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MARCH 1990

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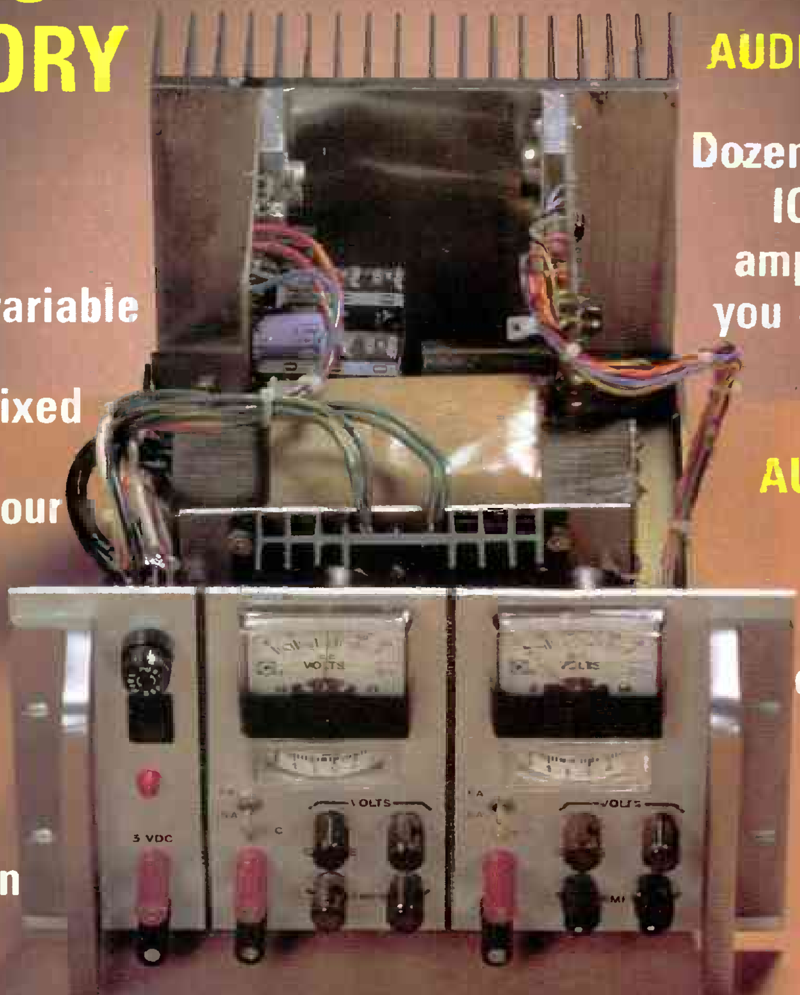

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Vol. 61 No. 3

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PAGE 71

PAGE 42

AND MORE

ON THE COVER

If you're looking for a power supply that combines high voltage, high current, and adjustability, then your search has ended. This month's cover project offers two fully floating, adjustable 50-volt, 5-amp supplies, along with a fixed 5-volt 3-amp supply.

The price of the supply is a steal when compared to commercially available units. Even better, a modular design allows you to build in only the features you need, keeping costs down even more. For all the technical and construction details, turn to page 31.

COMING NEXT MONTH

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AUDIO-AMP COOKBOOK
Automotive applications for power op-amp IC's.

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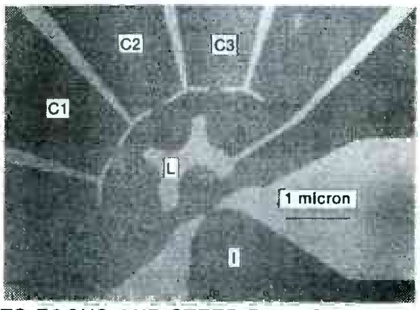
The Audit Bureau of Circulation

New path for computer electronics?

A team of IBM researchers led by Dr. Mordehai Heiblum have demonstrated that fast-moving "ballistic" electrons can be focused and steered as they travel at very low temperatures through gallium arsenide—a semiconductor material that holds promise for use in future computers. The result of studies at the Thomas J. Watson Research Center in Yorktown Heights, NY (where the same research group previously demonstrated that ballistic electrons can travel through ultra-thin layers of gallium arsenide at speeds greater than 1,000,000 mph), the discovery raises the possibility that 21st-century computer architects might possibly be able to use directed beams of electrons in computer-chip circuitry.



TO FOCUS AND STEER BALLISTIC electrons, traveling through a tiny region of the semiconductor material gallium arsenide, scientists "injected" them through an injector (I), focused the electron beam with a tiny metal lens (L), and "collected" the electrons in three areas (C1, C2, and C3).

Normally, electrons moving through a semiconductor travel only a very short distance—known as the "mean free path"—before they collide with atoms, other electrons, or impurities. That causes the electrons to scatter and, in the process, to lose energy and change direction. The mean free path in those experiments is lengthened by reducing the temperature to −450°F, which greatly reduces the normal motion of atoms in the semiconductor material, thus reducing the chance of collision with electrons. That allows the electrons to travel "ballistically"—in other words, without scattering.

The experimental setup was a type of microelectronic switch that involved "injecting" high-energy electrons on one side of a 2-micron region of semiconductor material, and "collecting" them at the other side. The electrons traveled ballistically through a "two-dimensional electron gas," a region free of impurities that might cause energy-wasting collisions.

