Since this method discharges the capacitor through the transformer first, the discharge will be less violent.

The first type of tests are "static" tests, meaning that the components are checked with the oven unpowered and unplugged. Turn on the Microanalyzer and switch to "capacitor test." Connect the black lead to the capacitor terminal connected to the high-voltage secondary, and the red lead to the capacitor terminal connected to the anode of the high-voltage diode. Depressing S5 should indicate a good capacitor, with no flashing of the indicator. If the indicator flashes, or the short indictor lights, disconnect all wires to the capacitor and check it again.

If the capacitor checks out, move the black test clip to ground, with the red lead remaining connected to the anode. Switch to "diode test" and press S5. Remember that if the test leads are connected backwards, all three diode test lamps will light. When testing capacitors and diodes, keep S5 pushed in for a few seconds. All indicators should be steady, as flickering lamps may indicate an intermittent breakdown problem.

If the diode and capacitor are good, check the magnetron filament. Pull both wires off of the

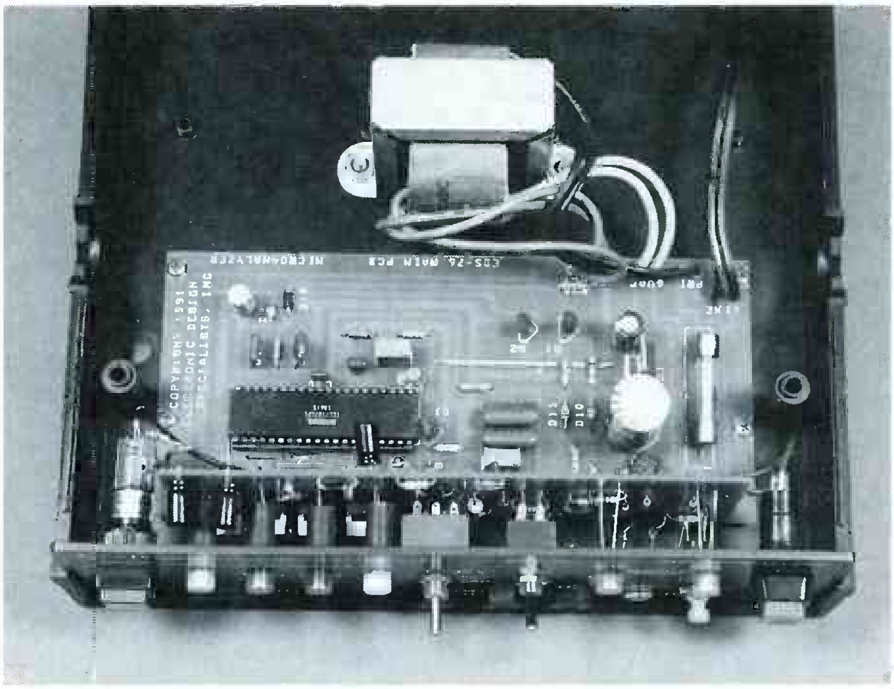


FIG. 8—THE INSIDE OF THE COMPLETED UNIT. The transformer and PC-board assembly are mounted in the bottom shell.

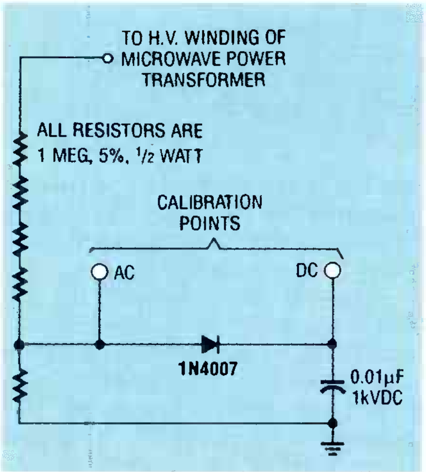
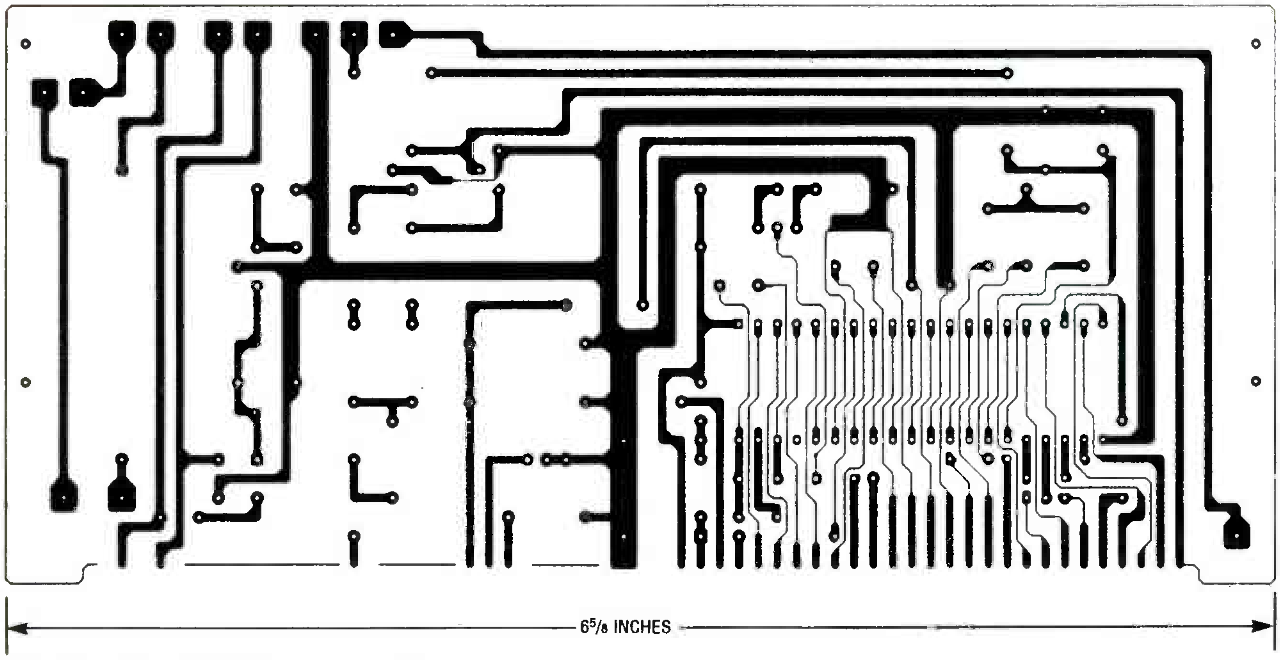



FIG. 9—CONSTRUCT A STRING of five 1-megohm, ½-watt, 2% resistors from the transformer's high-voltage output to ground, with a 1N4007 diode and 0.1-µF,1kV ceramic capacitor connected as shown.




**USE THIS FOIL PATTERN for the main PC board if you want to make your own.**

filament connectors at the base of the magnetron, and with the black test wire still at ground, connect the red lead to either filament connector and push S5. The Microanalyzer should be in the "capacitor test" mode. The "short" lamp should be off, unless the cathode is shorted to ground; however, the "capacitor OK" lamp may flash very slowly, indicating that the RF bypass capacitors inside the magnetron are functioning. If the "short" lamp remains off, connect the red and black leads across the filament and push S5; because of the very low resistance of the filament, the "short" indicator will light.

If all tests so far have not found the defective component, and the oven still blows fuses when operated, the most likely cause will be an improperly adjusted or defective micro switch. With the oven unplugged, you can use the Microanalyzer as a continuity tester by connecting to each microswitch and operating the door mechanism slowly, observing that the indicators show open and short as each as each switch goes through its motions. A sticky switch in the wrong position may cause a short when another switch is cycled by opening the oven door. You should also check continuity of thermal switches mounted to the magnetron or oven cavity, if the oven remains dead.

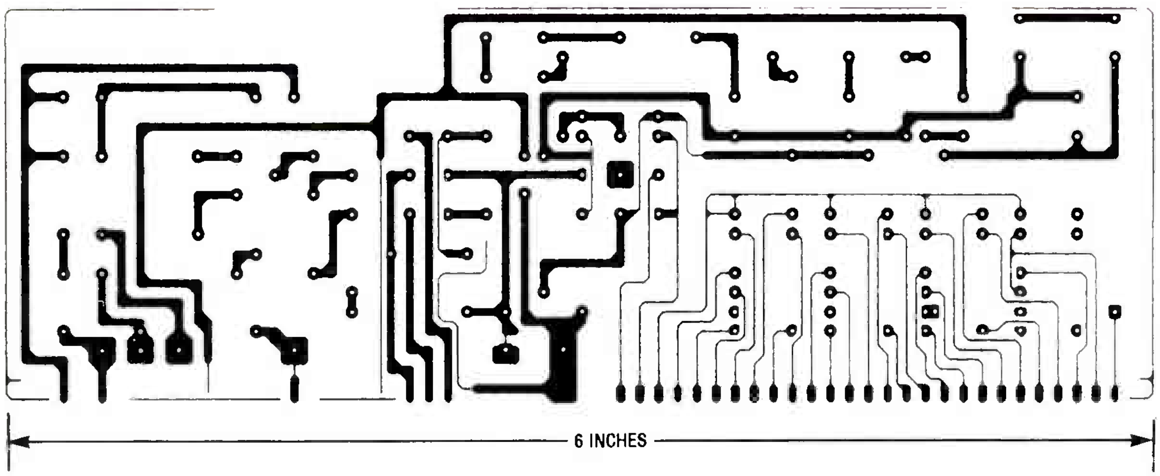
If you suspect the power transformer, its three windings can also be checked with the Microanalyzer in the "capacitor test" mode. The primary and filament windings should cause the "short" indicator to light, but the high-voltage winding will cause the "diode open" and "short" lamps to illuminate together, because of the high reverse-EMF generated by the high windings count.

Assuming that you have checked all components mentioned so far and still have not found any defective components using the static test method, active tests must now be performed. If the oven seems to be working, such as the lamp lights and the fan blows, but there is no heat, additional tests must be done to check whether power is getting to the magnetron.

Plug in and turn on the oven; listen for the three-second delay, then the one-second buzz that all magnetrons emit when they fire up. If you do not hear the magnetron fire, unplug the oven and discharge the capacitor, then connect the red and black test leads across the primary of the transformer. Switch the Microanalyzer to "volts AC," and power the oven. If there is no voltage reading, there may be a problem with the triac, relay or whatever power-switching system is used. If 120 volts AC is present, the filament voltage should be measured next.

Disconnect the high-voltage wire from the filament connectors of the magnetron, so that only the filament wires are connected and, with the unit in the "AC" mode, connect the leads across the filament connectors and check for 3.1 volts AC when the oven is operated. If there is any corrosion on the terminal connectors, the low-voltage filament current will have trouble lighting the tube. Clean all connections with contact cleaner and make sure all connectors are tight. If the problem has not been found yet, we must measure the AC and DC high-voltages.

WARNING: This part of the dynamic test involves measuring potentially lethal voltages so extreme care must be exercised. Never exceed 500 volts AC or DC when measuring voltage at input jack J1. With the oven unplugged and capacitor discharged, connect the black test lead to ground, move the red test lead to the HV jack J2, and connect the red test-lead clip to the high-voltage winding of the power transformer connected to the high-voltage capacitor. Double check all connections, stand back, and fire up the oven. The AC voltage should be in the area of 1500 to 2500 VAC. If that checks out, turn off and unplug the oven and




**THE DISPLAY BOARD can be made using this foil pattern.**

discharge the capacitor, move the red test clip to the other side of the capacitor, and switch the Microanalyzer to "DC."

Again, double check connections and fire up the oven. A normally operating oven will have a DC reading initially as high as 4.5 kV; as the magnetron fires up and current is drawn from the power supply, the reading will decrease to 2–2.5 kV and hold steady. Poor connections to the magnetron will usually show no voltage change, or a changing voltage as the connections make and break. A defective magnetron will either not fire and the high-voltage reading will remain high, or an intermittently shorting tube will cause the readings to be much lower than expected. Most better-quality ovens use a triac to power the transformer because they are much more reliable than a relay, but most technicians do not have a quick and positive way to test them. The Microanalyzer can be used to check the triac. The triac used in a typical microwave oven is usually either a one-inch square or round package about a half-inch thick with three terminals. The smallest terminal is the gate, or control pin, with the second main terminal (MT2) usually in the center, and the common, or first main terminal (MT1) opposite the gate.

Pull off the wires from the triac and connect the red test clip from J4 (the semiconductor test leads) to MT2, yellow to the gate, and black to MT1. Indicators LED1 and LED2 should be unlit; a shorted triac will light both LED's. Assuming the indicators are unlit, press test-switch S4; if the triac is switching, both indicators will light. If neither one lights, the triac is open and must be replaced. If only one LED lights, either the triac is partially defective, or it is an SCR.

If the oven uses a relay, open it and check for pitted or heat-damaged contacts; if required, burnish them, or replace the relay. If you believe the problem to be a relay drive transistor, the transistor may be tested by connecting the red J4 clip to the collector, yellow to base, and black to emitter. Initially, LED1 or LED2 may be lit dimly or may be dark, but pressing S4 will confirm the type and proper operation of the semiconductor. For the highest accuracy, the semiconductor may have to be removed from circuit if the readings in circuit are confusing. Triacs and SCR's should never light either indicator until S4 is depressed; a triac will light both LED's because it's an AC switching device, while an SCR or transistor will light only one indicator when S4 is pushed. NPN or PNP transistors may initially light either LED1 or LED2, but never both; if LED2 (N-CH) is lit before S4 is pressed, and dims after it is pressed, while LED1 illuminates, you have just checked a good NPN transistor. You must reverse readings for PNP.

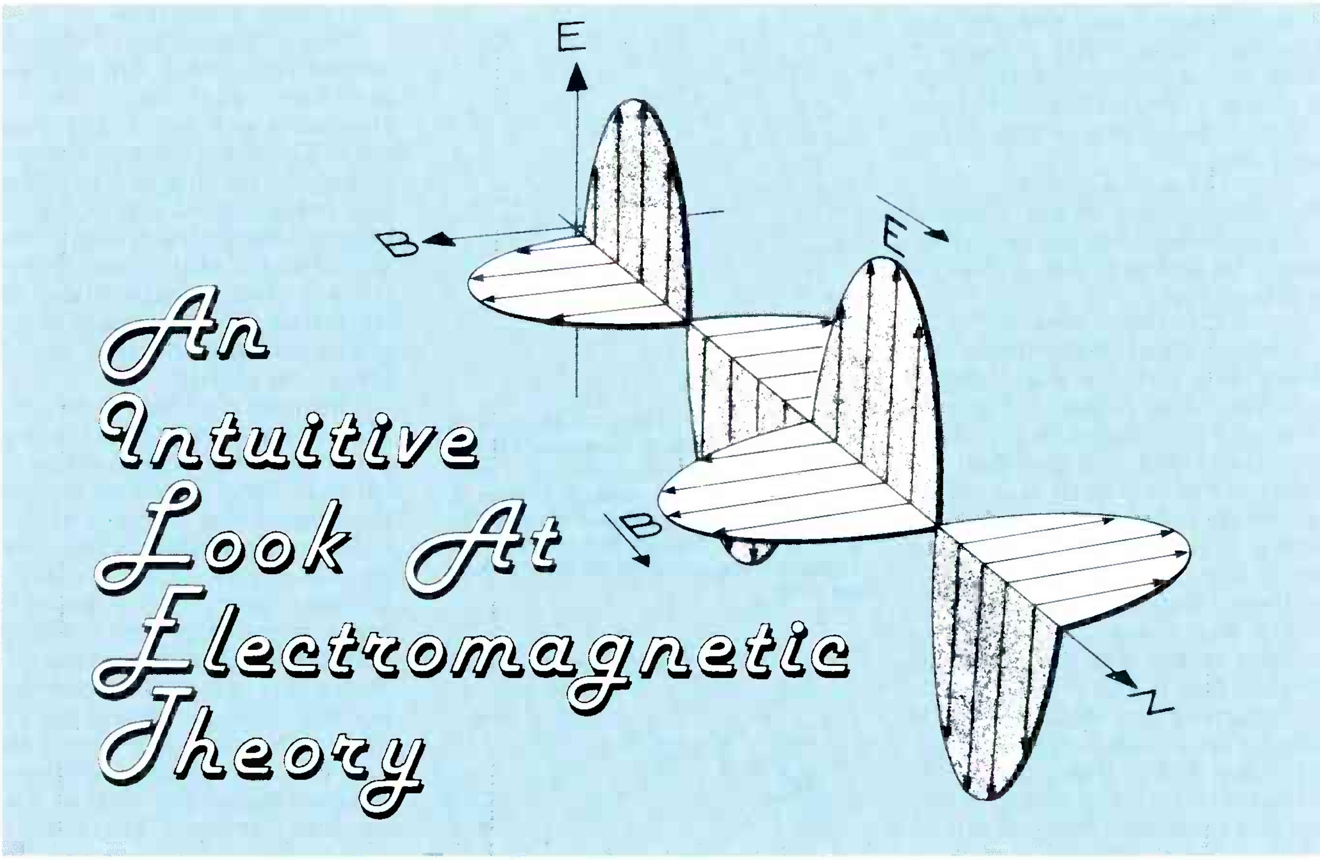
MOSFET's, usually intimidating to test, are easily checked with the Microanalyzer. Initially, a P- or N-channel device will illuminate either LED1 or LED2 respectively, and pushing S4 will cause the opposite LED to light, but without causing the original lamp to dim like ordinary bipolar transistors. Ordinary diodes can also be checked; with red at the anode and black at the cathode, LED1 will light.

If all components check out so far, but your microwave oven has the symptom of low heating, but otherwise seems to be working normally, check the waveguide cover at the top of the oven cavity at the exit of the waveguide. If it is coated with grease or food residues, it can absorb a large amount of power. Clean it with ammonia and water or, if it's burnt, replace it with the same type of plastic or mica material. A malfunctioning stirrer can also cause problems; that can be checked without even removing the oven cover. Stick several NE-2 neon bulbs in a styrofoam cup filled with water, and turn on the oven. A properly operating oven will ionize the neon gas and the neon bulbs will flash on and off as the stirrer rotates. If some lamps remain on while others stay off, the magnetron is good; the stirrer is inoperative. Check for a broken belt or a seized bearing in the stirrer mechanism.

A quick and dirty method of measuring microwave power is to run the oven for one minute at full power with eight ounces of water in a styrofoam cup (remember to start with cold water); a 500-watt oven will make the water almost too hot to stick a finger in, while a 750-watt unit will cause the water to steam.

The final check should be a test of the door seal with a properly calibrated microwave leakage tester. Although the FCC allows five milliwatts per square centimeter, most ovens will have almost unmeasurable leakage. **R-E**

# An Intuitive Look At Electromagnetic Theory




WILLIAM P. RICE

LAST TIME WE PRESENTED GENERAL concepts of electric fields and how they are related to static electric charges. We saw that the **E** field in empty space accounts for the forces between such charges. In this article, we'll see how the familiar units of volts and amperes are related to each other. Ohm's law and the concept of an **E** field in materials will be discussed with the help of a simple quantum theory viewpoint.