The scientists applied a voltage to a curved lens as the electrons passed underneath it, causing the electrons to slow down and be focused.

To demonstrate that the path of travel could be controlled, they applied a differential voltage across tiny metal gates as they injected the electrons into the semiconductor. They were able to steer the electrons about 60 degrees off the original path over a distance as long as two microns. (One micron equals 1/25,000th of an inch.)

Substantial development hurdles would still have to be crossed before the controlled electron beams could find any practical application in future computer technology.

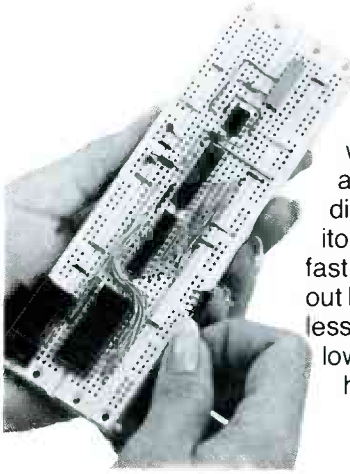
Satellite capabilities coming down to earth?

The first field trial of fiber-optic networks for broadcast television began in December 1989 with ABC's transmission of live television from New York to seven cities across the country. The first of five consecutive trials coordinated by Bellcore (Livingston, NJ) used coast-to-coast fiber-optic links to determine how efficiently network television studios can broadcast programming to affiliate stations using a land-based alternative to satellites, which are now used almost exclusively by major broadcasters to distribute and collect programming.

Besides ABC, CBS, FOX, NBC, and PBS are participating—along with some 50 television stations, manufacturers, suppliers, interexchange carriers, and exchange carriers. The trial networks, established between Atlanta, Boston, Indianapolis, Los Angeles, Minneapolis, New York, St. Louis, and Washington, transmit conventional television signals at 45 megabits per second (DS3 rate). The signals travel over a two-way, tree-branch-like network that permits broadcasters to distribute programming simultaneously to any number of affiliate stations and to receive programming from those stations individually. Eight Bell operating companies and five interexchange carriers are providing the fiber-optic networks for the trials, and several suppliers are providing equipment ranging from video and audio codecs to a new multi-cast switch.

Various factors have combined to make the tests possible, including the declining cost of a DS3 channel and the availability of fiber optics (about 300 cities are connected by fiber optics and are capable of transmitting video at the DS3 rate). Space is limited on satellites, which are also subject to the problems of aging. Further, fiber networks offer near-instantaneous customizing of a program's destinations, lack of signal interference, security from unauthorized receivers, multiple simultaneous audio-channel capability, and the flexibility to make every network affiliate a program source. **R-E**

5 WAYS TO STOP WASTING TIME IN ELECTRONICS.



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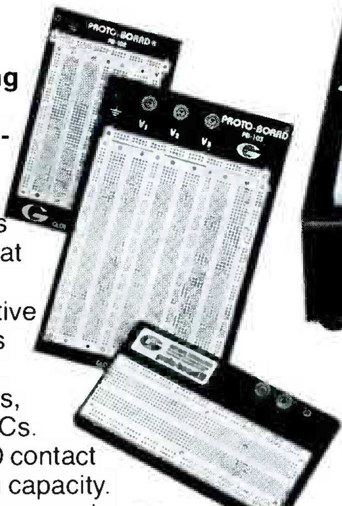

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VIDEO NEWS

DAVID LACHENBRUCH,
CONTRIBUTING EDITOR

• **LCD projectors.** Some technologies advance slowly, some rapidly. An example of the latter seems to be LCD projection TV, which uses liquid-crystal devices as light valves, or shutters. Those projectors can throw a large picture on an external screen. The first such projector to be marketed, introduced in the autumn of 1988 by Eastman Kodak (now being sold under the Seiko Epson name), had the drawback of a very coarse picture. Its three LCD's (one for each primary color) had resolution of 70,400 pixels. Last year, Sharp introduced its own version with much improved performance, with resolution of about 89.500 pixels. Evolution continues with a high-resolution version jointly introduced in Japan by JVC and Seiko, which provides resolution of 210,000 pixels. The LCD projectors are still high-priced ($3,500 to almost $7,000), but many video engineers believe that the LCD lightvalve is the key to giant-screen TV's future.

• **Giant TV tubes.** At a time when many critics are saying that there is no American TV-receiver industry, worldwide television manufacturers are sharply increasing their investment in the United States to build giant-screen picture tubes here. Before the current wave of expansion began last year, the largest size picture tube produced in the U.S. was 27 inches, measured diagonally. Most of the expansion is in plants to manufacture tubes 30 inches and larger, in some cases with provisions for later conversion to production of widescreen tubes for *H*igh-*D*efinition *TV* (HDTV). Major big-screen plants or additional facilities in the United States have been announced so far by Thomson Consumer Electronics (RCA and GE brands) to make 31- and 35-inch tubes; by Toshiba for 30- and 32-inch tubes; and by Philips (Philips, Magnavox, and Sylvania) for 27-inch tubes. Hitachi reportedly is seeking a plant in the United States to build giant tubes.

• **Interactive video.** Will the videodisc of the near future be based on the audio compact disc? Major developments seem to indicate that interactive audio-video discs with full realtime motion are in the works. Two systems—both using standard five-inch CD's—are in competition. Although the *C*ompact *D*isc-*I*nteractive (CD-I) was the first to be announced, its video capabilities heretofore have been confined to still motion and very limited animation. A competing system called *D*igital *V*ideo-*I*nteractive (DVI), developed at the Sarnoff Research Center and being prepared for production by Intel, claims full-motion, high-resolution video. Not to be outdone, Philips, one of the developers of CD-I, recently announced the breakthrough to 70 minutes of full-motion video. Both systems could be offered to the public late this year or early next year.

Intel is expected initially to aim DVI at computer users, while Philips, Sony, and others probably will push CD-I as a consumer-entertainment and -education medium. In addition to its interactive capabilities, the new type of video CD-ROM could become the first all-digital video product, eventually replacing the current 12-inch laserdisc (which has analog video and both analog and digital audio).

• **HDTV progress.** The tide is turning in American research on HDTV. The *A*dvanced *T*elevision *S*ystem *C*ommittee (ATSC), which is coordinating development and testing of proposed systems for the United States, notes that as tests get nearer many proposed systems are changing. The FCC has ruled that any American HDTV systems must be compatible with existing television, and that no system may use more than two 6-MHz channels. Most of the initial proposals envisioned the addition of a second "augmentation" channel to an existing conventional channel to add the extra lines of resolution and the "ears" for the wider picture. Now, ATSC Chairman James McKinney notes that most of the systems have switched to "simulcast" systems—those that leave the current conventional channels alone and add a separate 6-MHz channel to provide a complete HDTV picture. McKinney said recently that four of the five remaining proposals for HDTV systems envision simulcasting. **R-E**

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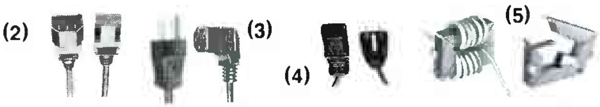

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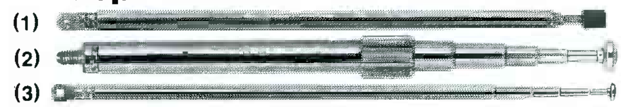

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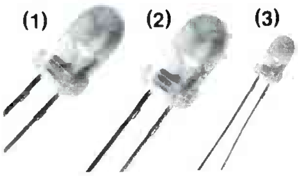

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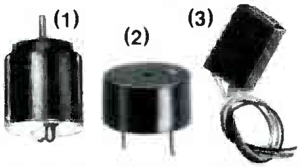

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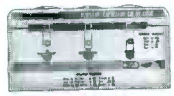

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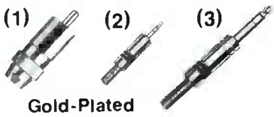

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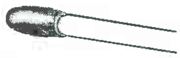

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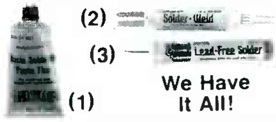

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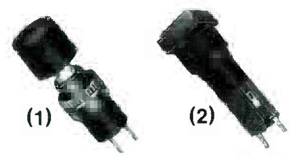

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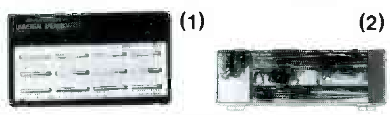

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AUTO NINTENDO

We have a Nintendo system and would like to be able to use it in our van when we're traveling. Our small portable TV works fine when operating off the car's 12 volts, but the Nintendo requires 9 volts at about 850 milliamps. Is there anything that can be done to enable the Nintendo to be powered by the car's electrical system?—M. McCalla, Lanett, AL

There are lots of ways to do that, and which one you choose depends on how much work you want to make for yourself. The answers range from a simple store-bought solution to a few hours on the bench building a box of your own. The choice is yours.

If you're only interested in results, there's no doubt that the easiest thing to do is stop at your local electronics store and see what's hanging around on the shelves. The adapters should be fairly easy to find because they're also needed by people who want to run a compact disc player off the car's electrical system and that, as we all know, is a very popular thing to do.

There are two things to watch out for when you're shopping for an adapter. The first is that it can supply the correct voltage at the required current levels, and the second has to do with the mechanical connection at the power plug.

You shouldn't have any trouble finding an adapter that can supply the proper voltage and current since compact-disk players usually want about the same amount of power. Assuming that you do find one, be very careful to check the voltage polarity at the power plug. There's unfortunately no standard whatsoever about assigning plus and minus. Some adapters put ground on the center terminal and others put it on the collar. The polarity should be marked on the adapter, and your Nintendo probably has it embossed on the plastic case. Double-check everything with a meter before you make any connections. If it is backwards, cut the wire and splice it correctly. It would be a lot better to resolder it at the plug, but most of the adapters use molded plugs.

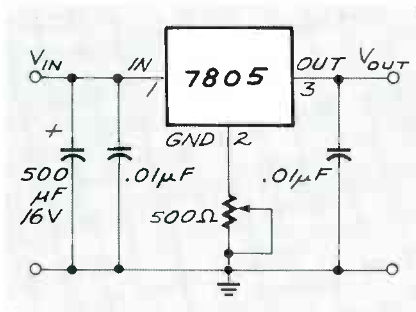

FIG. 1

If you can't find an adapter in the store, you can build one using the circuit in Fig. 1. That is just a simple 7805 regulated supply with the ground leg lifted to raise the output voltage. You can get 850 mA out of a 7805, but you'll have to heat-sink it properly to avoid thermal shutdown. Build the circuit in a plastic box and rotate the pot until you find the point where it's putting out nine volts.