## Potential

To quasi-statically move a charge q from point a to point b in an **E** field, a force that is infinitely close to being equal and opposite to the Coulomb force must be applied to q. That force is $-q\mathbf{E} = -\mathbf{F}_c$, as shown in Fig. 1. As we discussed in our previous article, when moving around a closed path

$$\oint \mathbf{E}\cdot d\mathbf{l} = 0,$$

or

$$\nabla \times \mathbf{E} = 0$$

at all points. So in moving the charge around a closed path

$$-\oint q\mathbf{E}\cdot d\mathbf{l} = 0.$$

The dot product gives the magnitude of force times distance in the direction moved, which is the work done or change in the potential energy $\Delta U$. The energy expended in moving along the path from a to b is just the sum of the contributions along that path, as defined in the calculus notation

$$\Delta U_{ab} = -\int_a^b q\mathbf{E}\cdot d\mathbf{l} \text{ (newton} \times \text{meters = joules).}$$

The energy change is independent of the path taken from point a to b, and the **E** field follows the laws of conservation: whatever energy is expended in moving the charge from point a to b is recovered when the charge moves from b to a. The energy is said to be stored in the **E** field since the field is responsible for the force.

Dividing by the charge gives us the change in energy per unit charge, the potential or voltage at point b with respect to a is

$$V_{ab} = \frac{\Delta U_{ab}}{q} = -\int_a^b \mathbf{E}\cdot d\mathbf{l} \text{ (joules / coulomb = volts).}$$

The use of the name potential is perhaps unfortunate because it's easy to confuse the term with potential energy.

Recall also that since $\nabla \times \mathbf{E} = 0$, **E** must be the gradient of a scaler field, which we now see is the potential V, therefore

$\mathbf{E} = -\nabla V$ (volts/meter = newtons/coulomb).

Along a surface of equal potential, there would be no change in V per length **dl**. Perpendicular to that surface the change in V per length would be a maximum, which is what the gradient tells us.

Since the field is obtainable by linear superposition, the potential difference is simply the sum of the potentials. For example, $V_{ac} = V_{ab} + V_{bc}$. That analysis is the basis of Kirchoff's voltage law, which states that the algebraic sum of the voltage rises and drops around a closed path must equal zero.

## Electric current

Imagine a Gaussian surface in space through which a number of q charges are moving, as shown in Fig. 2. (We are not concerned with the type of field influencing the motion, only that there is motion.) The current across that surface is defined as the charge per unit time (in seconds) crossing the surface. In order to calculate that, divide the surface into an infinite number of infinitesimal surfaces, **ds**. The charges move with velocity **v** through each surface. If there are n charges per unit volume, then the current density, or charge per unit area is

$$\mathbf{J} = nq\mathbf{v} = \rho\mathbf{v} \text{ (C/m}^2\text{s)}.$$

Multiplying that by the effective area and summing the contributions by integration gives the total current

$$I = \int \mathbf{J} \cdot d\mathbf{s} \text{ (C/s = amperes)}.$$

Positive charges flowing in one direction can be considered equivalent to negative charges flowing in the opposite direction (the Hall effect is a common exception) since both **J** and **ds** would then be negative. That is why a circuit can be analyzed in terms of either conventional currents or electron currents.

The way current is defined is similar to the way we explained electric flux ω except that flux is an apparent flow while current is due to an actual flow of charge. Charge conservation tells us that whatever charge flows into the surface must also flow out unless the current density inside is changing in time. That is the basis of Kirchhoff's current law, which tells us that the sum of the currents flowing into a junction is equal to the sum of the currents flowing out of that junction. Shrinking the Gaussian surface down to a single point and taking the ratio of the rate of change in current to the rate of change in volume gives the divergence

$$\nabla \cdot \mathbf{J} = -\frac{\partial \rho}{\partial t} \text{ (C/m}^3\text{s)}.$$

The partial differential symbol ∂, as in d, means an infinitesimal change in something. It also reminds us that we're only interested in ρ's change with respect to time, t. The negative sign indicates that a decrease in ρ, a negative $\partial\rho/\partial t$, gives a positive divergence. The net charge must therefore flow out through the surface.

## Conductivity

Up until this point we have been concerned only with charges in empty space. The space of solid materials, however, is far from empty. Atoms are located at positions called lattice points. An external **E** field applied to a solid material causes the electrons with a $-e$ charge to

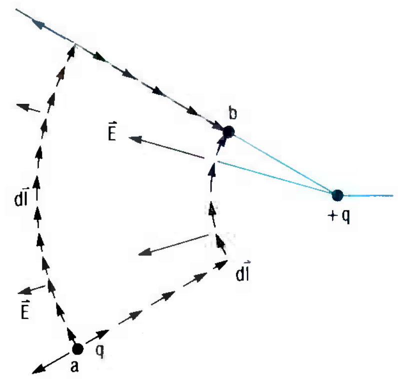



**FIG. 1—AN ELECTRIC CHARGE q is moved quasi-statically from point a to b in a static E field along either path, composed of an infinite number of lengths dl, by an external force qE (not shown). The work done or change in energy is the negative of the sum of all the qE·dl's along the path.**

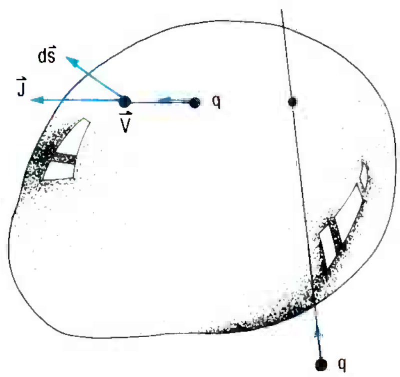



**FIG. 2—CURRENT DENSITY J is the number of charges q per unit volume moving with velocity v through an infinitesimal section ds of the Gaussian surface. The total current is found by summing J·ds over the entire surface. Any charge that comes in through one ds must leave through another. Any net outflow must be at the expense of the charge density enclosed by the surface.**

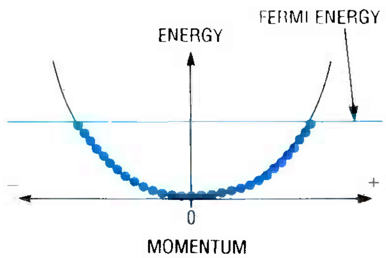



**FIG. 3—ENERGY VERSUS MOMENTUM for electrons in a material. Temperature and lattice effects are neglected. Each electron, represented by a dot on the curve, has a unique energy state. Those are the lowest states available. The highest occupied energy is called the Fermi energy.**

move. Quantum theory must be used to describe the effects of temperature and the lattice upon the motion of charges.

The electrons are in a state described by their energy, momentum, and spin. No two electrons can be in the same state. Electrons can change energy only by moving to a neighboring unoccupied energy state. Figure 3 shows the energy versus momentum states, neglecting the effects of temperature and the lattice. The two possible spin states for each electron are not shown for clarity.

The more electrons there are in the material, the higher the highest occupied energy state, or Fermi level. Only electrons near the Fermi level can respond to external effects such as thermal energy and electric fields. Supplying thermal energy excites some electrons to energies just above the Fermi level, leaving unoccupied states just below. The Fermi level is then taken as the energy with 50% occupancy. Electrons that can change energy, and hence momentum, are called conduction electrons. Thermally excited electrons have random momentum and velocity, and do not produce a net current.

Electrons act as waves and, therefore, experience interference effects due to interaction with the lattice. At certain wavelengths, standing waves result which produce energy gaps, as shown in Fig. 4. If only some of the energy states up to the gap are occupied or the gap is very small, the material will have many conduction electrons since little external energy is required to excite an electron to a higher state. Such materials are good electrical conductors. A good insulator (or dielectric) has occupied states up to a relatively large gap. A large amount of external energy is required to excite electrons to higher energies in a dielectric material. A material with a large gap and many occupied lower states exhibits noticeable electrical resistance.

If a potential difference is maintained across a material, an electric field is established. Conduction electrons will be subjected to a force **F**, which is equal to $-e\mathbf{E}$. Electrons tend to accelerate, and then "collide" and lose energy to the lattice. If τ is the average time between collisions, which is temperature dependent due to thermal motion of the lat-

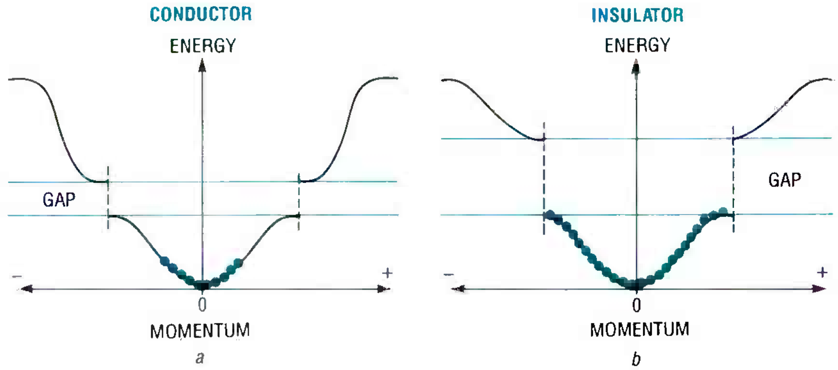



**FIG. 4—ENERGY VERSUS MOMENTUM** for electrons is a lattice of atoms. The gaps in the curves result from interference effects with the electron waves. In a conductor (*a*) the levels below the gap are partially occupied. External energy excites electrons to the unoccupied energy states. That allows them to participate in an electric current. In an insulator (*b*) the levels below the gap are filled and the energy gaps are large. Electrons cannot participate in a current unless a large amount of external energy is supplied.

tice atoms, then the average electron momentum is

$$\mathbf{F}\tau = -e\mathbf{E}\tau = m + \mathbf{v} \quad (\mathrm{N{\cdot}s} = \mathrm{kg{\cdot}m/s})$$

where m is the electron mass, and **v** is the average velocity. Solving for the velocity and substituting into the equation for current density gives us

$$\mathbf{J} = \frac{ne^2\tau}{m}\mathbf{E}$$

which is the vector form of Ohm's law. Since the number of electrons n and τ are properties of the material, the conductivity

$$\sigma = ne^2\tau/m \quad (\mathrm{C^2s/kg} = 1/(\Omega{\cdot}\mathrm{m}))$$

is a property of the material. The resistivity is defined as r = 1/σ. If the material is of uniform cross-sectional area S and of length L, **J** is uniform and normal to d**s**, therefore the current is

$$I = JS = \sigma\frac{V}{L}S$$

or V = IR where R = rL/S is resistance in more familiar units of ohms.

In metals, increasing the thermal energy excites electrons mainly into the unoccupied states of the lower band, but the time between lattice collisions decreases. Increasing the temperature increases the resistance. In some other materials resistance decreases with increasing temperature because the number of conduction electrons exceeds the effect of increased collision time.

Due to the low velocity of electrons in most solids, the magnetic effects can be neglected. Conduction becomes more complicated in gases and liquids since the atoms can also move, and velocities can become greater than in solids.

## The electric field in materials

When a material is placed in an external electric field $\mathbf{E}_o$, the wave functions of the atoms are changed. The net effect is that the regions with probability of finding electrons are shifted in the $-\mathbf{E}_o$ direction while the regions with probability of finding the positively charged nuclei are shifted in the direction of $+\mathbf{E}_o$ (Fig. 5). The shifts may not exactly align parallel to $\mathbf{E}_o$, and may not all be uniform except in what we call simple materials. A negative surface charge develops on the material near the source of $\mathbf{E}_o$, and a positive surface charge develops on the opposite side. We say the material has an induced charge, or that it is electrically polarized.

The induced charges produce a field $\mathbf{E}_d$ in the opposite direction to $\mathbf{E}_o$ in the material. In a very good conductor, there are enough free charges so that $\mathbf{E}_d$ equals $\mathbf{E}_o$, and the average field inside is zero. That is why metal is an effective shielding material, at least for static fields. Outside the conductor the $\mathbf{E}_o$ field vectors are changed so that they are normal to the surface.

In dielectrics, the large energy gap means the electrons are elastically attached to the lattice and only slight shifts are experienced. $\mathbf{E}_o$ and $\mathbf{E}_d$ don't cancel each other completely. In a simple dielectric, pairs of internal charges, −q and +q, are separated by a distance **R** taken in the direction of $\mathbf{E}_o$, from −q to +q. Those pairs of negative −q and positive +q charges are called electric dipoles. The vector quantity, q**R**, is called the electric dipole moment. If there are n dipoles per unit volume, then a measure of the polarization can be expressed as

$$\mathbf{P} = n(q\mathbf{R})\zeta \quad (\mathrm{C{\cdot}m/m^3} = \mathrm{C/m^2}),$$

which is called the dipole moment per unit volume. ζ is a function of the alignment and ranges from 0 to 1. For simple materials ζ = 1. Since n, q, **R**, and ζ depend on the material,

$$\mathbf{P} = \epsilon_o \varkappa \mathbf{E}$$

where ϰ, the electric susceptibility, is a measure of the ease of polarization of the material. $\epsilon_o$ is present to maintain correct units. The so called depolarization field $\mathbf{E}_d$ is equal to $-\gamma\mathbf{P}/\epsilon_o$, where γ is a number between 0 and 1, and is related to the geometry of the material. $\mathbf{E}_d$ is not, in general, very useful.

The surface charge $\sigma_b$ is an actual accumulation of charges

*continued on page 82*

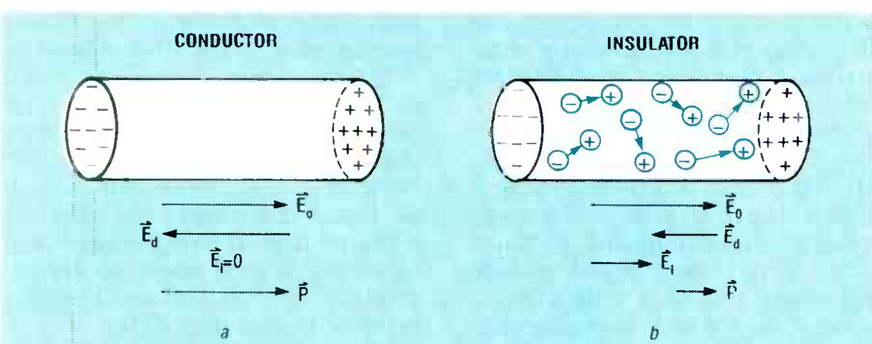
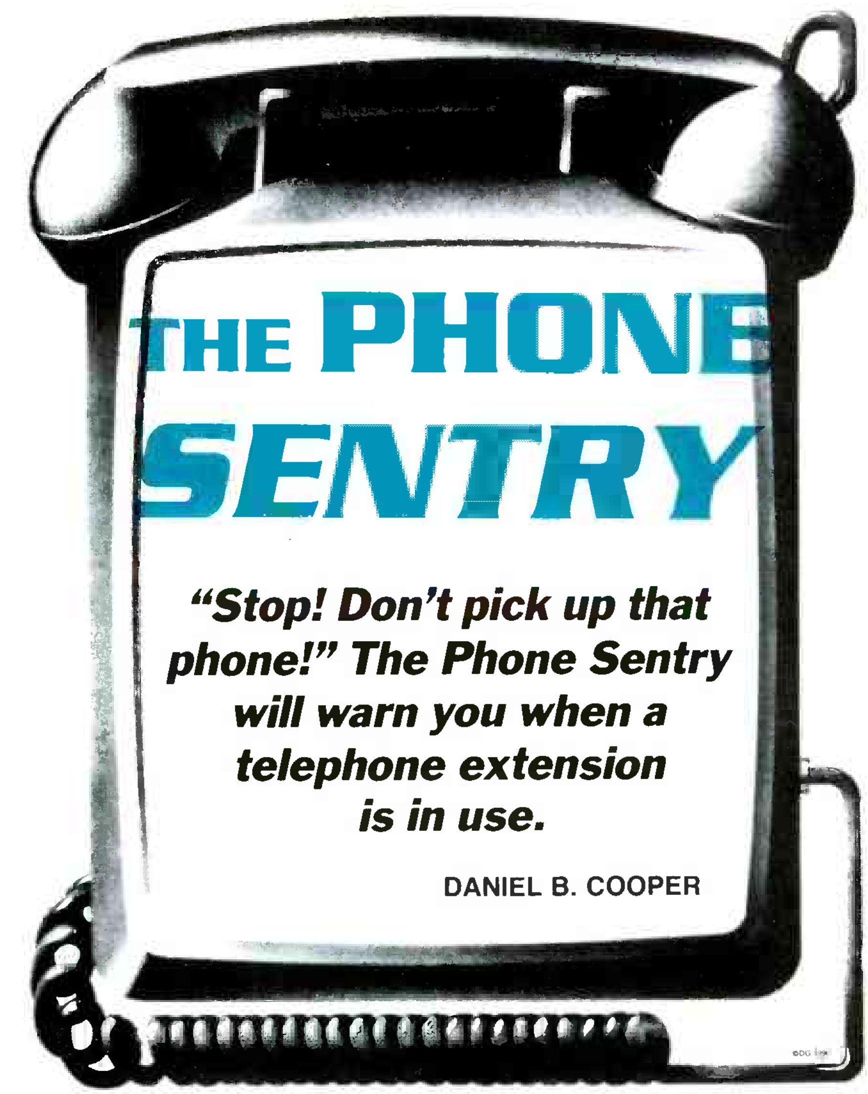



**FIG. 5—MATERIALS IN AN EXTERNAL ELECTRIC FIELD $E_o$** exhibit electric polarization. The resulting separation of positive and negative charge regions produce electric dipole moments qR, where q is taken as positive. In a conductor (*a*), enough electrons are free to move to create a depolarization field $E_d$ equal and opposite to $E_o$. The internal electric field $E_i = E_o - E_d$ is zero. In an insulator or dielectric (*b*), electrons are restricted in movement and $E_i$ is non zero. In both cases, the polarization or dipole moment per unit volume P is related to $-E_d$. The vectors are shown outside the material for clarity.



# THE PHONE SENTRY

***"Stop! Don't pick up that phone!" The Phone Sentry will warn you when a telephone extension is in use.***

DANIEL B. COOPER

If your home or office has more than one telephone extension, you've probably had the unpleasant experience of picking up the phone only to find it already in use. You may get an angry response from the person on the other end. If a modem is in use, you'll be greeted by the obnoxious squall of two computers exchanging bits. Such an interruption usually means a lost connection, or the corruption of a file being transferred.

A solution to that problem is the Phone Sentry—an inexpensive, simple, reliable indicator that warns you when a phone extension is in use. The Phone Sentry is easy to build and install in one evening, and presents no load to the phone line. It's small, inconspicuous, and costs only $5 a copy.

**How it works**

To understand how the Phone Sentry works, you need to understand how the telephone system works—or, at least, how the local subscriber loop works, since that's the part that enters into your house.

The telephone line is held at about 45 volts DC by the local switching office when it's hung up. When a telephone is taken off its hook, a 1K load brings the line down to 6 volts DC. The line stays at 6 volts DC until you hang up, then it returns to 45 volts DC and is disconnected.

The Phone Sentry operates by monitoring the telephone line voltage and switching on a flashing LED whenever the voltage drops below 20 volts. The Phone Sentry can be placed anywhere on a phone line, not just on an extension in use.