You can substitute an LM317 for the 7805 if you're really worried about drawing that much current, but a well-heat-sinked 7805 should be fine. And even though the Nintendo is rated for 850 mA, I doubt that it really requires that much.

CHIP REMOVAL

I have to repair my audio amplifier and, after spending some time on the circuit, I'm pretty sure that the problem is a bad operational amplifier. My problem is that the chip, like all the others in the amplifier, is soldered directly to the board. What's the best way to get the chips off the board so I can test them?—F. Geoffrey, New York, N.Y.

As sad as I am to say this, I don't believe there's any absolutely safe way to unsolder IC's from a circuit board. The best way I know to get a chip off a board with the least risk of damage is to use a solder pot, a spring-loaded extractor, and a steady hand.

You'll need enough solder in the pot to form a meniscus on the top. Once the solder is melted, put the spring-loaded chip extractor under the IC and carefully lower the foil side of the board into the solder. As soon as the solder on the board melts, the chip should pop out of its holes. You'll probably wind up with some solder bridges on the board afterwards, but you can easily clean them up.

If the board is double-sided or, worse yet, a multilayer board, the chances of success with that method are going to go from so-so to just about nonexistent. Solder has a nasty habit of leaching its way into places where it shouldn't go, and the more layers there are, the more places the solder can creep.

I've removed IC's using that method but, no matter how care-

ful I am, my success rate has never been any more than fifty percent. As a result, there's no way to be sure that a removed IC that tests bad wasn't destroyed in the act of removing it from the board.

If you suspect an IC of being bad, you're better off upgrading your suspicion to a certainty, and give up the idea of safely unsoldering the chip. Take a pair of cutters, snip the legs as close to the IC body as possible, and unsolder each leg from the board. Once you do that, you can clean the board, solder in an IC socket, and replace the chip with one you know is good.

OVERPOWERING AM

Every time I turn on my stereo I can hear a local AM station in the background. Is there anything I can do to get rid of it?—J. Saffir, Miami, FL

You can buy the station and close it down, but that's probably not what you had in mind. The reason that you're hearing the station is because the RF is being picked up by one of the early stages of your amplifier—usually one of the preamp sections, such as the phono input, that has lots of gain.

Check all the cables you have attached to the amplifier inputs to be sure that you don't have a broken ground wire. If you've still got a problem, try bypassing the inputs with small silver-mica capacitors. A good value to start with is 10 pF, but you can use a higher value if the radio station doesn't disappear completely. Don't go much over 470 pF because, above that, you'll be starting to filter out some of the audio. You'll know when that's happening because the high frequencies will be the first to go.

Keep the capacitor leads as short as possible or you'll be making the problem even worse. As a matter of fact, solder the leads right on the lugs of the connector inside the amplifier—and don't forget to turn off the power before you open the case. To be on the safe side, unplug the amplifier from the wall as well as turning it off.

VCR CONVERSION

I recently returned from a posting in England, and I brought back a VCR that I bought there. The machine is set to work off 240 volts at 50 cycles, so I can't use it here. Since it's a really good VCR without many hours of use, can you give me an easy way of converting it to work here in the USA?—C. Meyer, Washington, DC

Aside from ripping out the entire guts of the machine, and replacing them with American-standard parts, there is no simple solution. Not only are the power requirements different, but the electronics in the machine are designed to work with the English PAL video standard, and not the American NTSC standard. To put it mildly, the two are somewhat different. It would actually be a lot simpler and cheaper to go out and buy the VCR that you need, rather than try to modify one type of VCR to work with the other format. **R-E**

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LETTERS

CIRCUIT-BOARD SUPPLIES

A letter from Dr. Barry C. Mears ("Letters," **Radio-Electronics**, January 1990), referring to *Designer's Notebook* in the November and December issues, stated that KTI sells only through distributors, and that only one of those distributors sells the "Kodak chemicals" in small quantities.

Kepro Circuit Systems supplies anything and everything for people to produce printed-circuit boards on a prototype or short-run basis. Kepro has been offering KPR products in the form of pre-sensitized CopperClad since 1954, and has been distributing quarts of the KPR-3 Photo Resist, along with all the associated KPR products, since the late 1960's. All of their supplies and products are described in a 32-page catalog. Kepro's phone numbers are 314-343-1630 in Missouri, or 800-325-3878 out of state.
KEPRO CIRCUIT SYSTEMS, INC.
630 Axminister Drive
Fenton, MO 63026-2992

SIMPLE CIRCUIT BOARDS

I would like to comment on "Hardware Hacker" (**Radio-Electronics**, December 1989). I take exception to some of Don Lancaster's views on creating etched circuit boards.

I have been designing and etching circuit boards—as, I expect, have many of your readers—for over 12 years. I have tried all the available methods, and have read most of the articles on the subject in electronics magazines.