**Circuit operation**

The Phone Sentry circuit is deceptively simple, yet elegant in design. At the heart of the circuit is IC1, a CMOS CD4093B quad NAND gate Schmitt trigger.

Ordinary CMOS gates switch midway between the voltage of the positive and negative supplies. For a circuit powered from 5 volts, this point (called 0.5 V+) is 2.5 volts. When the input voltage rises past or falls below that point, the output will switch. Normally, that's a desirable characteristic, and is one of CMOS's good points. However, when a CMOS input is presented with a slowly changing or noisy input, the symmetrical switching characteristic can cause the circuit to jitter or oscillate as the input nears the 0.5 +V point.

The Schmitt trigger input handles noisy environments by separating the rising and falling voltage-switching points. A Schmitt trigger input will react to a rising input voltage only when it passes a threshold that is higher than 50% of the supply voltage, usually about 70%, or 0.7 +V. A falling input voltage will cause a change only when it falls below a much lower threshold of about 30% of the supply, or 0.3 +V. An input voltage between those two thresholds will have no effect until it rises above 0.7 +V, or falls below 0.3 +V.

The region between the 70% and 30% switching levels is called the hysteresis gap, or dead band. Hysteresis permits a Schmitt trigger input to respond very cleanly to noisy or irregular input signals. It also permits some fancy tricks, such as one-gate oscillators. It is the latter capability for which a Schmitt NAND gate is used in the Phone Sentry.

Figure 1 shows a block diagram of the Phone Sentry. The four gates of the CD4093B are used as three separate elements. One Schmitt-trigger NAND gate acts as an input comparator to monitor a phone line. It in turn gates another NAND gate used as an oscillator, which drives a high-current buffer for LED1.

The schematic of the Phone Sentry is shown in Fig. 2, with its circuit waveforms at critical locations shown in Fig. 3. Bridge rectifier D1–D4 eliminates any phone-line polarity problems. It also removes the 80-volt peak-to-peak ring signal, which could damage the Phone sentry or make LED1 flicker.

The output of the bridge rectifier is divided down by R1-R2, with 27% of the input voltage reaching IC1-a. 27% represents the voltage divider of the [R2/(R1 + R2)] ratio, which equals

$$[1 \text{ megohm}/(1 \text{ megohm} + 2.7 \text{ megohm})] = 0.27$$

The bridge always presents two of the four diodes as a phone-line load, D1-D4 or D2-D3, dropping the line voltage down by 0.7 volts DC each, or 1.4 volts total. Since the input impedances of pins 12 and 13 of IC1-a are almost infinite, they draw no current. What appears across R1 and R2 in series should be about

$$45 \text{ V} - 1.4 \text{ V} = 43.6 \text{ V}.$$

The voltage at pins 12 and 13 with the phone hung up is therefore

$$43.6 \text{ V} \times 0.27 = 11.78 \text{ V},$$

which is 2.78 volts above the 9-volt DC supply. The IC, however, is protected from overcurrent burnout by R1 and internal diodes. When an extension is in use, the 6 volts on the line goes down to

$$(6 \text{ V} - 1.4 \text{ V}) \times 0.27 = 1.24 \text{ V}.$$

Capacitor C1 filters out small spikes that can be generated during the ringing cycle, protecting the IC and eliminating any residual tendency of the LED to flicker.

Because the comparator is a Schmitt NAND gate, its output (pin 11) will be low whenever the input voltage is above about 6.3 volts (70% of 9 volts), and high whenever the input drops below about 2.7 volts (30% of 9 volts). Those switching values fit perfectly with the 11.78 and 1.24 volts generated from the phone line by the rectifier and divider. The output will be low when all phones are on-hook, and high when any phone is picked up, or a modem is connected to the line.

The LED could be driven directly by IC1-a, but B1 would be drained in about 10 hours because LED1 draws 10 milliamps when lit. To extend battery life to at least 100 hours, IC1-b, the low 5% duty-cycle oscillator, is gated by IC1-a, driving LED1 and giving a bright flash with much lower current drain.

The output of the comparator is used to gate an oscillator on and off. That oscillator consists

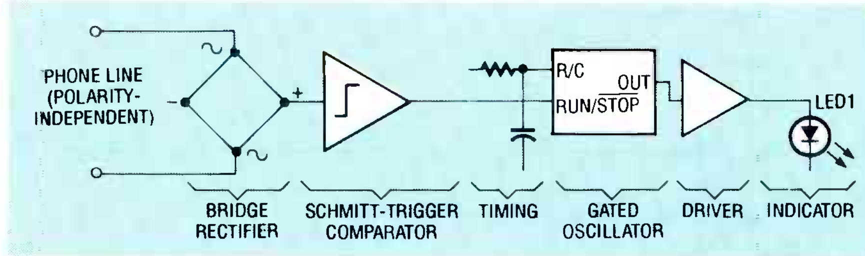



**FIG. 1—BLOCK DIAGRAM OF THE PHONE SENTRY. The rectified phone-line voltage drives a comparator, whose output gates a low duty-cycle oscillator. The oscillator drives a CMOS buffer/driver. The period and duty cycle of the oscillator are controlled by timing components R3, R4, and C2.**

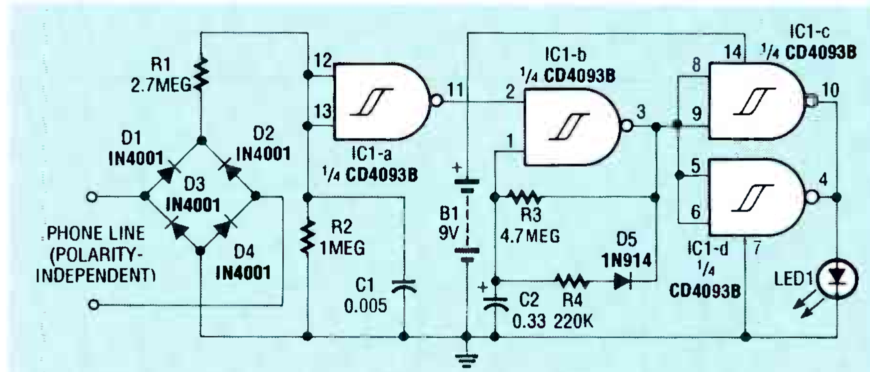
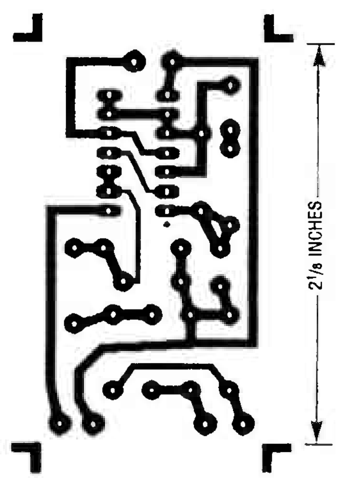



**FIG. 2—SCHEMATIC OF THE PHONE SENTRY, using a CD4093B quad NAND-gate Schmitt trigger. The green (tip) and red (ring) phone-line wires are polarity-independent due to D1–D4. Input comparator IC1-a gates IC1-b, a single-gate oscillator, which drives IC1-c and -d, used in tandem as a high-current buffer/driver.**




**THE PC-BOARD FOIL PATTERN FOR the Phone Sentry.**

of a second Schmitt NAND gate (IC1-b), R3, R4, C2, and D5. When pin 2 of IC1 is held low by the comparator, the output of the gate is held high. That output is used to charge timing capacitor, C2, through timing resistor R3. The junction of components R3 and C2 is connected to pin 1. With the output held high, the charge on C2 will rise to the level of the supply voltage.

When a phone is picked up and the loop voltage drops, the comparator's output goes high and the oscillator is enabled. Since

### PARTS LIST

**All resistors are ¼-watt, 5%.**
R1—2.7 megohms
R2—1 megohm
R3—4.7 megohms
R4—220,000 ohms
**Capacitors**
C1—0.005 µF, 100 volts, disc or monolithic
C2—0.33 µF, 16 volts, tantalum or electrolytic
**Semiconductors**
D1–D4—1N4001 diode
D5—1N4148 diode
IC1—CD4093B quad Schmitt trigger NAND-gate
LED1—light-emitting diode, any size or color
**Miscellaneous:** 9-volt alkaline battery with clip, PC board (see foil pattern), 22-AWG wire, plastic case (optional), LED mounting clip (optional), modular plug-to-bare wire phone cable (optional), two-way phone jack duplexer, 14-pin DIP IC socket.

both inputs are now high, the output switches low. The charge of C2 is drained, partly through R3, but more quickly through R4 and D5. When the voltage at pin 1 drops below the Schmitt input's lower threshold, the output of the gate switches high, and the capacitor begins charging again through R3. When the capacitor voltage reaches the Schmitt's upper threshold, the output switch-

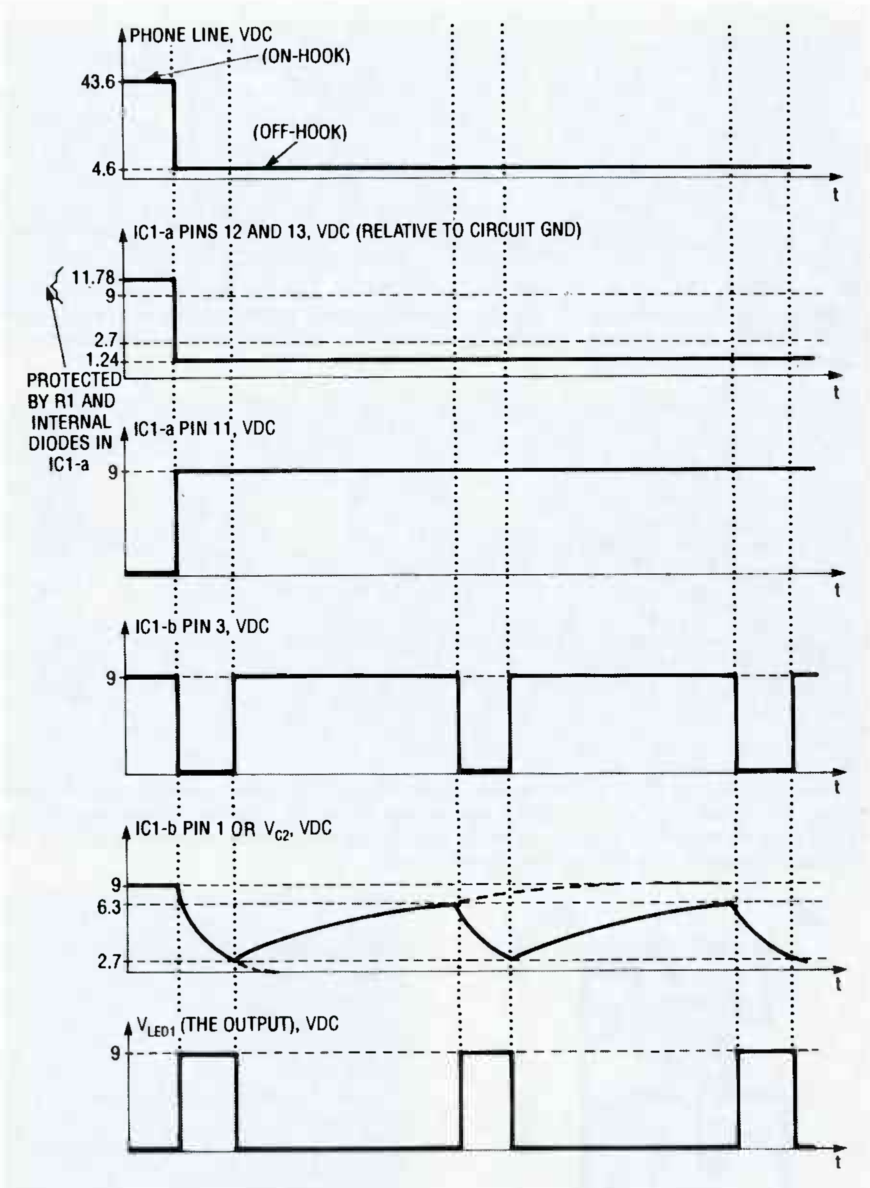



FIG. 3—CIRCUIT WAVEFORMS OF THE Phone Sentry. Shown are the voltages on the phone line, pins 12 and 13 of IC1-a, pin 11 of IC1-a, pin 3 of IC1-b, pin 1 of IC1-b (the voltage across C2), and across LED1.

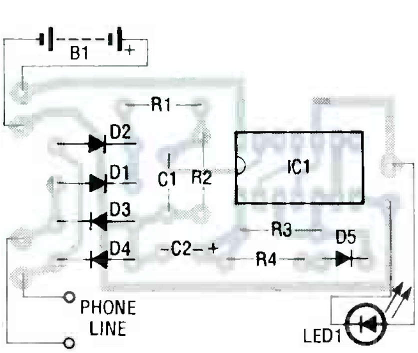



FIG. 4—THE PARTS PLACEMENT DIAGRAM of the Phone Sentry. You can mount LED1 in several ways, depending on how you mount the PC board.

es low again and the process repeats until the gating input is again brought low by the phone going back on-hook.

The output of the oscillator (pin 3) is inverted and used to drive the indicator LED. When the oscillator's output is high, the output of the driver (pins 10 and 4) is low, and the LED is off. When the oscillator output is low, the driver output is high, and the LED is on. Since the capacitor discharge time (oscillator output low) is much shorter than the charge time (oscillator output high), the LED is on much less time than it is off, resulting in a very low duty cycle, and low battery drain.

Because the capacitor starts each cycle charged much higher than the Schmitt input's upper threshold, it takes longer to discharge to the lower threshold the first time. Therefore, the first flash of the LED is longer and brighter than those that follow. That's a nice touch, because all of the Phone Sentries in the house will give an initial bright flash when a phone is first picked up to answer a call.

## Construction and installation

The Phone Sentry can be assembled on either a PC board, shown here, or on perforated construction board of similar size. The PC board is about the size of B1, so housing the unit is simple, and its construction is straightforward. Figure 4 shows the parts placement diagram; use a socket for IC1, and install it using proper anti-static handling techniques.

The Phone Sentry is small, with several installation options. Once you decide how to mount it, you can select how to wire both the phone line and LED1. If you put the Phone Sentry inside an extension or a wall-mount jack, then solder a foot of 22-AWG wire to each input terminal.

If you use a small case for plugging into a wall socket, solder the green (tip) and red (ring) wires of a modular plug-to-bare-wire phone cord, and clip the yellow and black wires. You may want to solder LED1 directly to the PC board, or mount it in a visible location with two 6-inch pieces of stiff wire.

You can mount both the PC board and B1 in a standard desk phone. Open the phone and secure both the PC board and battery clip to the baseplate with double-sided foam tape. Drill a small hole in the dialing button escutcheon, and use silicone sealant or an LED clip to mount LED1. Connect the two input wires to the tip and ring wires, insert B1, replace the cover, and plug the phone back in.

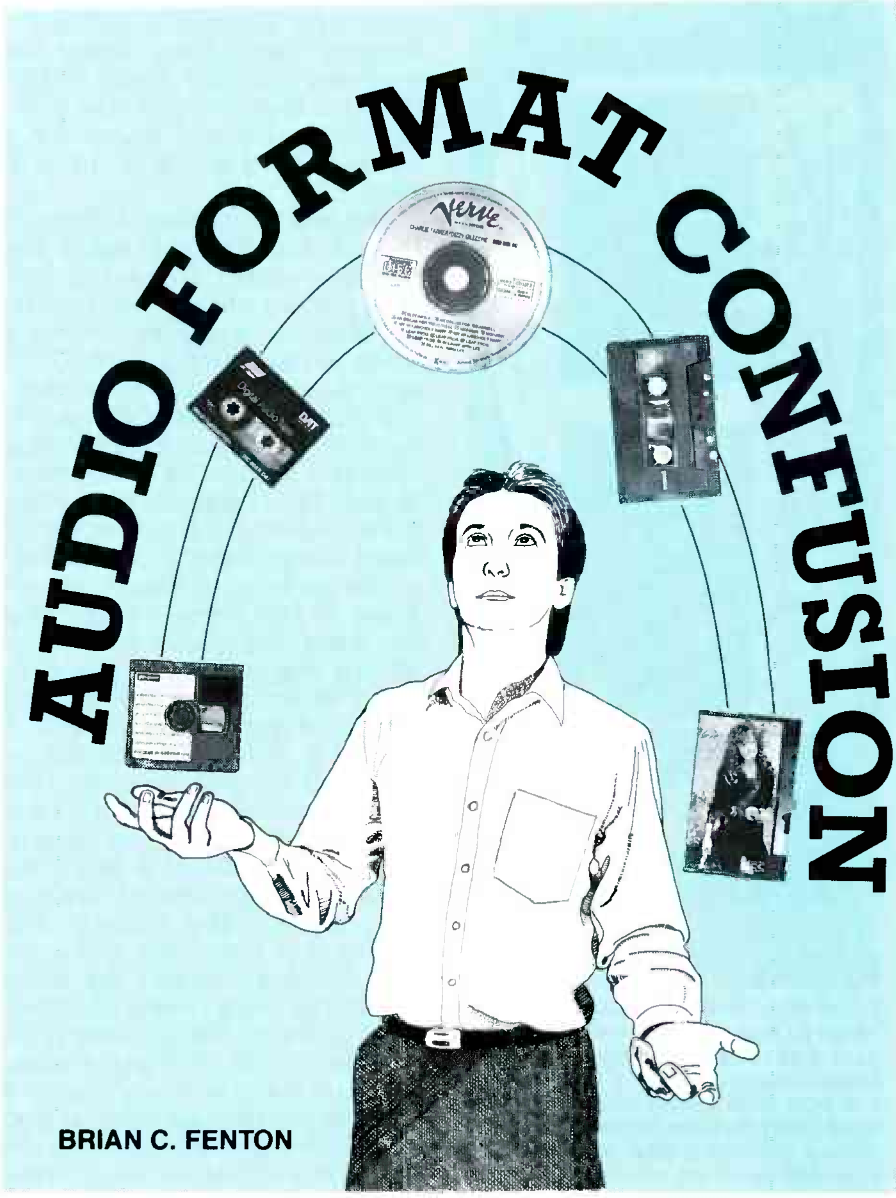
If there's no space for the Phone Sentry and B1, use a small plastic box on the side of the phone for the PC board, B1, and LED1, and pass the tip and ring wires through a hole in the box and phone case to the connecting points inside the phone. For a wall phone, mount the same case near the wall jack and run the wiring into the wall jack, so it's independent of the phone. **R-E**

IT'S BEEN LESS THAN A DECADE sense the compact disc was introduced. In that short time, the CD has brought high-quality audio reproduction to the masses, and taught us to appreciate good sound. We're not exaggerating when we say that the CD has changed the way we listen to music.

It's rare for a new technology and format to catch on so quickly—especially one that threatens to make its predecessors obsolete. CD was a success not only because of consumer acceptance, but because it also offered something to manufacturers, recording companies, and retailers.