I have found that the quickest method is the direct method using Radio Shack Dry Transfers (276-1577). It works great for single-sided boards as long as you burnish the design when finished. One of the "stupid" (according to Don Lancaster) things that I do is to use ferric chloride, also from Radio Shack. I seem to have no problem producing clean, sharp traces.

The only problem I run into using that method is that as soon as I finish and have the board in its enclosure, my friends all want duplicate boards so they can build the same project, so I'd have to start all over again. Not on your life! Instead I use the second method, which is to screen print the board and make two or three extras.

With the proper registration I can produce single- or double-sided boards with excellent results. The second "stupid" thing that I do is to etch the boards with the resist side up in a glass or plastic container. I have never yet had a board come out bad. The only time they've been bad is when I've flipped the board resist-side down and the resist has become scratched and left a gap in the traces.

If any of your readers are interested, I have available an instructional video tape that shows the hows and whats of screen-printing circuit boards. For information, send an SASE to:
FRED AYRES
4423 West 69
Brooklyn, OH 44144

PROBLEM-FREE PC BOARDS

One of the features that I always look forward to reading in **Radio-Electronics** is "Hardware Hacker," but after reading that column in the December issue I must protest. Don Lancaster's diatribes will certainly scare away more printed-circuit-board makers than create them.

Mr. Lancaster must have had some bad experience making PC boards by the direct method, but the method is not (as he says) "... more hassle than it is worth, and ends up just about totally worthless." I have made many circuit boards, all by the direct method, and have not had a single failure. All are one-of-a-kind, and were made in a lot less time than if I had used any of his recommended alternative methods. Contrary to what Mr. Lancaster says, one problem is to get the pattern on the copper with something that will truly resist the etching solution. Fingerprints, etc., won't hack it. I've had bad results on test pieces from the commercial inking pens and ended up using shellac tinted with an organic dye. It is cheap, easy to use, and easy to clean off the boards.

Mr. Lancaster says that at one time ferric chloride was used as the etchant. Ferric chloride is still being used by the majority of modern commercial circuit-board manufacturers—and by me. It is efficient and has an indefinite storage life, even though it does stain. From what I have read, ammonium persulfate has a short life and must be purchased from new stocks.

Scrubbing circuit-board material at 2 minutes per square inch is a ridiculous waste of time. A few seconds with a kitchen sponge and Comet cleanser does the job very well. I almost always etch boards face-up, unless I am reusing some old solution and the volume is not enough to cover the board very well. (And, when I make a double-sided board, one side necessarily will be face up.) I etch the boards in rectangular Pyrex baking dishes. I find that if the solution is kept moving, there

CIRCLE 109 ON FREE INFORMATION CARD

is no problem at all doing it face up.

I haven't had any direct experience with sensitized boards, but friends have sensitized their own boards and had satisfactory results. They say it was simple, and there were no problems. I have two board designs that I want to make about 60 boards from, and I hope to do it with silk screen—otherwise it will be with commercially sensitized boards.

KENNETH E. STONE
Cherryvale, KS

COMPARING CD PLAYERS

The "Audio Update" column in the December 1989 issue of **Radio-Electronics** left the reader with the impression that all CD players sound the same and the only important thing to consider when selecting a player is the features. While Larry Klein did state that in the ABX test conducted in *Stereo Review*, all of the players were in the $750–$2500 price range, an important point that was not emphasized. I agree that when comparing CD players in a particular price range they will all sound essentially alike. However, a "top-of-the-line," $1500 unit will always sound different (i.e., better) than a $300 model. That is due to several factors—probably the most important is that the $1500 model most likely will use dual digital-to-analog convertors (18 bits or more) with at least 8× oversampling, while the $300 model probably will use a single D/A convertor (14 or 16 bits) with only 2× oversampling. Even the casual listener would be able to differentiate between the two players.

I thought that point needed to be brought up. I enjoy Mr. Klein's column.

DWAYNE ROSENBURGH
Elkridge, MD

CORRECTION

In Fig. 2, in the "RGB-to-NTSC Converter" story (**Radio-Electronics**, December 1989), the junction of XTAL1 and C3 should not be connected to any other components. In Fig. 5, the video output connector pins were mislabeled. Pin 1 should be 4, 5 should be 8, and 9 should be 12. Incidentally, the circuit will not run with EGA.

ETCHING-TANK TIPS

First I'd like to say that I enjoy **Radio-Electronics** very much. I'd like to suggest a better way of working the Plexiglas material used in the article "Make Your Own Etching Tank" (**Radio-Electronics**, December 1989). If you cut the plastic as described in the article, you probably found out that a considerable amount of filing or sanding was needed to produce the square edge needed for a good solvent-weld joint. The "score-and-break" cutting method is perfectly fine if you are making plastic window panes, but it makes a messy edge for solvent-welding purposes.

The remarks in the article about

sawing the material are true—but the problem is easy to overcome. To make a good solvent-welding joint, the smoother the cut the better. The smoothest cutting line can be accomplished by sawing with a very fine-tooth blade in a power saw with a rip fence. The melting problem can be overcome by keeping it cool with water. Don't worry about being electrocuted; you only need a little water, not a garden-hose full. A pump-spray bottle will do fine. The surface of the Plexiglas need only be kept wet enough so that a small puddle stays around the saw blade or drill bit. Be sure not to push the saw too hard—let the saw do the work.