It wasn't the CD's "gee whiz" appeal—nor was it the promise of perfect audio reproduction—that caused sales to catch fire. It was *convenience*. When compared to the LP that it replaced, CD's were a dramatic breakthrough. They can store more audio in a package a fraction of the size. They can be lent to even your most careless friends without getting scratched. They even play back more conveniently, because you can skip tracks that you don't want to listen to, or re-arrange the order in which the songs play back.

It's convenience, also, that makes the venerable compact cassette our music medium of choice. (Cassettes outsell CD's by a ratio of about 1.5:1.) They fit in your shirt pocket, and they stand up reasonably well to abuse. They're ideal for use in a car or in a personal stereo because they're relatively immune to shocks. So what if they can't come close to the audio quality of a CD or even an LP?




# AUDIO FORMAT CONFUSION

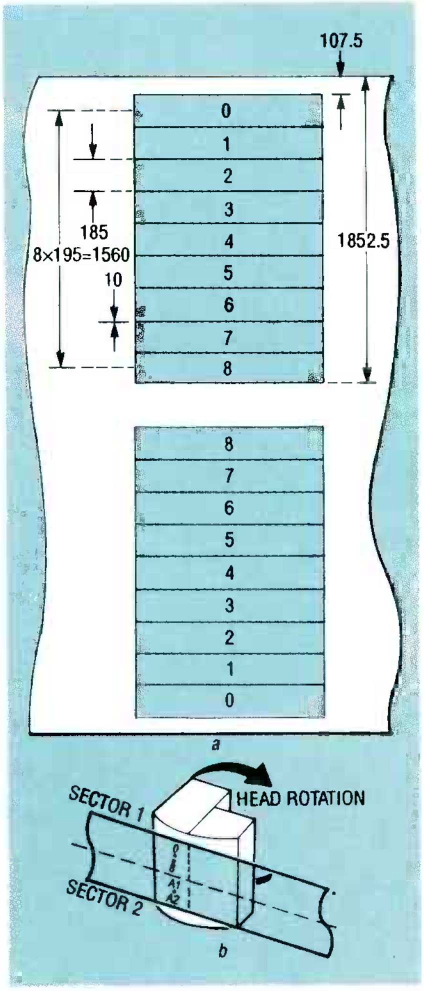
BRIAN C. FENTON

***Two new digital audio formats—Sony's Mini Disc and Philips' Digital Compact Cassette—promise to battle each other as they create consumer confusion.***

**How about DAT?**

In the belief that consumers had fallen so much in love with the idea of digital audio because of their exposure to CD, Japanese manufacturers reasoned that Digital Audio Tape (DAT) would be to the CD what the compact cassette was to the LP. Unfortunately, it didn't work out that way for a number of reasons. First, the record industry, spearheaded by the RIAA (Recording Industry Association of America), threatened lawsuits against any Japanese manufacturer who exported the DAT machines to the U.S. The RIAA was concerned about DAT's potential to make virtually perfect copies of CD's. (They seemingly missed the fact that, for most people, cassettes do the same thing. And despite that, *pre-recorded* cassettes have outsold both LP's and CD's combined since 1982! They've outsold blank tapes as well.) The threats of lawsuits were enough to stop DAT dead in its tracks, despite considerable accolades for the format in the audio and general press.

Although some DAT machines were available on the "gray market" of unofficially imported goods, DAT officially arrived in the U.S. market last year—with generally disappointing results. Whether it was the years of delay, the taint of the lawsuits, the expense of the machines, or the lack of pre-recorded software that have killed DAT in the consumer market, we'll never know for sure. Perhaps DAT failed because




**EIGHT TRACKS OF MUSIC DATA are contained on each "side" of the Digital Compact Cassette, as shown in *a*. (All dimensions shown are in micrometers.) The DCC head shown in *b* is manufactured using thin-film techniques. It contains a set of 8 digital recording and playback heads as well as two analog playback heads.**

it doesn't offer the avarage consumer anything that they're not already getting from their favorite compact cassettes.

Although the compact cassette—even with its inherent problems—is just fine for most people, Philips, the originators of the compact cassette, was convinced that the format could be improved, and that consumers would buy into the updated format. Thus, DCC, the Digital Compact Cassette, was born.

## Enter DCC

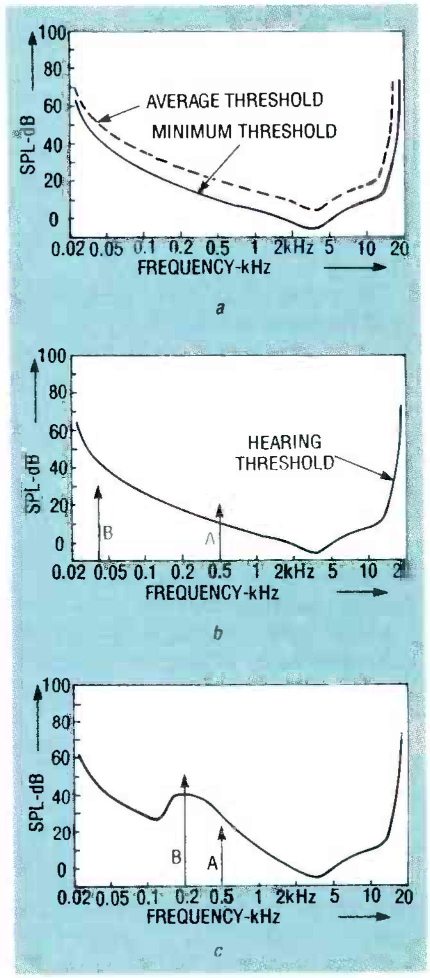
In January of this year, Philips announced that "a new era of audio reproduction has started." DCC, a digital extension of the compact cassette, would offer "the best opportunity available for consumers and industry to enter into the field of digital recording." Tandy Corporation announced that they would be the first U.S. licensee of Philips' technology, and would introduce a home recording deck in late 1992.

The most important feature of DCC is that it doesn't make the familiar cassette obsolete. All DCC players will play back existing analog cassettes, so even when you make the jump to DCC, you can still listen to your existing library of tapes. (You won't, however, be able to record analog cassettes on your DCC machine, or play DCC tapes on your standard cassette deck.) That "backward compatibility" could convince some consumers to upgrade to DCC even though they like what they already have. After all, an upgrade won't just give them better sound, but as we'll see, more convenience as well.

A DCC deck is essentially a standard cassette recorder that includes some extra digital electronics and a new head design. The dimensions of a DCC cassette are essentially the same as that of a standard cassette, but the digital cassette's sides are flat—the case doesn't get fatter where the head enters the shell. Also, since the DCC standard demands that all DCC players feature auto-reverse, there's never a need to flip the tape over, so you don't need to have holes for the reels on both sides of the cassette. That means that one full side of the cassette can be used for information and graphics—something the recording companies love.

The spool holes and the tape surface are protected against dust and fingers by a sliding metal cover, which also locks the tape hubs. There's no need for an carrying case, so the digital cassette is easier to use and store, especially in a car.

The key to maintaining compatibility with standard cassettes is a new thin-film semiconductor head, manufactured using a process similar to that used for integrated circuits. The first layer of the head contains one set of 9 magneto-resistive heads for digital playback, and a pair of similar heads for analog playback. On the second head layer is one set of 9 integrated




**PHILIPS' PASC ENCODING ignores sounds that are below the hearing threshold (*a*). Of the signals shown in *b*, only A would be recorded because B, below the hearing threshold, would not be heard. The hearing threshold, however, varies dynamically depending on what other signals are present. In *c*, signal B has altered the threshold, making A inaudible.**

recording heads for digital recording. We'll see shortly why 9 digital heads are required.

## PASC makes it work

The key to the DCC system is the a new digital coding technique called PASC, or precision adaptive sub-band coding. The goal of PASC is to produce a signal equivalent to that of a CD. The results? A dynamic range better than 105 dB, and a total harmonic distortion, including noise, of less than 0.0025%

PASC is based on two important phychoacoustic principles. The first is that we can hear sounds only if they're above a certain level, called the hearing threshold. The second is that loud signals mask soft ones by raising the hearing threshold.

The hearing threshold, as you might expect, varies from person to person. Even a very sensitive ear, however, won't be able to hear a sound if it is masked by a louder sound. (You couldn't, for example, hear an unamplified violin at a rock 'n' roll concert!) The theory behind PASC's efficiency can be expressed by the question, "If you can't hear it, why record it?"

During encoding, the PASC processor analyzes the audio signal by splitting it into 32 subband signals. By continuously taking into account the dynamic variations of the hearing threshold, the PASC processor encodes only the sounds that will be audible to the human ear. Each subband is allocated the number of bits that are required to accurately encode the sound within it. If a subband doesn't require .ny bits—because it contains sounds that are masked, for example—its bits are re-allocated to other subbands so that the sounds within them can be encoded more accurately. On average, the PASC system needs to encode only one quarter the number of bits that a CD or DAT encoder would to reproduce a given audio signal.

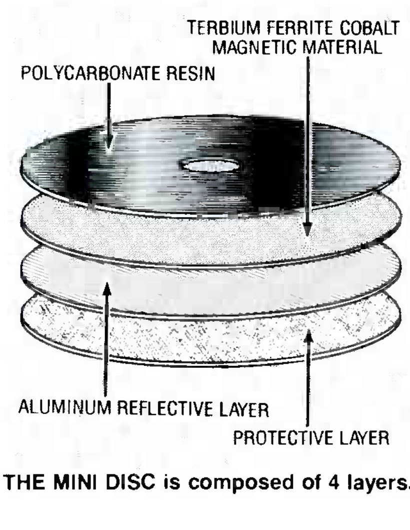
The encoded data is multiplexed into an 8-channel data stream, and error-detection and -correction codes are added. The eight channels are recorded on 8 parallel tracks on the DCC tape. The ninth track can be used to carry auxiliary data, such as song titles, recording times, and the like). The auxiliary track could be used to generate hundreds of characters of text per second, so decks could include readouts for song lyrics or other information about the selection.

A PROTOTYPE MINI DISC player and a pre-recorded disc.

DCC, an elegant extension of the most popular music carrier we have, seemed to be a sure-fire hit. It had something for everyone, including hardware manufacturers, record companies, retailers, and consumers. It now appears, however, to have run up against a formidable competitor: Sony's Mini Disc.

## Sony's Mini Disc

In May of this year, in what seemed to be a deliberate attempt to derail DCC before it got moving, Sony announced a brand new recordable audio format, the Mini Disc or MD. Sony, however, denied that their MD was meant to compete with DCC. In response to the question of what MD replaces, the President of Sony Corporation of America answered "We are replacing nothing. We are Creating new markets."



THE MINI DISC is composed of 4 layers.

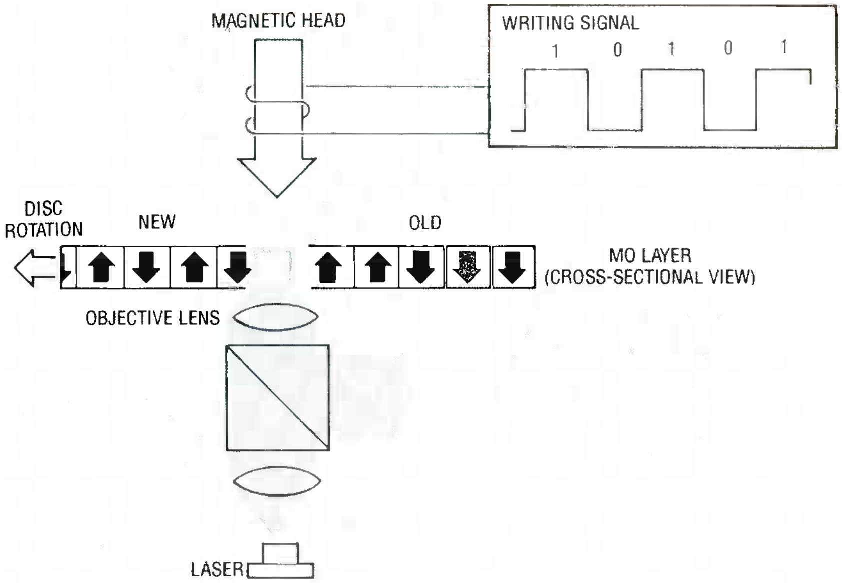
The Mini Disc format is specifically designed for portable applications (personal stereos, boom boxes, etc.) and is slated for introduction, conveniently, in late 1992—the same time that DCC decks are due. The disc, about 2½ inches in diameter, looks—and acts—like a cross between a compact disc and a micro floppy computer disk. Like a compact disc, the Mini Disc is an optical medium—it is read by a laser and can store up to 74 minutes of digital audio. Like a floppy disk, the mini disc can be magnetically recorded again and again.

How did they manage to get the same capacity as a CD on a disc that has about ¼ the surface area? Interestingly, by treating audio in much the same way as DCC does. Sony's encoding scheme, which is called ATRAC, or adaptive transform acoustic coding, is also based on the psychoacoustic principles regarding the threshold of hearing and the masking effect.

Because the ATRAC encoder ignores sounds that fall below the threshold of hearing (which varies dynamically because of signal masking) it can encode data five times more efficiently than CD or DAT systems. That's even better than DCC's 4:1 advantage!

Can a recording that "leaves out 80% of the bits" sound as good as a CD? In theory, if all you're leaving out is things you can't hear, then yes. In practice, we don't know yet. At Sony's announcement, they demonstrated a prototype by playing some pop/rock for a half minute or so. It sounded OK, we guess, considering that the listening environment was a crowded hotel meeting room. No A/B comparisons were provided between CD and MD. Sony claims that "only 2% of the population will be able to hear the difference."

The Mini Disc is constructed of four layers, including a newly developed magnetic layer of terbium ferrite cobalt. Since magneto-optical discs can't come in contact with the recording heads, it's important that the magnetic material be able to



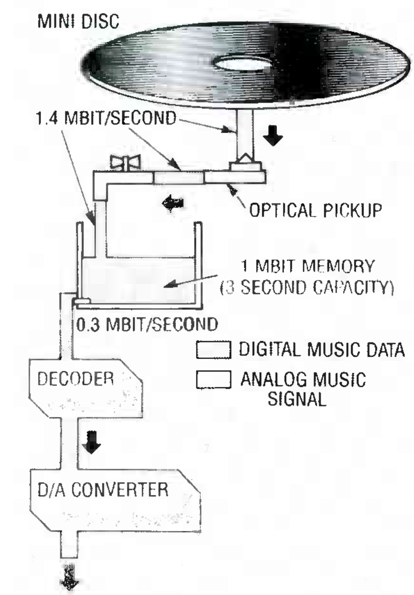

**MAGNETO-OPTICAL OVERWRITE TECHNOLOGY. When the magnetic layer is heated by the laser, it becomes possible for the magnetic head to change its polarity. The polarity is then detected by the laser during playback by noting the direction of reflection.**

change polarity when subject to a very small magnetic field. The new material fills the bill.

The Mini Disc requires both a laser and a magnetic head for recording. When the magnetic layer is heated by the laser (to a temperature of about 400°F), it loses its coercive force—that is, it becomes very easy to magnetize. The head then supplies a magnetic field to set the material's magnetic polarity. When the heated spot cools, the new polarity is "locked in" and, thus, the digital data are recorded.

Sony's Mini Disc has a couple of advantages over other optical recording methods. The structure of the head is much simpler because the laser can be on continuously during recording and playback. And the low-coercivity of the magnetic material greatly reduces the power required, making portable operation feasible.

One feature of Mini Disc touted by Sony is that the portable Walkman players will have "shock-proof memory." One of the problems with current portable CD players is that they don't work too well unless they're standing still. Any sharp jarring causes the laser to mistrack. Mini Disc players shouldn't suffer from that problem because data is read off the disc at a rate far faster than required by the ATRAC decoder, creating a data buffer of




**SHOCK-PROOF MEMORY promises to make Mini Disc an ideal portable format. Since the data is read off the disc far faster than required by the ATRAC decoder, a buffer as long as three seconds is created.**

three seconds. If the laser mistracks, the listener won't hear it. The buffer will feed data to the decoder while the laser finds its way back to the right spot. Sony's announcement included a demonstration where a prototype player was shaken vigorously without any audible result. The prototype continued to play even after the disc was removed until the 1-megabit buffer was empty! Of course, there's no technological reason why portable CD players couldn't offer their own shock-proof memory buffer. But since the buffer would have to be 5 times the size, it would add greatly to the cost.

## Who wins?

Ever since we forecast that DAT would be a sure-fire success, we've been reluctant to make predictions. But let's look at some of the issues involved, and how DCC and MD stack up.

For consumers—assuming that both formats offer high-quality audio—DCC has the decided advantage in that existing libraries of cassettes won't be obsolete. Both formats have the potential to supply such convenience features as song title and lyric readouts, but MD offers much faster random access of tracks Although it's too early to say for sure, prices for home DCC decks should be under $500 when introduced, while a portable MD player is expected to cost around $400. For consumers, we give DCC a slight edge.

The recording companies will have a hard time taking sides. Both technologies will use the serial copy management system or SCMS, an anti-piracy system. Manufacturers will be able to duplicate DCC at 64 times normal speed on equipment similar to what is now used for standard cassettes. Mini Disc players will be able to play back not only magneto-optical discs, but pre-recorded optical discs as well—discs manufactured using the same process as is used for CD's. Various recording companies have expressed support for each format. Which way will the record companies go? For us, it's too close to call.

Hardware manufacturers should prefer DCC because standard tape transports can be used. Retailers, always reluctant to have to stock the same titles in various formats, are dreading the thought of re-vamping their stores to accommodate either DCC or MD.

What about you? In the long run—since both formats seem destined to compete with each other for your money—it's you who will decide whether DCC or MD is the personal recording format of the 90's and beyond. **R-E**

# HARDWARE HACKER

## Driving inductive loads, more on phone caller ID, Bakerizing and laminating, alternators as stepper motors, and programmable logic resources.

DON LANCASTER

Let us first pick up on several updates to some of our earlier *Hardware Hacker* topics. One good source for those BA1404 FM stereo broadcasting kits is *DC Electronics*. They also stock the super new *Signetics* NE602 mixer/converter chips and the TEC-200 film for direct toner printed circuits. Another NE602 source is *Active Electronics*.

Telephone caller ID is certainly one hot topic these days. And yet another source of call identifier magic boxes is *Hello Direct*. Prices start at $60. You must, of course, have the ID service available before you can use these magic boxes. States that have at least some local availability of caller ID should now include AL, CA, FL, GA, IL, IN, MD, ME, MI, NC, NE, NJ, NV, OH, OK, SC, TN, VA, VT, WV, and Washington DC. Other areas are still in the planning stages. Most services are still for local calls only.

One handy and rather non-obvious benefit of this new service: When you come back from lunch, you have a complete and time-stamped list of everyone who tried to call you when you were out. Most useful.

I thought we might round up a big collection of odds and ends for this month's column...

### Driving inductive loads

If you blindly connect a transistor or another solid-state device to an inductor such as a relay or a motor coil, you will almost certainly blow out your circuit the very first time you power it up. Special protection techniques are *always* needed when you try to control an inductor's current with any solid-state device. These inductive-circuit protection techniques are cheap and simple, but you do have to understand what is coming down to use them properly.

Take a coil of wire and connect it to a voltmeter. Now shove a magnet through the center of your coil. As you insert the magnet, you generate a positive induction voltage. Remove the magnet, and you'll generate a negative induction voltage. Any time your magnetic field *changes*, you generate an induced voltage. And the faster the change, the more voltage you create.

Since any current through a coil can generate a magnetic field, any change in your coil current should produce a change in the magnetic field, which in turn induces a voltage spike. The greater or the more sudden the change in the current, the greater the induced voltage. The basic math here says that:

$$e = L\Delta i/\Delta t$$

or, in plain English, your induced voltage across any coil is proportional to the size of the inductor and the *rate of change of current through the coil*.

Say you decide to control a relay. You turn your relay on by sending a current through your coil. And then you attempt to turn your relay off by suddenly disconnecting your coil current. What happens?

Your magnetic field will suddenly collapse, generating a horrendous voltage spike. You tried to make $\Delta t$ zero, and, since you're now trying to divide by zero, you get a theoretically *infinite* voltage spike. Thus, *suddenly ceasing the current in any inductance is guaranteed to create a humongous voltage spike*.

Sometimes you might choose to purposely do that. For instance, the current through the coil in any car ignition is suddenly broken to step up the 12-volt battery into many tens of thousands of volts of ignition-spark voltage. And a related technique gets used for television high-voltage.

But, should you suddenly cease a current through any coil in any solid-state circuit, the voltage spike you'll get is almost certain to blow up the transistor of whatever happens to be controlling your coil.

The rule here is simple: *Never let the current through an inductive load suddenly drop to zero in any solid-state circuit!*

Figure 1 shows you how to add a plain old power diode to your relay coil to provide spike protection. Note that the diode appears "backward" so that it does *not* normally conduct any supply current.

If you suddenly try to turn off the inductor current, a small induced voltage will immediately be created that, in turn, forward biases and turns on the protection diode. *The current you had before can then continue on through your protection diode and back into the relay coil.* The current will now drop down to zero fairly quickly, dissipating itself in the forward drop of the diode and in the internal resistance of your relay coil. At no time is any voltage spike generated that exceeds the 0.6 volts or so of your diode's forward drop.

This simple diode despiker works quite well. But there are some minor side effects that can sometimes cause problems. Note that your relay will *stay* pulled in for a brief time delay after you thought you turned if off. That happens because there is still diode-provided current going through your coil. In a larger relay, the time delay could extend a few tenths of a second, and could cause you timing problems.

The physical dropout of your relay can also end up slower and sloppier. Which could cause contact arcing in higher-current uses.

Your protection diode should also turn on fairly fast. If you use a slow diode, or if there is not enough stray

**NEED HELP?**

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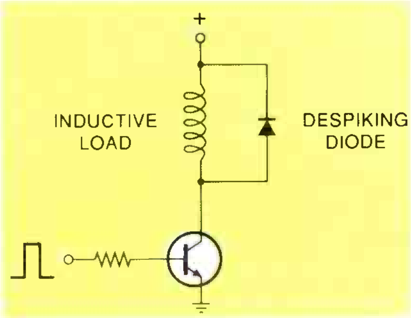


**FIG. 1—ANY SEMICONDUCTOR can be instantly destroyed if you use it to suddenly turn off the current in an inductive load. The despiking diode shown here allows the coil current to continue long enough to safely dump the magnetic flux energy without creating a killer transient.**

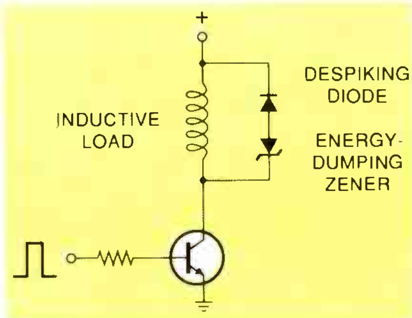


**FIG. 2—ADDING A SERIES Zener diode shortens and sharpens the dropout time. This minimizes turn-off delay and contact arcing in power relays. Your control transistor must be able to block the supply voltage PLUS the Zener voltage.**

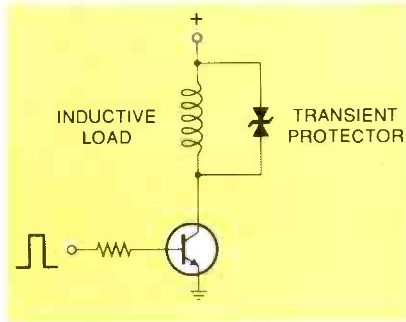


**FIG. 3—TRANSIENT SUPPRESSORS are commercially available bi-directional devices that are also known as varistors, MOV's, TRANSILS, or several other trade names. These must be carefully matched to the allowable voltage rise and the magnetic flux energy to be dumped.**

circuit capacitance around, a large and possibly destructive spike can build up during the time your diode actually starts conducting.

Figure 2 shows you an improved spike-protection circuit. Here we have added a 24-volt Zener diode in series with the protection diode. This combination will conduct no current in one direction and will conduct in the other direction only when the voltage across it exceeds the Zener breakdown of 24 volts. You can think of this series combo as an "inefficient diode" with a 24-volt forward drop.

Whenever you suddenly disconnect your relay current, a large but acceptable 24-volt high-voltage spike is created, which turns on both diodes in the series pair. The current continues through the diodes, but will fall to zero *much* faster as you now have a 24-volt drop burning up all of your remaining coil energy. Thus, the circuit will still give you protection, but will shorten the excess holding time by a factor of 40 or so. Your contact release will also be that much faster.

What happens is that you've now made a tradeoff. You are allowing a reasonably sized spike in exchange for a big reduction of the release time. Note that your transistor will see a maximum voltage of your supply voltage *plus* the drop of the Zener during break time. For instance, on a 12-volt supply, your transistor would have to block at least 36 volts if it is not to be damaged.

There are special back-to-back Zener-like components intended for spike protection. They go by the names of *varistors*, *MOV's*, or *transient protectors*, and do have various brand names. They work the same way as Fig. 2 in that they do not conduct until spike time. Then they do conduct heavily and internally dissipate the inductor's flux energy. Figure 3 is a typical circuit.

*SGS* is one of many suppliers of the *TRANSIL* spike protectors. Their BZW04P23 is typical. At 25 volts or under, it draws only 5 microamps. Above 30 volts it starts conducting heavily, and by 41.5 volts it draws at least 10 amperes. Despite the tiny package, these devices can withstand 50 amps for 10 milliseconds. Higher-power units are also available.

You do have to carefully match your protection device to the size of the spike you are willing to allow and the amount of energy that you need to dump from your coil. If at all possible, you should also isolate your coil drivers from more sensitive parts of your circuit. Optoisolators and individual power supplies are great for this. More info on spike protection and computer interfacing appears in my *Micro Cookbook*, volume II.

### Alternators as steppers?

A *stepper motor* differs from an ordinary motor in that it can deliver incremental motion in the form of tiny precise steps, rather than as a continuous rotation. The important advantages of a stepper motor are the precision with which you can set an output shaft position, the ability to rapidly and conveniently change the direction or the speed of your output steps, and the capability of strongly holding a zero-speed position.

Small stepping motors are widely used for such things as printer paper feeds, automobile idle controls, pen plotters, and sometimes for disk-drive head positioners. And most any old surplus electronics catalog will have lots of small steppers and all their drivers cheaply available. But what about the heavy stuff?

There are lots of good hacking uses for power stepper motors. Obvious examples include robotics, machine-tool power feeds, animation stands, plotters, sign cutters, solar pumps, and even Santa Claus machines. As you have probably noticed by now, power stepper motors are rare, horrendously expensive, hard to get, and harder to drive. Did I mention being hot and noisy?

An industrial arts teacher out of Phoenix by the name of Bob Knight stopped in the other day with what just might be a brilliant hack. Junkyard car alternators cost under $5 each, especially if you don't particularly care which model you are getting. Can you convert an alternator into a power stepper?

The needed modifications do appear to be simple and obvious. And power FET or Darlington drivers are no big deal these days.

My first response was "yes, but...," and I immediately came up with a dozen good reasons why this flat out would not work. At least not very well. Things like a wide air gap, low-frequency mechanical resonances, DC biasing, giant step sizes, all the non-optimum magnetic paths, very poor damping, backlash, slow speeds, and an efficiency that probably would be an outright joke.

On the other hand, if you pulse an alternator, there is no way you can hold onto it when you do. The kick is definitely there.

At best, I would guess that you could not get as much useful force with a car alternator as you could by using a much smaller "real" stepper motor. And the alternator would end up ridiculously slower to boot.

I'd like you to try and prove me wrong. Either as this month's contest or for a winning school lab project, experiment with a car alternator and find out exactly how useful a power stepper motor you could convert it into. Could you in fact create a $5 machine-tool power feed with one? How fast can you go? How much output force can you get? How good are the steps? What is the best computer interface?

There will be the dozen or so of our usual *Incredible Secret Money Machine* book prizes, along with a big all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

Okay, Fig. 4 shows you some conversion hints.

Most real stepper motors do use a permanent magnet rotor. With an alternator, you would use the field winding and slip rings as a giant electromagnet, running as much current through it as you can without overheating. This forms a group of seven shaft-attached magnets that you can rotate to a desired position by activating the stator coils.

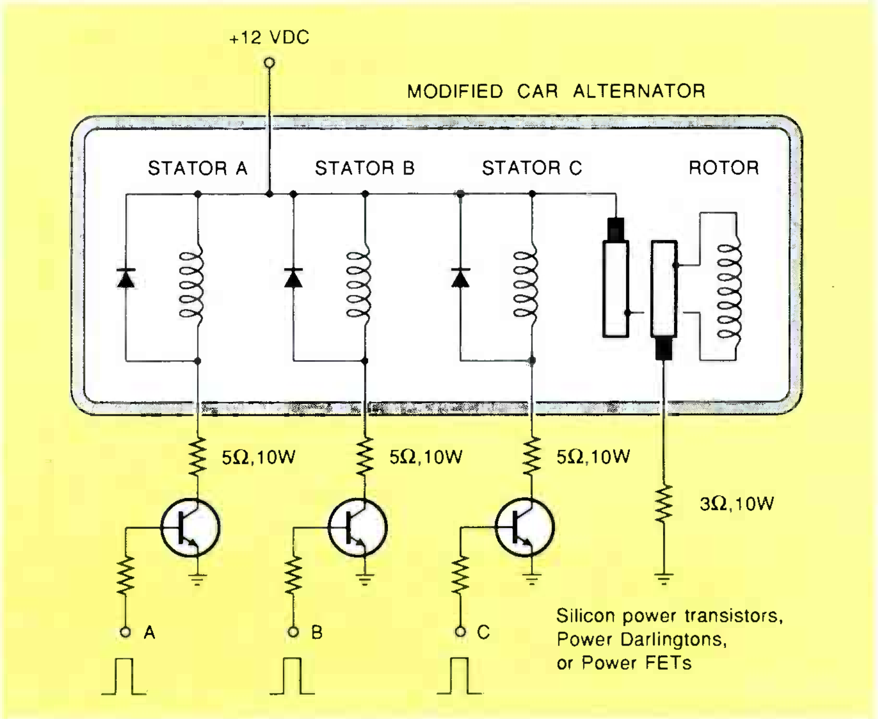


**FIG. 4—CAN A CAR ALTERNATOR get converted into a $5 power stepper for a machine tool drive? Only hackers know for sure. To experiment, use the rotor as a powered electromagnet. Find the floating stator wye connection and bring it out as a power terminal. Pulse one stator winding at a time in an ABC (clockwise) or an ACB (counterclockwise) sequence. Be sure to limit stator currents.**

And speaking of which, there are normally three sets of stator coils. These are usually hooked up in what is known as a three-phase *wye* circuit. For stepper use, you will want to find the floating splice where your wye connection is made and bring it out as a separate positive terminal. Which should then give you three distinct and independent winding sets.

Let's call the windings A, B, and C. Power the field via the slip rings, and pulse winding A. Keep your current down around an amp or two at first to

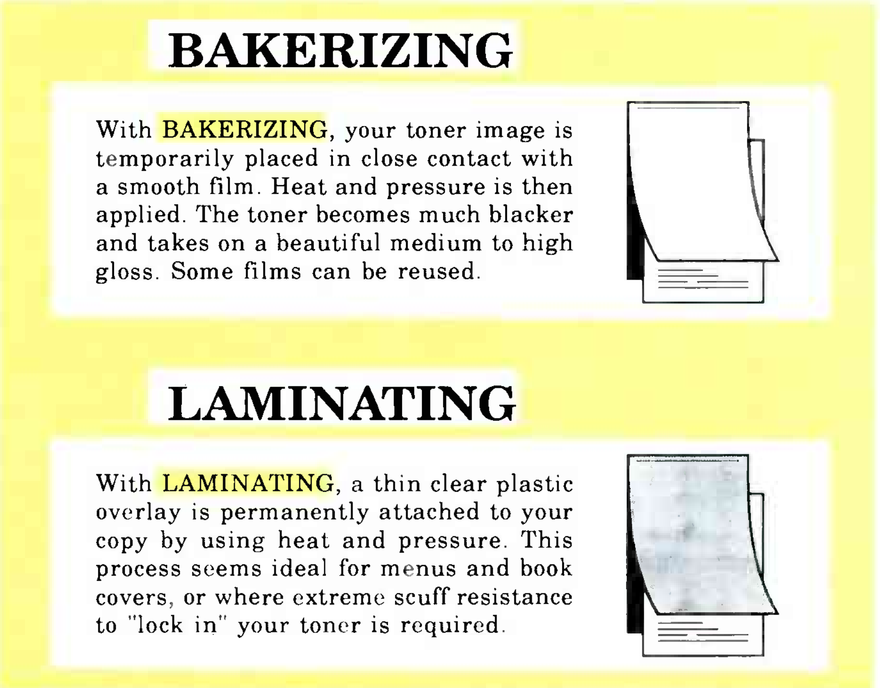


**FIG. 5—THESE TWO "MAGIC" FILMS can dramatically improve the appearance and durability of any toner image. Evaluation sheets are newly available.**

prevent any overheating or driver problems. The rotor will align itself with the nearest pole piece and should lock itself to some position. Now turn off winding A and activate winding B. The rotor should now jump one step clockwise. Turn off B and whap C. And you should jump yet another step clockwise.

To step clockwise, use an ABC sequence. To step counterclockwise, just use ACB instead. You'll probably want to keep at least one winding energized at all times so that you can hold a position when not stepping.

Note that you could end up in position A, B, or C, depending on your power sequence. You'll have to remember where you are with your controller or host computer. A typical alternator should give you 21 possible positions, and a resultant step angle of around 17 degrees.

You would disconnect all of the alternator diodes during your conversion. These could later get used as protection diodes with your driver circuits if you do not have anything better available.

One hint: Your slip ring brushes can "explode" whenever you take an alternator apart. And the two brush springs will fly off into the hinterlands. Look closely, and you'll find a toothpick-size hole in the insulated brush holders. To reassemble, you just put a toothpick or a stiff wire through the hole to hold the brush springs compressed. Done just right, you should be able to remove the toothpick from the outside after your reassembly.

The rotor winding of an alternator is a fairly high resistance, usually around 5 ohms or so. It will safely current limit itself. But your stator windings are an extremely low impedance, typically under a quarter ohm. Thus, you *must* externally limit your rotor currents to keep things from burning up. Plain old power resistors are a good way to handle this for your early experiments.

There are some tricks you could pull to improve the number of steps per revolution. One would be to allow two windings to be active at once. That could double your resolution.

A fancier technique would be to allow several different values of the current for each winding, leading to various new *microstepping* opportunities. Microstepping is a proven concept with real stepper motors.

Another possibility is to use a *bridge*-type drive that lets you run current either way through any given winding. You could now use both attraction and repulsion, and, once again, should be able to double the number of steps.

And a final resolution enhancer would be to put a nutplate of some sort on the shaft end, creating a *linear stepper*. A threaded shaft through the nutplate will then move forward or backward as the alternator steps.

For instance, with a ¼-20 thread, each full revolution would advance you fifty mils. One single step at 21 steps per revolution would advance you a mere 2.38 mils, besides giving you a really major mechanical advantage to boot.

Simple gearing could also be used to increase your step resolution. But you will have to watch for backlash when you try this. And do note that the finer the resolution, the slower your maximum allowable operating speed. Sorry about that.

You might also like to look at some *dual current* scheme that gives you a brief high-current pulse when stepping and some lower holding current between the actual steps.

After you do have your stepper working reasonably well, you'll want to increase the operating currents. Overheating, saturation effects, and overshoots set your ultimate limit.