That cutting method will create an edge that requires a lot less filing for a good welding surface and a water-tight joint.

STUART D. HARDEE
Loris, SC

WHEN LESS IS MORE

I would like to comment on Michael Catudal's letter ("Letters," **Radio-Electronics**, December 1989). While I agree with Mr. Catudal that your magazine should feature more articles on new technology, especially some of the newer chips, I disagree that all of the featured projects should be based on the latest state-of-the-art technology.

Many years ago, when I was an engineering student, I remember a professor saying that an engineer's task will be to find the minimum of means that will solve the problem. As an example, he said, anyone could send out a 16-ounce hammer for a crew to use to drive carpet tacks—but an engineer would be expected to send out the lightest hammer that could do the job. My boss would really think I was nuts if I used an 80960 with four 27C1024's to solve a problem that an 8039 with a 2716 could handle sufficiently.

Even though I don't build them, I find many unique and time-saving hints and circuits in most of the projects in **Radio-Electronics**. I've used many of those circuits, time and time again, in designs. Keep up the good work.

CHARLES J. MANCUSO
Sandpoint, ID

R-E

EQUIPMENT REPORTS

Jameco Electronics Wishmaker II Prototype Design Station

A portable, self-contained prototyping station to make your design wishes come true!

CIRCLE 38 ON FREE INFORMATION CARD

THERE IS NO QUESTION THAT PROTOTYPING requires organization. While engineers are seldom noted for neatness, they'll be the first to acknowledge the importance of making a neat prototype. There's a simple reason for that: When the circuit doesn't work the first time, a clean prototype is much easier to troubleshoot.

If, despite your best intentions, your circuit prototypes seem to always end up in a tangled mess, you might need some help from the *Wishmaker II* Digital Prototype Design Station from Jameco Electronics (1355 Shoreway Road, Belmont, CA 94002).

The *Wishmaker II* combines a breadboard with power supplies, test equipment, and more in a convenient and portable package. The entire package is housed in a square, briefcase-like plastic case that measures 13½ × 14 × 4¾ inches. The case opens to reveal a large, removable solderless breadboard with more than 3500 tie points. Above the breadboard is a sloped panel containing various test and measurement equipment. The case top, which is removable, holds a box of assorted stripped and pre-formed jumpers, and a set of test leads.

The *Wishmaker II* offers four separate power supplies. Fixed supplies deliver +5 volts at 3 amps and −5 volts at 500 milliamps. Variable supplies deliver +1.2 volts to +15 volts and −1.2 volts to −15 volts at 500 milliamps.

Built-in testing

The output of the supplies, or the output of any circuit you build, can be monitored using several built-in test instruments. For example, an analog multimeter can measure DC and AC volts (250 volts maximum), DC current (250 milliamps maximum) and resistance.

Your circuits can also be monitored with the built-in logic probe; red, green, and yellow LED's indicate logic highs, lows, and pulses. Input to the probe can be provided to either a tie-point socket or to a test probe.

A three-digit frequency counter can measure signals to 999 MHz in three ranges. Input to the probe is provided to a tie-point socket.

Two BCD-to-7-segment decoder/drivers are provided to display the outputs of digital circuits. Binary inputs are automatically converted for display on 7-segment LED's. While such a circuit would be easy enough to build on the breadboard, its inclusion on the top panel helps to keep the breadboard clutter to a minimum.

Along with the monitoring equipment, *Wishmaker II* provides several devices to provide inputs for your circuits. The simplest is a bank of eight 3-way toggle switches, that can be manually switched to provide high, low, and floating inputs. The switches are arranged so that in the "up" position, the output is high, and so on. However, to monitor the outputs, you might want to use the eight LED display drivers. The bi-color LED's turn red with a high level is presented to their inputs, and green when a low is presented.

The *Wishmaker II* can also provide pulses to your circuits. Two pulse switches provide debounced pulses. Each switch has two outputs, one normally low, and the other normally high; pressing the switch causes the low output to go momentarily high, and vice versa. A pulse generator provides 50% duty-cycle pulses. Seven discrete frequencies are available, ranging from 1 Hz to 1 MHz.

A signal generator provides sine, square, and triangle outputs from 1 Hz to 100 kHz in 5 ranges. Unlike the pulse generator, the output is continuously adjustable. The exact output frequency can, of course, be measured with the built-in frequency counter.

If any of the circuits you design on the *Wishmaker II* need to be connected to a computer, a set of DB-25 connectors makes it easy. One connector, on the side panel of the unit, is internally connected to another DB-25 on the front panel. Jumper wires can easily bring the appropriate signals to the breadboard.