It might also be very interesting to rewind all the stator coils. Use lots more turns of a much smaller-diameter wire, and try bridging only a single

**NAMES AND NUMBERS**

**Active Electronics**
11 Cummings Pk
Woburn MA 01801
(800) 677-8899
CIRCLE 301 ON FREE INFORMATION CARD

**Airpax**
150 Knotter Drive
Cheshire, CT 06410
(203) 271-6000
CIRCLE 302 ON FREE INFORMATION CARD

**DC Electronics**
PO Box 3203
Scottsdale, AZ 85271
(800) 423-0070
CIRCLE 303 ON FREE INFORMATION CARD

**Galco**
26010 Pinehurst Dr
Madison Heights MI 48071
(313) 542-9090
CIRCLE 304 ON FREE INFORMATION CARD

**Hello Direct**
140 Great Oaks Blvd
San Jose, CA 95119
(800) 444-3556
CIRCLE 305 ON FREE INFORMATION CARD

**Maxim**
120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600
CIRCLE 306 ON FREE INFORMATION CARD

**Memory Card Systems & Design**
6300 S Syracuse Way, Ste 650
Englewood, CO 80111
(303) 220-0600
CIRCLE 307 ON FREE INFORMATION CARD

**Motorola**
5005 East McDowell Road
Phoenix, AZ 85008
(800) 521-6274
CIRCLE 308 ON FREE INFORMATION CARD

**Photocomm, Inc**
7681 East Gray Road
Scottsdale, AZ 85260
(800) 223-9580
CIRCLE 309 ON FREE INFORMATION CARD

**Rochester Electronics**
10 Malcolm Hoyt Drive
Newburyport, MA 01950
(508) 462-9332
CIRCLE 310 ON FREE INFORMATION CARD

**SGS-Thomson**
100 East Bell Road
Phoenix, AZ 85022
(602) 867-6259
CIRCLE 311 ON FREE INFORMATION CARD

**Slo-Syn**
383 Middle Street
Bristol, CT 06010
(203) 582-9561
CIRCLE 312 ON FREE INFORMATION CARD

**Sprague**
70 Pembroke Road
Concord, NH 03301
(603) 224-1961
CIRCLE 313 ON FREE INFORMATION CARD

**Synergetics**
Box 809-RE
Thatcher, AZ 85552
(602) 428-4073
CIRCLE 314 ON FREE INFORMATION CARD

**Trade winners**
PO Box 7-250
Taipei, Taiwan, ROC
(02) 733-3988
CIRCLE 315 ON FREE INFORMATION CARD

**JC Whitney**
1917-19 Archer Avenue
Chicago, IL 60680
(312) 431-6102
CIRCLE 316 ON FREE INFORMATION CARD

## PROGRAMMABLE LOGIC RESOURCES

**Actel**
955 East Arques Avenue
Sunnyvale, CA 94086
(800) 227-1817, ext. 60
CIRCLE 317 ON FREE INFORMATION CARD

**Altera**
2610 Orchard Parkway
San Jose, CA 95134
(800) 800-EPLD
CIRCLE 318 ON FREE INFORMATION CARD

**Advanced Micro Devices**
PO Box 3453
Sunnyvale, CA 94088
(800) 222-9323
CIRCLE 319 ON FREE INFORMATION CARD

**Catalyst**
2231 Calle de Luna
Santa Clara, CA 95054
(408) 748-7700
CIRCLE 320 ON FREE INFORMATION CARD

**Cypress Semiconductor**
3901 North First Street
San Jose, CA 95134
(800) 952-6300 Dept. C4P
CIRCLE 321 ON FREE INFORMATION CARD

**Fujitsu**
3545 North First Street
San Jose, CA 95134
(800) 642-7616
CIRCLE 322 ON FREE INFORMATION CARD

**Gould AMI Semiconductor**
2300 Buckskin Road
Pocatello, ID 83201
(208) 234-6668
CIRCLE 323 ON FREE INFORMATION CARD

**International CMOS Technology**
2125 lundy Avenue
San Jose, CA 95134
(408) 434-0678
CIRCLE 324 ON FREE INFORMATION CARD

**Intel**
1000 Business Center Drive
Mt. Prospect, IL 60056
(800) 548-4725
CIRCLE 325 ON FREE INFORMATION CARD

**Lattice Semconductor**
5555 NE Moore Court
Hillsboro, OR 97124
(800) FAST-GAL
CIRCLE 326 ON FREE INFORMATION CARD

**Mitsubishi**
1050 East Arques Avenue
Sunnyvale, CA 94086
(408) 730-5900, ext. 2106
CIRCLE 327 ON FREE INFORMATION CARD

**National Semiconductor**
2900 Semiconductor Drive
Santa Clara, CA 95051
(800) 272-9959, ext. 40
CIRCLE 328 ON FREE INFORMATION CARD

**NEC Corporation**
401 Ellis Street
Mountain View, CA 94039
(415) 965-6000, ext. 6357
CIRCLE 329 ON FREE INFORMATION CARD

**GEC Plessey Semiconductor**
13900 Alton Parkway, S 123
Irvine, CA 92718
(800) 927-2772
CIRCLE 330 ON FREE INFORMATION CARD

**Raytheon**
350 Ellis Street
Mountain View, CA 94039
(415) 962-7930
CIRCLE 331 ON FREE INFORMATION CARD

**Texas Instruments**
PO Box 117692
Carrollton, TX 75011
(800) 336-5236, ext. 3707
CIRCLE 332 ON FREE INFORMATION CARD

**Toshiba**
1220 Midas way
Sunnyvale, CA 94086
(800) 321-1718
CIRCLE 333 ON FREE INFORMATION CARD

**Waferscale Integration**
47280 Kato Road
Fremont, CA 94538
(415) 656-5400
CIRCLE 334 ON FREE INFORMATION CARD

**Xicor**
1511 Buckeye Drive
Milpitas, CA 95035
(408) 432-8888
CIRCLE 335 ON FREE INFORMATION CARD

**Xilinx**
2100 Logic Drive
San Jose, CA 95124
(408) 879-5199
CIRCLE 336 ON FREE INFORMATION CARD

stator pole rather than three. Ampere turns is the name of the game here. You could also try improving the rotor flux paths and air gaps.

For further resources on power stepping in general, check out *Airpax* and *Slo-Syn* for iron, the *PCIM* and *Motion* trade journals for info, and *SGS, Sprague*, or else *Motorola* for drivers. One distributor that stocks a wide selection of power-electronics stuff is *Galco*. And good old *J.C. Whitney* has bunches of alternators and parts available, including some rewound 100-amp stators that go for around $18. You will find lots more on power electronics in our brand new *Hardware Hacker III* reprints. There's lots of possibilities here. Let's see what you can come up with.

### Programmable logic

Besides all those good old hacker EPROM's, we now have dozens of variations on low-cost you-program integrated circuits. Some (such as EPROM's) are based on exhaustive table lookups. While others (such as PLA's) do multilevel AND-OR digital logic using combinations of gates and registers.

Some are one-shot programmed by blowing fuses. Others are easily re-programmable. And yet others use a *flash* technology where the needed connections can get saved to a non-volatile RAM memory during power-down times.

The prices of some programmable chips are now down in the $2 range. Important advantages of these new devices are that you can place the exact circuit you want into one or two packages; that they are easy to debug and modify yourself; that some can recalibrate or update themselves later on in-circuit; and that you are (at least temporarily) the sole source of your "secret" inside programming connections. All with instant delivery and no staggering setup charges.

I've tried to gather together some of the more popular programmable logic suppliers into this month's resource sidebar. You may want to get data from many of these sources.

One side note that is both alarming and sad: Many of these houses refuse to divulge the key programming info needed to use their chips. While I consider this a monumentally stupid way to cut off your nose to spite your face, their argument is that they most definitely do want you to use some "approved" programmer that is more likely to keep their products reliable in the final circuit.

Here's a trick that *may* help you get programming info should reasonable and direct tries fail. The magic new buzzword in chip programmers these days is "DAC per pin." Just tell those application engineering people that you are about to ship production quantities of your new PC-based DAC-per-pin programmer, and that you would like to be able to include pro-grammability for their chips.

Our helpline has been full of horror stories on programming info, but this ploy seems to work so far. At least till they catch on. Please do continue to send in your horrors stories.

More details on the use of EPROM's appears in my *CMOS*

*Cookbook* and *TTL Cookbook*, while the listings in our resource sidebar and the usual trade journals will also have lots of application info.

## Bakerizing secrets

Despite my screaming it from the rooftops for quite a few years now, Bakerizing seems to remain a top-secret procedure. Which amazes me because anyone that sees what the process does is absolutely stunned.

Bakerizing is a sneaky trick you can apply to most any toner image, especially all your PostScript laser-printed output. Bakerizing instantly makes toner a high-gloss jet black, while at the same time dramatically increasing the durability and crease-resistance.

While excellent for business cards, Bakerizing works nearly anywhere that you want a blacker and denser toner image. And the process is nearly free!

All you have to do to Bakerize is take a sheet of special high-gloss, slip-coated polyester film. You then *temporarily* place the film in contact with your toner image and then apply heat and pressure. This remelts your toner in contact with an ultra-smooth surface. Which then can produce a *calandering* process similar to that ferrotype drum on older darkroom glossy print processors.

The simplest way to Bakerize is to put the magic sheet on top of your hard copy and shove it back through your printer while imaging a blank page. The best way to Bakerize is to use a *Kroy Color* or *Canon* fuser unit or some sort of laminating machine. But even a plain old iron can sometimes be used effectively.

With care, any single Bakerizing sheet can be reused dozens of times. Which can drop your per-page costs to a few pennies per copy.

I have gone ahead and custom ordered a zillion sheets of Bakerizing film and will be offering it as a stock product here at *Synergetics*. I've also now got some more traditional yet toner-compatible laminating materials suitable for nice looking menus and book covers. Figure 5 shows you how these two films differ. Give me a call if you want to play with either of these really exciting new materials.

## New tech lit

From SGS, the new *Shortform 91* catalog that is especially strong in automotive, telephone, VCR, and consumer audio chips. From *Rochester Electronics*, a *1991 Catalog*. They specialize in stocking many types of out-of-date and discontinued semiconductors.

A free design guide and catalog on *Solar Electric Power Systems* from *Photocomm Inc.* is now available. And the latest free volume of the *Maxim Engineering Journal* has all sorts of goodies in it on efficient regulators, digital filters, and other innovative new chips.

Two informative trade journals for this month do include *Memory Card Systems & Design* on the new RAM and EPROM memory cards used for laptops and whatever; and *Trade Winners*. The latter journal is sort of a Hong Kong version of *Computer Shopper* that can give you *direct* access to many Far East manufacturers and distributors of electronic parts and systems.

Let's see. I've just reprinted my *Incredible Secret Money Machine*, along with a new introduction and update section. And we are now Book-on-demand publishing our *Hardware Hacker III*, *Ask the Guru III*, and also my *Midnight Engineering I* reprints.

A reminder about my new BBS up as *GEnie PSRT*. Besides all of the PostScript and desktop publishing stuff, you'll find all sorts of ongoing *Hardware Hacker* and our *Midnight Engineering* resources here. You can get your voice connect info by dialing (800) 638-9636.

Finally, I do have a pair of new and free mailers for you. One includes dozens of insider hardware hacking secret resources, while the other is on PostScript and Desktop Publishing. Write or call for info. As usual, most of the items mentioned here appear in the *Names and Numbers* or the *Programmable Logic Resources* sidebars. **R-E**

*I've heard you were looking for me. . . Super conductor!*

# AUDIO UPDATE

## Future products?

LARRY KLEIN

Despite my thirty-plus years as an editor and writer for major hi-fi magazines, I've always been an odd-man out among audio journalists. When I saw a development that struck me as a genuine advance in the audio-video arts, I was pleased to say so. But unlike many, if not most, of my colleagues, I never felt an obligation to be a knee-jerk cheerleader for each new audio concept, device, or format. Hopefully, over the years my approach has helped readers find their way through the fast-changing and sometimes confusing world of audio electronics.

### In-store recording

Sometimes new developments are hard to call. For example, loyal readers may remember my November 1988 writeup of the Personics in-store tape-it-yourself machine. It permits consumers to record their own top-40—or whatever—compilations at perhaps a buck a shot from its thousands of digitally stored masters. I was impressed by Personics' very sophisticated technology, but I asked whether it might not be a technically feasible idea that, nevertheless, wouldn't get off the ground because it didn't dovetail with the perceived social or economic needs of the marketplace.

My question was recently answered when Personics filed for Chapter 11 bankruptcy protection. It seems that although the record stores were pleased to install the machines, the record companies wouldn't provide Personics with a sufficient number of their more popular selections, despite the fact that they earned royalties on every selection taped. They obviously felt that it would hurt prerecorded cassette and CD sales. It seemed to me that Personics had made a good case that their machine would help cut back on "illicit" home taping, but the record companies obviously didn't see it that way.

### Recordable CD's

A product/format that I ignored when it was first introduced was Radio Shack's home-recordable compact-disc system, dubbed "Thor" for Tandy High-Intensity Optical recording. Announced in June 1988, the Thor recorder/player was to be priced at under $500 and be on the market in less than two years. The press went wild! Laudatory articles appeared in major publications and at least one audio columnist predicted that it "could well become the dominant recording method for the next several decades." Well, here we are three years later, and the product is nowhere to be seen.

A recent call to Radio Shack/Tandy revealed that Thor was still in the works; it had reached the "product development" stage, but Radio Shack thought it prudent not to reschedule a release date. In our conversation, I indicated that I saw the recordable high-density disc as suitable for computers (a sort of cheap recordable CD-ROM), but I didn't see much future for it as a hi-fi medium. My friend from Radio Shack told me that they were working in the opposite direction. A year, or two, or three, from now we may know who was right.

### Mini discs

Scheduled to appear sometime in late 1991, the Sony Mini Disc system uses 2.5-inch record/playback discs physically similar to 3.5-inch computer discs. The MD system uses a combination of optical and magnetic digital technology; prerecorded discs are optically read with a laser, and home recording is done using a sophisticated thermal/magnetic system with the laser providing the thermal element. Guestimated introductory price is in the $350 range.

The Mini Discs have a storage capacity virtually identical to that of a conventional CD, thanks to Sony's newly developed digital compression system call ATRAC (Adaptive Transform Acoustic Coding). ATRAC works by analyzing the audio signal and extracting and encoding only those components that are audible to


**DOES SONY'S MINI DISC SYSTEM WITH RECORDABLE DISCS represent the audio format of the future?**

the ear. In other words, frequencies that would be psychoacoustically masked by other frequencies are left unencoded as are frequencies on the loudness scale judged to be below the threshold of perception. Although the dynamic range of the MD system is given as 105 dB, I wonder if playback through an external home audio system will reveal any ATRAC inadequacies.

In any case, Sony's present plans are to concentrate on portable applications which are far more forgiving of compression artifacts. There are several other important technological developments incorporated into the MD format that are important enough to deserve further discussion, but they are outside the scope of this column.

Is this Sony's answer to the DCC format discussed last month? Well, Mr. Norio Ohga, President of the Sony Corporation, stated in his prepared remarks at the Mini Disc press conference, that the "sales of prerecorded music cassettes are declining, especially in Japan. We have investigated the reasons for this decline, and our own research showed that consumers are not totally satisfied with music compact cassettes, primarily because of slow access time and such problems as wow, flutter, and distortion."

I suspect that the fall-off in prerecorded cassette sales has more to do with the success of CD than newly bothersome flaws in the cassette format. When the earlier choice was between an LP or a prerecorded cassette, the cassette won on the basis of convenience and ruggedness. Now that the choice is between CD's and cassettes, the CD has the edge in convenience and ruggedness—and you can always make your own cassette copy to take with you in your travels.

I also differ with Mr. Ohga on the importance of the fidelity factor for the U.S. mass music market. If fidelity was that important to most rock music consumers, prerecorded cassettes would never have outsold LP's—as they did for several years before CD's arrived. Is the marketplace ready for another non-compatible portable/car format? I wish Sony well, and I'm impressed by the technology developed for the Mini Disc, but I'm not optimistic about its ultimate success in the marketplace.

**HDTV**

Billed as high fidelity for the eyes, high-definition television is a favorite topic among Sunday supplement magazine writers. Soon, they would have us believe, our 30- or 40-inch home TV screens will be showing pictures that, in respect to aspect ratio, clarity, and detail, will rival those seen in movie houses. Well, don't hold your breath—or put off purchasing a TV set with today's old fashioned technology. HDTV is not just around the corner.

HDTV's major problems are not technological—they are economic and sociological. To start, the broadcasters must transmit separate HDTV and standard signals simultaneously in order to comply with the FCC's compatibility rule. If they want to originate programs, they need new cameras, recorders, control-room boards, and dedicated transmitter.

Then there's the antenna problem. In many instances, an additional tower will have to be put up for HDTV. And we shouldn't forget the problem of the required extra channel space, which just isn't available in all market areas. Direct-broadcast satellite will short circuit some of the above problems, but only at the expense of the local broadcasters who would protest its adoption.

Given all of the above, I suspect that the FCC will start seriously considering authorizing the use of one of the "enhancing" systems that provides a better and wide-screen picture from the current NTSC system. For the broadcasters, the equipment required to encode additional information into their present transmission systems should be relatively inexpensive as such things go. For the consumer, however, I suspect that the price of an enhanced TV system will move it out of the casual purchase category.

Which brings me back to the same old question—is there a large enough audience for HDTV (or enhanced TV) to make it a commercially viable enterprise? The fact that you can get a much better picture from a videodisc than a video tape hasn't had much positive impact on videodisc sales. Obviously Japanese and U.S. manufacturers would like to sell all sorts of newly developed enhanced-TV goodies to the American public. But even if he had the money, is John Q. really interested? **R-E**

# COMPUTER CONNECTIONS

## MS-DOS 5.0.

JEFF HOLTZMAN

DOS 5.0 is finally here—and it's a winner. DOS now includes a frugal approach to memory usage as well as the most important must-have utilities. File utilities face off squarely against products including the Norton Utilities and PC Tools; built-in memory management facilities now compete favorably with products from Quarterdeck (QEMM) and Qualitas (386MAX). The third-party products are generally more powerful and more versatile than those provided by DOS. But for the majority of tasks performed by the majority of users, it may just be that DOS and its new utilities are good enough.

### New features

The most important feature of DOS 5.0 is the ability to load part of itself into the High Memory Area (HMA), the first 64K of memory above the 1MB mark. (Normally, memory above 1MB is unavailable to DOS programs, but due to a quirk in the Intel addressing scheme, real-mode DOS programs can get at the first 64K of extended memory without switching the microprocessor into protected mode. Although use of the HMA has been understood for several years, Digital Research's DR-DOS, released about a year ago, was the first and, until recently, the only operating-system product to use it. The HMA is only available on 286 and higher machines with extended memory.) By loading DOS in the HMA, you can boot your machine with *much* more memory than before. For example, I now boot with about 625K of free memory.

DOS 5.0 also includes a 386/486 memory manager that can map RAM into upper memory blocks (UMB), unused address space in the area between 640K and 1MB. You can then install device drivers and TSR's in that area. For example, I load device drivers for a disk cache and a RAM disk, a special video driver for a Hercules Graphics Station Card, several keyboard-related TSR's, a mouse driver, and LANtastic networking software—and still have about 625K of free conventional memory. That's a nice feeling. But does it work?

It sure does. Microsoft wanted to avoid the kind of controversy that surrounded the release of DOS 4.0, so the company went through extensive qualification procedures (including some 7000 beta testers). And it shows. I've got a fairly complex setup, including a SCSI-based hard disk, the 34010-based Hercules card, tape backup unit, and networking interface card. Installation was smooth and documentation clear; it all worked the first time, without a hitch.

### Goodies

DOS 5.0 includes lots of neat little goodies, including built-in help messages for most commands, that may take the wind out of utility vendors' sales. (Some of those utilities were in fact licensed from those vendors, who have already announced enhanced versions.) Following are selected highlights of some of the updated commands.

The Del command accepts /p to prompt you to confirm file deletion. The Devicehigh command loads device drivers into UMB's. The Dir command will sort files in forward or reverse order by name, extension, date/time, and size; you can also display by attribute (hidden, system, read-only, archive); you can include subdirectories; there are other options as well; and you can set up an environment variable (DIRCMD) that specifies your favorite format.

Doskey provides a command-line editor/macro/history facility like CED and DOSEDIT.

The Format command has a "quick" option (/q) that empties the file allocation table (FAT) and root directory of a floppy disk, but does not erase the data area (or scan for bad sectors).

The Graphics command, though slow, at long last supports all standard video modes and numerous printers, including LaserJets.

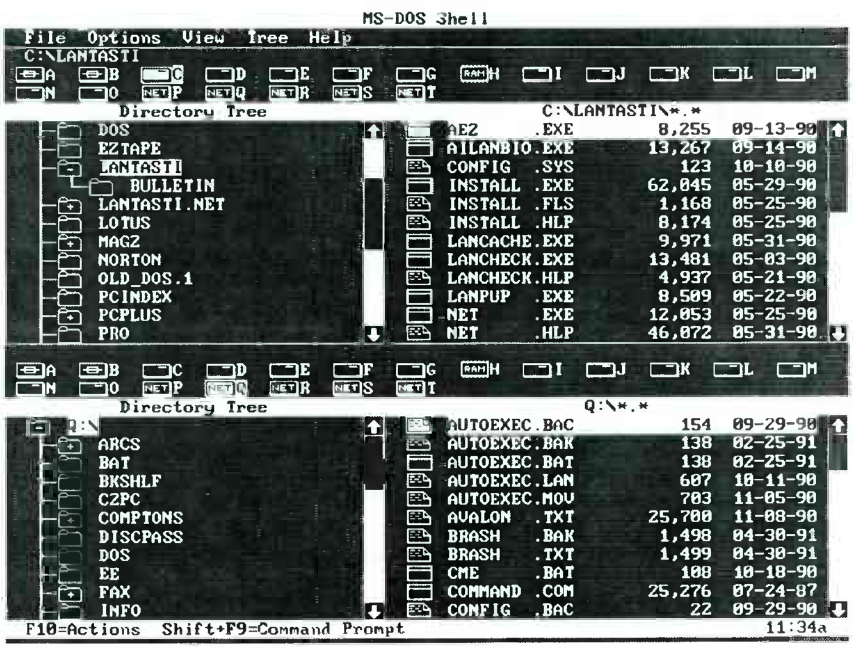


**FIG. 1—MS-DOS 5.0 combines users' most-requested features in a comprehensive package that frees 45K of conventional memory on 286 and 386 machines, has built-in undelete and unformat utilities, and a file manager/task swapper. This is the DOS you've been waiting for.**

Loadhi lets you load TSR's into the UMB area on 386 and higher CPU's. Mem displays information about the amount of free memory and loaded programs.

The Mirror command backs up important information about your hard disk. Mirror also optionally installs a TSR that keeps track of deleted files. Undelete and Unformat use that information to help in case of disaster.

Mode now lets you specify 43- and 50-line VGA video modes, and keyboard repeat and delay rates; it also supports COM3 and COM4 at rates as high as 19,200 bps.

QBasic, which supersedes GWBASIC, is based on Microsoft's QuickBASIC environment. QBasic includes a hypertext help system but no printed documentation; programs can be saved in ASCII format to disk but cannot be compiled without the full QB environment. DOS 5.0 also includes a full-screen editor; the editor is the QBasic environment. (For comparison, invoke EDIT.COM then QBASIC /EDITOR.) And yes, Edlin is still included.

Ren (rename) still has not been upgraded; I guess I'll continue to use my 800-byte 1985-vintage utility to rename subdirectories. Nor is there a Move command, although you can use the DOS Shell to move files.

Tree displays a graphical view of your directory structure, but is quite slow. I've got a 500-byte 1985-era PD utility that works ten times faster.

Undelete and Unformat may cause trouble for the Norton Utilities. Sys will make a disk bootable whether it is empty or not.

In addition to ANSI.SYS and DRIVER.SYS, DOS 5.0 now includes device drivers for setting up a RAM disk (RAMDRIVE.SYS) and a disk cache (SMARTDRV.SYS); these drivers supersede the ones included with Windows 3.0.

Another device driver (386EMM.EXE) provides EMS memory emulation on a 386 or higher CPU; it can also optionally map RAM into the UMB area. To avoid conflicts with various hardware adapters, 386EMM.EXE includes options for including and excluding particular address ranges, and other options for specifying the address of the EMS page frame, and the number of task-switching handles and register sets.

Installation is clean and easy; if you're upgrading from a previous version of DOS, the process saves your old DOS version in a separate subdirectory, and even forces you to create a bootable backup floppy in case something goes wrong.

### DOS is DOS, not Windows or OS/2

DOS 5.0 includes a file manager called DOSSHELL that allows you to perform standard file manipulation (copy, move, rename, run, view), that can serve as a launching pad for your applications, and that can even switch among several DOS programs. It does not however perform multitasking in the manner of DESQview or OmniView (to say nothing of Windows or OS/2). So you can't download files from your favorite BBS while simultaneously working in your word processor; you'd have to use Windows, OS/2, or a competing package for that.

### Conclusions

Microsoft has really done its homework on DOS 5.0. On one hand, it has users' most requested features: It returns a big 45K chunk of RAM to the user, obviates the need for more than half a dozen utilities (DOS shell, keyboard enhancer, 386 memory manager, disk cache, RAM disk, undelete and unformat utilities), and allows large disk partitions (2 GB). You can get more powerful versions of these utilities from other vendors. But you may not need to—or want to. DOS 5.0 has some glaring deficiencies, but most of the new additions are worthwhile. In short, it works. Bugs may turn up in the future, but DOS 5 has already shown itself more reliable, not to mention useful, than its predecessor.

On the other hand, with the resources Microsoft has at its disposal, surely it could have included a DESQview type of multitasker. Why not? DOS 5.0 is careful not to infringe on the multitasking turf staked out for Windows (and OS/2).

The question now is: What next? There is talk that the next version of DOS will include built-in networking, an installable file system, multiple concurrent DOS sessions, clean access to extended memory... that sort of thing.

Congratulations, Microsoft. When will we get a version of OS/2 that works as well?

## News bits

**IBM/Microsoft sparring** continues: IBM has been going to great lengths recently to demonstrate its independence from Microsoft. First, as reported last time, IBM has teamed up with Micrografx to build a better graphics engine for OS/2. Since then the company has shown Digital Research's DR-DOS running under OS/2 2.0; both DR and IBM are committed to full compatibility.

In addition, IBM has teamed up with Borland, whose C++ programming environment will be released for OS/2 2.0 by the end of the year. IBM is also developing its own 32-bit programming kit for OS/2. The company has publicly shown an early version of the OS/2 Presentation Manager (PM) that looks more like the Macintosh Finder than Windows; there are rumors circulating around that IBM is even looking into the possibility of licensing the Macintosh OS. Microsoft, on the other hand, is busy at work developing a set of tools for porting OS/2 code to the Windows environment.

Windows vs. OS/2 is becoming a religious issue in the trade press. Recent articles contain phrases like "pounded another stake through the heart of Presentation Manager," "Why OS/2 is dead," and so on. Sure, IBM doesn't want to become dependent on Microsoft. But both companies are developing products called OS/2, advanced versions of Windows and OS/2 have remarkably similar specifications, each company is licensed to the other's product, and both companies realize the devastating effects of proprietary systems. We may end up with two different products—but there will be a high degree of compatibility between them.

**Multimedia mania.** A high-ranking IBM official banged the drum for multimedia at Comdex once again, rattling off several challenges the industry must meet before mainstream multimedia becomes a reality, including standard data formats and API's (among IBM, Apple, Microsoft, and Commodore), a breakthrough in optical storage, reasonably priced full-motion video, compelling software, and extreme ease of use.

On the equipment front, numerous companies are announcing expansion cards that provide digital audio capabilities for the PC: Covox (Sound Master) Brown-Waugh (Sound Blaster), Ad Lib Sound (Ad Lib), MediaVision (Pro Audio Spectrum), Turtle Beach Systems (MultiSound). These cards typically include MIDI compatibility, music synthesis, 44-kHz audio digitizing/playback, multi-source mixing, CD-ROM interface, microphone inputs, 12-bit A/D and D/A, audio amplifiers, etc. Prices range from $200 to $1000.

Microsoft's multimedia strategy is about to blossom. In early summer, the company will release multimedia extensions to Windows. A multimedia version of Windows will be released on CD-ROM, which will include all documentation in a hypertext help facility, and will also include new accessory programs for accessing multimedia data. The company is also scheduled to release a Multimedia Development Kit (MDK) during the summer.

**Friendly Windows development tools** are sprouting up all over the place. Borland released a form-based package called ObjectVision several months ago, and more recently, Turbo Pascal for Windows. Microsoft returns to its roots with a release of BASIC called Visual BASIC. These products promise to revolutionize Windows product development efforts; watch for lots of powerful and fun new utilities and application programs. **R-E**

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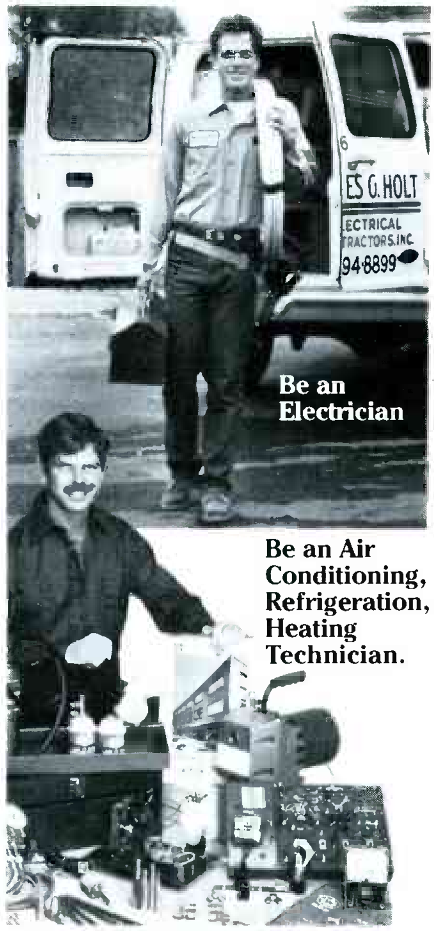


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## ELECTROMAGNETIC THEORY

*continued from page 59*

that are bound directly to the atom and cannot flow. If **N** is of magnitude 1 and is normal to the surface then

$$\sigma_b = \mathbf{P}\cdot\mathbf{N} \text{ (C/m}^2\text{)}.$$

Imagine a Gaussian surface inside the dielectric. With a nonuniform charge distribution some of the bound charges will be displaced across the surface by **P**, leaving a net charge within the surface. In the same manner that we found $\nabla\cdot\mathbf{E} = \rho\epsilon_0$, where ρ is the volume charge density of all the charges contributing to **E**, we can see that the volume charge density in the dielectric is

$$\nabla\cdot\mathbf{P} = -\rho_b \text{ (C/m}^3\text{)}.$$

The negative sign means that the dipole moment per unit volume, **P**, points from negative to positive in the dipoles.

It is customary and convenient to consider a field associated with just the free charge density $\rho_f$ since $\rho_b$ is due to the response of the material. That field must be due to the total charge density less the bound charge density, therefore

$$\rho_f = \rho - \rho_b = \nabla\cdot\epsilon_0\mathbf{E} + \nabla\cdot\mathbf{P} = \nabla\cdot[\epsilon_0\mathbf{E} + \mathbf{P}].$$

The term in brackets is called the displacement field vector

$$\mathbf{D} = \epsilon_0\mathbf{E} + \mathbf{P} \text{ (C/m}^2\text{)}.$$

In simple dielectrics, **P** and **E** are parallel, and the following relation holds true

$$\mathbf{D} = \epsilon_0(1 + \chi)\mathbf{E} = \epsilon\mathbf{E}.$$

$\epsilon_0$ can now be interpreted as the ability of empty space to support an electric field, and is called the permittivity of free space. ε is the permittivity of the material. A commonly used quantity is the dielectric constant

$$K = 1 + \chi = \epsilon/\epsilon_0.$$

K is greater than 1 for any material, and goes to infinity for a conductor because $\mathbf{E} = 0$ in a conductor. K can be thought of as a measure of the modification of free space by the presence of a material.

From our previous analysis, we have obtained one of Maxwell equations, Gauss' law which reads

$$\nabla\cdot\mathbf{D} = \rho_f.$$

Gauss' law says that the apparent spreading out of the displacement field vector **D** through a Gaussian surface is due to the density of free charges inside. Gauss' law doesn't say, however, that **D** is not producing a swirl. The static **E** contribution can't produce swirling, but the **P** contribution can.

**Capacitance**

We know that two conductors, separated by a dielectric with dielectric constant *k*, form a capacitor. If one conductor has charge +q and the other −q, the measure of the amount of charge that must be placed on a conductor to change its potential by one volt is called the capacitance, which is in units of coulombs per volt

$$C = q/V \text{ (farads)}.$$

If the free charge q increases, the displacement field vector **D**, which equals the $\epsilon_0 k$ field also increases. That causes a proportionate increase in voltage as **E** rises. Given a particular charge q, the only way to change the capacitance is to change the voltage. That can be done by changing the charge separation distances or by changing the properties of space to give different **E**'s. Simply filling the separation space with a material of greater dielectric constant reduces the **E** field in that space, which reduces the voltage and increases the capacitance.

We can use Gauss' law, without involved calculations, to determine the change in the electric field when any capacitor is filled with a dielectric. In empty space, $\mathbf{P} = 0$ and all the charges are free charges, therefore

$$\nabla\cdot\mathbf{D}/\epsilon_0 = \nabla\cdot\mathbf{E} = \rho_f/\epsilon_0,$$

and

$$\nabla\cdot\mathbf{D}/\epsilon_0 = \nabla\times\mathbf{E} = 0.$$

If the space is filled with a simple dielectric, $\mathbf{D} = \epsilon_0 k\mathbf{E}$, therefore

$$\nabla\cdot\mathbf{D}/\epsilon_0 = \nabla\cdot k\mathbf{E} = \rho_f/\epsilon_0.$$

**P** is aligned with **E** so there is no apparent rotation and

$$\nabla\times\mathbf{D}/\epsilon_0 = \nabla\times k\mathbf{E} = 0.$$

The divergence and curl of **E** completely characterize the field. By comparison, the **E** for a charged capacitor with empty space as a dielectric is the same as *k***E** for the same charged capacitor with a dielectric constant *k*. In a capacitor filled with a dielectric, **E** is reduced by 1/*k*. The capacitance C = q/V is increased by *k* since the voltage potential V is reduced by 1/*k*.

In our next edition, we'll look at the effects of electric charges in motion. We'll see that another type of field, the **B** field, is required to describe the magnetic forces associated with them. **R-E**

## EQUIPMENT REPORT

*continued from page 18*

frequency steps.

A number of scanning functions are available: full memory scan, memory block scan, and seek scan, (with two delay modes). The *R8* can also be set to scan from the frequency of VFO A to VFO B. The two VFO's are available so that you can instantly switch and tune between two different frequencies. The second VFO can be thought of as a sort of temporary memory location. One of the nicest features is that you can instantly transfer the frequency of the active VFO into the inactive one. So if you're tuning and come across an interesting signal—but not the one you're looking for—you can put it instantly in the inactive VFO as you continue your search. Returning to the interesting frequency is only two keystrokes away.

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We were impressed by the quality of the Drake *R8*. It is easy to use thanks in part to the clean layout of the controls, and to Drake's decision not to clutter up the front panel with a lot of unnecessary controls (which some manufacturers seem to think looks "hi tech"). We were even more impressed by the control the *R8* gave us to hear the weaker signals we would have simply ignored on other world-band radios.

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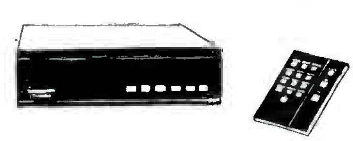

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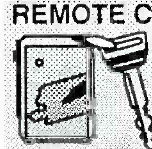
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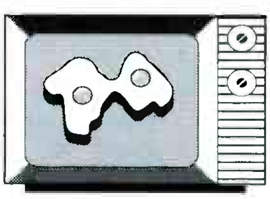

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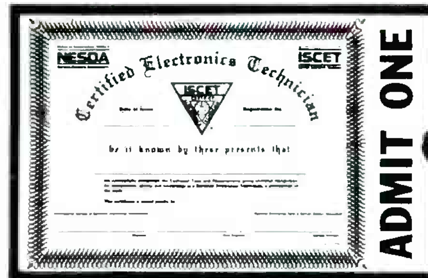


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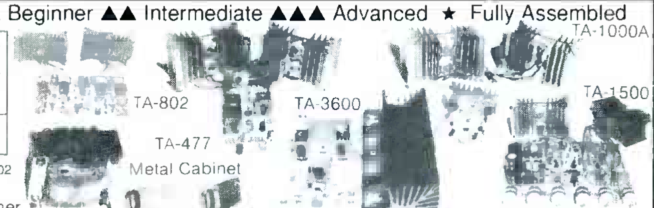


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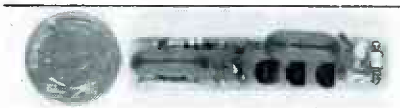

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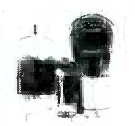

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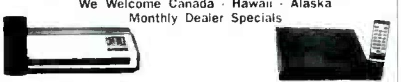

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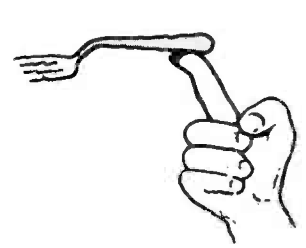

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PIONEER

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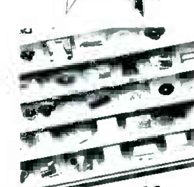

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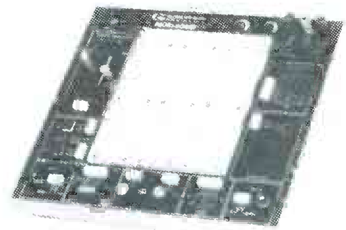

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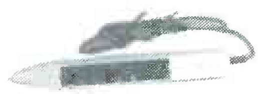

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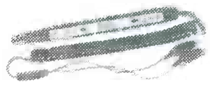

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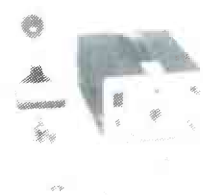

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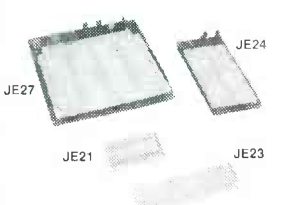


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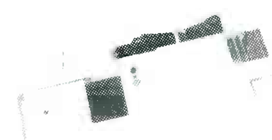

- Erases all EPROM's • Erases 1 chip in 15 minutes and 8 chips in 21 min
- UV intensity: 6800 UW/CM²

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| TMS2532-35 | 9.95 | 2764-25 | 3.75 | 27256-15 | 5.95 |
| TMS2532A | 7.95 | 2764-45 | 3.49 | 27256-20 | 5.25 |
| TMS2564 | 5.95 | 2764A-20 | 3.95 | 27256-25 | 4.75 |
| TMS2716 | 5.95 | 2764A-25 | 3.25 | 27C256-15 | 5.95 |
| 1702A | 3.95 | 27C64-15 | 3.95 | 27C256-20 | 4.95 |
| 2708 | 4.95 | 27C64-25 | 3.25 | 27C256-25 | 4.49 |
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| 2716-1 | 3.95 | 27128-20 | 6.95 | 27512-20 | 6.95 |
| 27C16 | 4.25 | 27128-25 | 7.95 | 27512-25 | 5.95 |
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| 2732A-20 | 4.95 | 27128A-20 | 4.49 | 27C512-20 | 6.49 |
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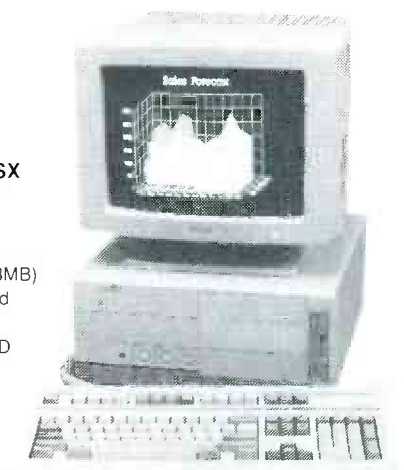