The *Wishmaker II* is an wish come true for engineers, technicians, hobbyists, and students. Besides being an excellent prototyping tool, it would be an excellent teaching tool in an electronics lab course. The *Wishmaker II* is priced at $249.95. A similar device, the $199.95 *Wishmaker I* analog prototype design station. The *Wishmaker* I does not offer the frequency counter, pulse generator ordebounced pulse switches, but does add a speaker and 4 potentiometers. **R-E**

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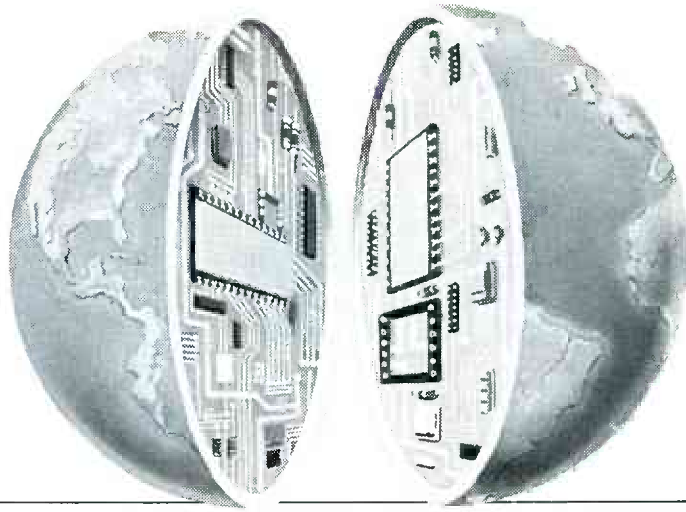

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Beckman Industrial FG3A Sweep/Function Generator

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CIRCLE 39 ON FREE INFORMATION CARD

FOR MEASURING THE RESPONSE OF AN audio amplifier, finding the resonant points of a filter network, or examining any system that operates over a broad frequency range, nothing beats the combination of an oscilloscope and sweep generator. That point was driven home recently when we had the opportunity to examine the *FG3A*, a new sweep function generator from Beckman Industrial Corporation, 3883 Ruffin Rd., San Diego, CA 92123-1898).

The *FG3A* can provide sine, square, triangle, and ramp signals in seven ranges from 0.2 Hz to 2 MHz. A pulse output, at either TTL or CMOS levels (or anywhere in between) is also available. Any of the outputs can be swept either linearly or logarithmically throughout the entire range, or any portion of it. An external VCF or VOLTAGE-CONTROLLED FREQUENCY jack allows an external signal to vary the frequency of the output; A 0–10 volt signal causes a 1000:1 change in frequency. The selected output can also be amplitude- or frequency-modulated by an internal or external signal.

The output amplitude of the *FG3A* is 20 volts p-p into an open circuit, or 10 volts p-p into a 50-ohm load. The duty cycle of the outputs are continuously adjustable from 1:1 to 10:1.

The frequency of the output is displayed on the built-in 5-digit frequency counter. That counter sports an external input, and can be used to measure external signals of up to 10 MHz.

The *FG3A* is ruggedly built in a 9 × 3 × 13-inch shielded plastic case and weighs about 4½ pounds. The front panel features an intelligent layout that is dominated by the 5-digit LED display. Switches are grouped according to function, which makes the unit very easy to operate.

Using the sweep generator

Although the sweep function generator is not one of the most popular test instruments, it is an extremely versatile one. The most common application is measuring the frequency response of amplifiers, filters, and other networks. That task is performed by feeding the output of the generator to both the network under test to one oscilloscope channel. The output of the network is fed to the other scope channel.

If, for example, you were testing an audio amplifier, the sweep generator would be set up to provide sine waves in the audio-frequency range, and the scope would be set to display both the input and the output. At a glance, you would see the response of the amp over the entire operating range.

Using the same technique, it is a simple matter to determine the resonant point of filter networks. Carrying that a bit further, it's possible to identify the value of an unmarked inductor or capacitor, even without an LC meter. Assuming you know the value of one of the components, you can set up a simple LC network and manually sweep the generator for a null. Knowing the resonant frequency and the value of one of the components, simple arithmetic will yield the value of the unmarked part.

The *FG3A* is a unit that has the look, feel, and performance that you might not expect from a $475 sweep function generator. We congratulate Beckman on a job well done. **R-E**

TEST METHODS

MIKE ROGALSKI

Easy impedance measurements

IMPEDANCE MEASUREMENTS OFTEN CONjure up an image of complex test equipment and tricky calculations involving at least a square root or two. However, none of that is necessary if you understand a relationship that exists between impedance and decibels.

That relationship is this: If you cut your load impedance in half, the output of the circuit drops by 3 dB. Using that knowledge, it's easy to design a simple piece of test equipment that will give you the AC impedance of a circuit, and all you need is a potentiometer, a switch, and a VOM having resistance and decibel scales. Switching between the dB- and DC-resistance readings will yield the effective AC impedance of a circuit at a given frequency.

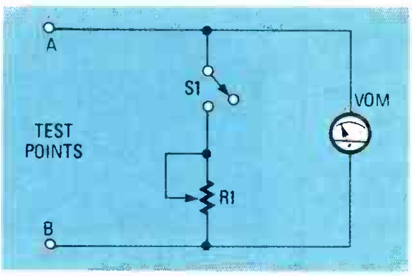

FIG. 1—THE EFFECTIVE AC IMPEDANCE of a circuit can be determined using this circuit.

Figure 1 shows the simple test circuit, which is a simplification of the Wheatstone bridge used in complex impedance-measuring equipment. To use it, connect the two test probes, A and B, across the circuit under question. Then take a relative reading on the dB setting of the meter with the potentiometer out of the circuit (S1 open). If possible, make the circuit's output as high as you can in order to make the reading as accurate as possible. Next, place the potentiometer in the circuit (close S1) and adjust it to a point where the meter reads 3 dB lower than the first reading. Without changing the setting of R1, disconnect the circuit under test and measure the DC resistance of the potentiometer; it will be the equivalent DC resistance of the AC circuit at the frequency used during the test. You may want to take several readings at different frequencies.