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| 7407 | .39 | .29 | 7483 | .69 | .59 |
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| 7411 | .35 | .25 | 7490 | .49 | .39 |
| 7414 | .35 | .25 | 7493 | .45 | .35 |
| 7417 | .35 | .25 | 74116 | 1.19 | 1.09 |
| 7420 | .29 | .19 | 74121 | .49 | .39 |
| 7427 | .35 | .25 | 74123 | .49 | .39 |
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| 7432 | .39 | .29 | 74151 | .39 | .29 |
| 7438 | .45 | .35 | 74160 | .59 | .49 |
| 7442 | .49 | .39 | 74161 | .69 | .59 |
| 7445 | .75 | .65 | 74192 | .79 | .69 |
| 7446 | .89 | .79 | 74193 | .79 | .69 |
| 7447 | .89 | .79 | 74194 | 1.19 | 1.09 |

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| | | | | | |
|---|---|---|---|---|---|
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| 4164-120 | 120ns, 64K x 1 | 1.89 | 41256-120 | 120ns, 256K x 1 | 1.89 |
| 4164-150 | 150ns, 64K x 1 | 1.59 | 41256-150 | 150ns, 256K x 1 | 1.85 |
| 41256-60 | 60ns, 256K x 1 | 2.75 | 511000P-80 | 80ns, 1MB x 1 | 7.95 |
| 41256-80 | 80ns, 256K x 1 | 2.49 | 511000P-10 | 100ns, 1MB x 1 | 6.95 |

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| 1N4004 | .10 | 1N751 | .15 | 2N3055 | .69 |
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| LS9201 | TOSHIBA | 670 nm | 5 mW | 80 mA | 2.4v | 59.99 |
| LS9211 | TOSHIBA | 670 nm | 5 mW | 50 mA | 2.3v | 69.99 |
| LS9215 | TOSHIBA | 670 nm | 10 mW | 45 mA | 2.4v | 109.99 |
| LS3200 | NEC | 670 nm | 3 mW | 85 mA | 2.2v | 79.99 |
| LS022 | SHARP | 780 nm | 5 mW | 65 mA | 1.75v | 19.99 |

## Dynamic RAMS

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|---|---|---|---|---|---|
| 41256-60 | 256K x 1 | 60 ns | 2.59 | 2.46 | 2.21 |
| 41256-80 | 256K x 1 | 80 ns | 2.19 | 2.08 | 1.87 |
| 41256-100 | 256K x 1 | 100 ns | 1.99 | 1.89 | 1.70 |
| 41256-120 | 256K x 1 | 120 ns | 1.89 | 1.80 | 1.62 |
| 41256-150 | 256K x 1 | 150 ns | 1.79 | 1.70 | 1.53 |
| 511000-70 | 1 meg x 1 | 70 ns | 5.49 | 5.22 | 4.70 |
| 511000-80 | 1 meg x 1 | 80 ns | 5.29 | 5.03 | 4.53 |
| 511000-10 | 1 meg x 1 | 100 ns | 5.09 | 4.84 | 4.36 |
| 514256-70 | 256K x 4 | 70 ns | 6.49 | 6.17 | 5.55 |
| 514256-80 | 256K x 4 | 80 ns | 6.09 | 5.79 | 5.21 |
| 514256-10 | 256K x 4 | 100 ns | 5.69 | 5.41 | 4.87 |
| 541000-80 | 4 meg x 1 | 80 ns | 26.99 | 25.64 | 23.08 |
| 544256-80 | 1 meg x 4 | 80 ns | 31.99 | 30.39 | 27.35 |

## EPROMS

| STOCK # | SPEED | 1-24 | 25-99 | 100+ |
|---|---|---|---|---|
| 2716 | 450 ns | 3.29 | 3.13 | 2.82 |
| 2732 | 450 ns | 4.19 | 3.98 | 3.58 |
| 2732A | 250 ns | 3.29 | 3.13 | 2.82 |
| 2764 | 250 ns | 3.49 | 3.32 | 2.99 |
| 2764A | 250 ns | 3.09 | 2.94 | 2.65 |
| 27128 | 250 ns | 4.79 | 4.55 | 4.10 |
| 27C128 | 250 ns | 4.79 | 4.55 | 4.10 |
| 27256 | 250 ns | 4.59 | 4.36 | 3.92 |
| 27C256 | 250 ns | 4.29 | 4.08 | 3.67 |
| 27512 | 250 ns | 5.49 | 5.22 | 4.70 |
| 27C512 | 250 ns | 5.49 | 5.22 | 4.70 |
| 27C1024 | 200 ns | 10.99 | 10.44 | 9.40 |
| 27C2048 | 200 ns | 21.99 | 20.89 | 18.80 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LT7770 | 543nm (Green) | 0.5mW | 1.0mW | 0.71mm | ≤ 1.2 mrad | random | 1750v ± 110v | 6.5 mA | ≤ 8 kV | 81k Ω | 37 x 350 | 200 | II | 799.99 | 749.99 |
| LT7650 | 632.8nm (Red) | 0.5mW | 2.0mW | 0.49mm | ≤ 1.7 mrad | >100:1 | 1000v ± 100v | 3.5 mA | < 7 kV | 68k Ω | 25 x 146 | 70 | IIIa | 529.99 | 479.99 |
| LT7656 | 632.8nm (Red) | 0.5mW | 2.0mW | 0.34mm | ≤ 2.4 mrad | random | 1050v ± 100v | 2.8 mA | ≤ 8 kV | 82k Ω | 22.5 x 118 | 60 | IIIa | 134.99 | 124.99 |
| LT7655 | 632.8nm (Red) | 0.5mW | 2.0mW | 0.49mm | ≤ 1.7 mrad | random | 1000v ± 100v | 3.5 mA | ≤ 7 kV | 68k Ω | 25 x 150 | 70 | IIIa | 144.99 | 134.99 |
| LT7655S | 632.8nm (Red) | 1.0mW | 2.0mW | 0.49mm | ≤ 1.7 mrad | random | 1000v ± 100v | 3.5 mA | ≤ 7 kV | 68k Ω | 25 x 150 | 70 | IIIa | 159.99 | 144.99 |
| LT7632 | 632.8nm (Red) | 1.2mW | 3.0mW | 0.61mm | ≤ 3.0 mrad | random | 1300v ± 100v | 3.5 mA | ≤ 7 kV | 81k Ω | 20 x 210 | 70 | IIIa | 249.99 | 229.99 |
| LT7621S | 632.8nm (Red) | 2.0mW | 5.0mW | 0.75mm | ≤ 1.2 mrad | random | 1300v ± 100v | 5.0 mA | ≤ 7 kV | 68k Ω | 30 x 255 | 140 | IIIa | 204.99 | 191.99 |
| LT7634 | 632.8nm (Red) | 2.0mW | 5.0mW | 0.75mm | ≤ 1.2 mrad | >500:1 | 1300v ± 100v | 5.0 mA | ≤ 7 kV | 68k Ω | 30 x 255 | 140 | IIIa | 209.99 | 194.99 |
| LT7621MM | 632.8nm (Red) | 5.0mW | 15mW | 1.0mm | ≤ 2.5 mrad | random | 1250v ± 100v | 6.5 mA | ≤ 7 kV | 68k Ω | 30 x 255 | 140 | IIIb | 359.99 | 334.99 |
| LT7627 | 632.8nm (Red) | 5.0mW | 15mW | 0.80mm | ≤ 1.1 mrad | random | 1900v ± 100v | 6.5 mA | ≤ 8 kV | 81k Ω | 37 x 350 | 200 | IIIb | 369.99 | 344.99 |
| LT7628 | 632.8nm (Red) | 5.0mW | 15mW | 0.80mm | ≤ 1.1 mrad | >500:1 | 1900v ± 100v | 6.5 mA | ≤ 8 kV | 81k Ω | 37 x 350 | 200 | IIIb | 389.99 | 364.99 |
| LT7627MM | 632.8nm (Red) | 10mW | 30mW | 1.2mm | ≤ 4.0 mrad | random | 1750v ± 100v | 6.5 mA | ≤ 8 kV | 81k Ω | 37 x 350 | 200 | IIIb | 479.99 | 444.99 |

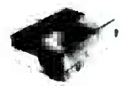
### Laser Pointer

- Output: 3.5 mW
- Wavelength: 670NM
- Power Supply: 2xAAA Batteries (included)
- Beam: Approx. 3" @ 100 yards

Quantity Discounts Available

| STOCK # | PRICE |
|---|---|
| LSPOINT | $199.99 |

### Power Supply



- Input: 115/230V
- Output: +5v @ 3.75A
  +12v @ 1.5A
  -12v @ .4A
- Size: 7" L x 5¼" W x 2½" H

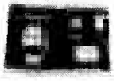
| STOCK # | PRICE |
|---|---|
| PS1003 | $19.99 |

### Collimator Pen

- Output: 2.5 mW (max.)
- Current: 90-150 mA
- Op. Volt.: 2.2-2.5V
- Wavelength: 820NM
- Data Sheet inc.

| STOCK # | PRICE |
|---|---|
| SB1052 | $39.99 |

### Disc Drive & Computer Cleaning Kit



Not just a drive cleaner-but a complete computer cleaning kit. Includes swabs, head cleaning fluid, anti-static cleaner, screen wipes and cleaning diskette.

| STOCK # | | PRICE |
|---|---|---|
| SB1099 | 3½" Kit | $6.99 |
| SB1100 | 5¼" Kit | $6.99 |

### Disc Drive Head-Cleaning Kit

Includes cleaning fluid and head-cleaning diskette

| STOCK # | | PRICE |
|---|---|---|
| SB1105 | 3½" Drive Kit | $1.99 |
| SB1106 | 5¼" Drive Kit | $1.99 |

### Anti-Static Screen Wipes

For static-sensitive applications. Dispenser packs, individually wrapped.

| STOCK # | | PRICE |
|---|---|---|
| SB1104 | Dispenser pack of 25 wipes | $1.99 |
| SB1107 | Dispenser pack of 100 wipes | $4.99 |

### Robotic Arm Kit

Robots were once confined to science fiction movies. Today, whether they're performing dangerous tasks or putting together complex products, robotics are finding their way into more and more industries. The Robotic Arm Kit is an educational kit that teaches basic robotic arm fundamentals as well as testing your own motor skills. Command it to perform simple tasks.

| STOCK # | PRICE |
|---|---|
| YO1 | $49.99 |

### Avoider Robot Kit

An intelligent robot that knows how to avoid hitting walls. This robot emits an infra-red beam which detects an obstacle in front and then automatically turns left and continues on.

| STOCK # | PRICE |
|---|---|
| MV912 | $49.99 |

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## VHF - UHF RF TRANSISTORS

| Order # | Price | Output Pwr. (W) | Input Pwr. (W) | Frequency Range (Mhz) | Gain db/Mhz | *Package |
|---|---|---|---|---|---|---|
| MRF221 | 16.35 | 15 | 3.5 | 136-174 | 6.3/175 | 211-07 |
| MRF237 | 3.69 | 4 | 0.25 | 136-174 | 12/175 | 79-05 |
| MRF238 | 15.95 | 30 | 3.7 | 136-174 | 9/175 | 145A-09 |
| MRF240 | 17.49 | 40 | 5 | 136-174 | 9/175 | 145A-09 |
| MRF240A | 17.49 | 40 | 5 | 136-174 | 9/175 | 211-07 |
| MRF247 | 24.75 | 75 | 15 | 136-174 | 7/175 | 316-01 |
| MRF260 | 11.95 | 5 | 0.5 | 136-174 | 10/175 | 221A-04 |
| MRF262 | 12.95 | 15 | 3.5 | 136-174 | 6.3/175 | 221A-04 |
| MRF317 | 64.95 | 100 | 12.5 | 30-200 | 9/150 | 316-01 |
| MRF321 | 24.95 | 10 | 0.62 | 100-500 | 12/400 | 244-04 |
| MRF340 | 9.95 | 8 | 0.4 | 30-200 | 13/136 | 221A-04 |
| MRF401 | 13.49 | 25 (PEP/CW) | 1.25 | 2-30 | 13/30 | 145A-09 |
| MRF406 | 14.99 | 20 (PEP/CW) | 1.25 | 2-30 | 12/30 | 211-07 |
| MRF422 | 35.95 | 150 (PEP/CW) | 15 | 2-30 | 10/30 | 211-11 |
| MRF426 | 19.49 | 25 (PEP/CW) | 0.16 | 2-30 | 22/30 | 211-07 |
| MRF427 | 16.95 | 25 (PEP/CW) | 0.4 | 2-30 | 18/30 | 211-11 |
| MRF428 | 59.95 | 150 (PEP/CW) | 7.5 | 2-30 | 13/30 | 211-11 |
| MRF450A | 14.49 | 50 | 4 | 14-30 | 11/30 | 145A-09 |
| MRF455A | 12.69 | 60 | 3 | 14-30 | 13/30 | 145A-09 |
| MRF458 | 19.95 | 80 | 5 | 14-30 | 12/30 | 211-11 |
| MRF515 | 2.95 | 0.75 | 0.12 | 400-512 | 8/470 | 79-04 |
| MRF555 | 3.49 | 1.5 | 0.15 | 400-512 | 10/470 | 317D-02 |
| MRF559 | 2.25 | 0.5 | 0.08 | 806-960 | 8/870 | 317-01 |
| MRF607 | 2.49 | 1.75 | 0.12 | 136-174 | 11.5/175 | 79-04 |
| MRF641 | 20.49 | 15 | 2.5 | 400-512 | 7.8/470 | 316-01 |
| MRF646 | 25.95 | 40 | 13.3 | 400-512 | 4.8/470 | 316-01 |
| MRF652 | 11.49 | 5 | 0.5 | 400-512 | 10/512 | 244-04 |
| MRF654 | 19.95 | 15 | 2.5 | 400-512 | 7.8/470 | 244-04 |
| MRF660 | 13.95 | 7 | 2 | 400-512 | 5.4/470 | 221A-04 |
| 2N3866 | 1.25 | 1 | 0.1 | 100-400 | 10/400 | 79-04 |
| 2N4427 | 1.25 | 1 | 0.1 | 136-174 | 10/175 | 79-04 |
| 2N5641 | 16.95 | 7 | 1 | 30-200 | 8.4/175 | 144B-05 |
| 2N5642 | 18.49 | 20 | 3 | 30-200 | 8.2/175 | 145A-09 |
| 2N5643 | 19.95 | 40 | 6.9 | 30-200 | 7.6/175 | 145A-09 |
| 2N5944 | 11.95 | 2 | 0.25 | 400-512 | 9/470 | 244-04 |
| 2N5945 | 11.95 | 4 | 0.64 | 400-512 | 8/470 | 244-04 |
| 2N5946 | 14.95 | 10 | 2.5 | 400-512 | 6/470 | 244-04 |
| 2N6080 | 9.89 | 4 | 0.25 | 136-174 | 12/175 | 145A-09 |
| 2N6081 | 11.95 | 15 | 3.5 | 136-174 | 6.3/175 | 145A-09 |
| 2N6082 | 14.95 | 25 | 6 | 136-174 | 6.2/175 | 145A-09 |
| 2N6083 | 14.95 | 30 | 8.1 | 136-174 | 5.7/175 | 145A-09 |

*Complete dimensions, pin-outs and pictures of all packages are contained in Motorola's RF Device Databooks (See Right).

## AMIGA COMPUTER CHIPS*

| Order # | Price | Description | Pins |
|---|---|---|---|
| 5719 | 17.95 | Gary (8386) | 48 |
| 8362R8 | 39.95 | Denise "Half Bright" (252126-02) | 48 |
| 8364R7 | 37.95 | Paula (252127-02) | 48 |
| 8372A | 99.95 | Fatter Agnus (1MB) For A500/A2000 (318069-02) | PLCC 84 |
| 8520A | 16.95 | Complex Interface Adapter For A500/A2000 (318029-03) | 48 |
| 315093-02 | 34.95 | Kickstart ROM 1.3 | 40 |

***NOTE: No data available on Amiga computer chips**

## RELAYS

•Dimensions: 1.187" x .95" x .735"
•Cross To: P&B* R10 series
•Mounting: Solder terminals

*P&B = Potter & Brumfield

| Order # | 1-9 | 10+ | Description | Coil Res. | Contact Rating | Contact |
|---|---|---|---|---|---|---|
| R185-3 | 6.99 | 5.99 | Relay 12VDC | 185Ω | 3A | DPTD |
| R185-7 | 7.99 | 6.99 | Relay 12VDC | 185Ω | 7.5A | DPTD |

## MOLDED RF CHOKES

| Order # | 1-9 | 10+ | L±10% (uH) | Test Freq. | Resist. (DC) | Induct. |
|---|---|---|---|---|---|---|
| CH.22 | .89 | .79 | 0.22 | 25Mhz | 0.14Ω | 935mA |
| CH.39 | .89 | .79 | 0.39 | 25Mhz | 0.30Ω | 640mA |
| CH.82 | .89 | .79 | 0.82 | 25Mhz | 0.85Ω | 380mA |
| CH1.0 | .89 | .79 | 1.00 | 25Mhz | 1.00Ω | 350mA |
| CH2.2 | 1.09 | .99 | 2.20 | 7.9Mhz | 0.40Ω | 550mA |
| CH4.7 | 1.09 | .99 | 4.70 | 7.9Mhz | 1.20Ω | 320mA |
| CH6.8 | 1.49 | 1.39 | 6.80 | 7.9Mhz | 2.00Ω | 245mA |
| CH10 | 1.49 | 1.39 | 10 | 7.9Mhz | 3.70Ω | 180mA |
| CH22 | 1.49 | 1.39 | 22 | 2.5Mhz | 3.30Ω | 190mA |
| CH47 | 1.49 | 1.39 | 47 | 2.5Mhz | 4.50Ω | 165mA |

## MOTOROLA DATABOOKS

### RF Device Data – Volumes 1 & 2

This two volume set contains over 2200 pages of data on RF Power TMOS FETs, RF Power Bipolar Transistors, RF Small Signal Transistors, Tuning and Switching Diodes, and RF Amplifiers. Also included are drawings, diagrams, dimensions and pin-outs on all packages.

Order # **DL110** 14.95 RF Device Vol. 1 & 2 ............Weight: 4.25 lbs.

### Telecommunications Device Data

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Order # **DL136** 11.95 Telecommunications Device Data........Weight: 1.75 lbs.

### MPU/MCU/Peripheral Data – Volumes 1 & 2

Over 2800 pages on Motorola's Microcontroller and Microprocessor families such as the MC6800, MC6802, MC6821, MC6845, MC146818, MC68701, MC68705, etc.

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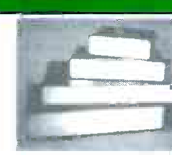

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| E3119F | 19.95 | 18.95 | Steel Enclosure | 2.5" x 17" x 11" | 6.82 lbs. |
| E3119G | 13.95 | 12.95 | Steel Enclosure | 3.5" x 8" x 7" | 2.86 lbs. |
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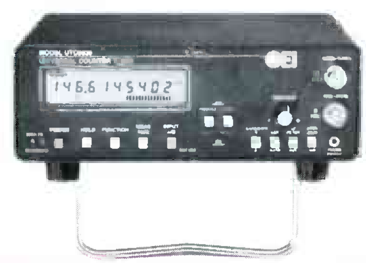

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