Troubleshooting potentiometers

There is a unique way to check a potentiometer's wiper for continuous contact on the resistive element. The circuit shown in Fig. 2 enables you to place a potentiometer in an audio-operating environment so you can hear how it affects an audio signal without the distraction of the music itself. The circuit is particularly useful in recording studios, where audio faders tend to get a lot of wear and tear, but it is equally useful in other situations.

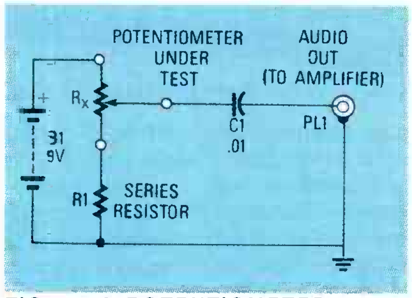

FIG. 2—A POTENTIOMETER can be checked out using this simple test circuit.

The principle behind the circuit is very simple: A DC voltage is applied to the potentiometer in question, and the wiper is moved back and forth at a steady rate. Whenever there is a "dirty" spot on the potentiometer, the DC circuit is interrupted, and a spike appears at the output of the circuit and is fed into a mini-amplifier. The audible signal from the amplifier indicates where the dirt or defect is on the potentiometer, which can then be cleaned or repaired if possible. The trick to the circuit is the output capacitor. While there is only an uninterrupted DC source, there is no signal coupled to the audio amplifier. When the DC voltage is interrupted, the capacitor sees the interruption as an AC signal and passes it to the amp as a pop.

The DC voltage from the battery generally will not burn out wirewound potentiometers, but some carbon-composition potentiometers could be affected. To be safe, calculate how much current you anticipate through the circuit and choose a series resistor that will limit the current to ¼ of the device's power rating. That will keep the battery from destroying the component you are testing. **R-E**

NEW PRODUCTS

ANALOG/DIGITAL STORAGE SCOPES. Besides real-time sampling speeds of up to 250 MS/s, and analog and digital bandwidths of up to 100 MHz, two analog/digital storage oscilloscopes from *John Fluke* provide microprocessor-calculated measurements. The 60-MHz, 250-MS/s *PM 3355* and the 100-MHz, 250-MS/s *PM 3375* (pictured) DSO's are also designed for ease of use, with such features as cursors and full AUTOSET.


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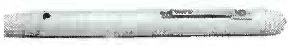
The *PM 3375* uses repetitive sampling for acquisition of recurrent signals of up to 100 MHz, and has 100-MHz analog bandwidth and 150-MHz triggering bandwidth. The *PM 3355* has 60-MHz analog bandwidth and 100-MHz triggering bandwidth. Both units provide 250-MS/s real-time sampling for signals to 25 MHz at 10 samples per second, four 4K memories for high-resolution acquisition and storage of digital signals, and post-trigger capability of up to 5,000 divisions. Other features include averaging for improved noise suppression and greater accuracy, digitally delayed timebase for in-depth signal examination while troubleshooting, 8-bit vertical resolution, and an envelope mode to track signal variations over time.

Signal analysis is simplified with cursor facilities that allow instant, on-screen measurement with numeric readouts of measured and calculated values, automatically compensating for the probes in use. The AUTOSET feature gives automatic channel selection and setting of amplitude, timebase, and triggering for any input signal. To ensure repeatability and efficiency in routine measurements, 64 front-panel settings can be stored. The front panel on each scope also gives clear information on the sensitivity of both channels as well as timebase and trigger setting, memory status, and a display magnification indicator. Optional RS-232 and GPIB/IEEE-488 interfaces allow the DSO's to be operated under computer control or in automatic measuring systems.

The *PM 3355* has a list price under $4500.00; the list price of the *PM 3375* is $5390.00. The factory-installed interface options cost $500.00 each.—**John Fluke Mfg. Co., Inc.**, P.O. Box 9090, Everett, WA 98206; Tel. 800-443-5853.

INFRARED-DETECTOR PEN. Technicians in the consumer-electronics repair industry will appreciate the *B.I.R.D.*, a battery-operated infrared-detector pen from *Parts Express*. The device instantly confirms operation of infrared-emitting products, such as remote controls, VCR tape-stop circuits, and alarm-system infrared detectors. The *B.I.R.D.'s* slim design makes easy work of reaching IR emitters on crowded VCR boards. An LED conveniently placed in the top of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the pen is there to indicate the presence of infrared light in normal light conditions.

The *B.I.R.D.* infrared detector pen costs $55.00.—**Parts Express International, Inc.**, 340 East First Street, Dayton, OH 45402; Tel. 800-338-0531.

WAVEFORM MONITOR/VECTORSCOPE. Designed with the user's needs in mind, *Leader Instruments'* model *5872* combination waveform monitor and vectorscope is loaded with features that accommodate video-signal monitoring easily and effectively. It offers simultaneous vector and waveform display and dual-channel display for observation of two video sources on the same screen.

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ages. The instrument is housed in a metal cabinet with a handle and feet for bench use; the cabinet can be removed for rack mounting purposes.

The model *5872* combination waveform monitor/vectorscope costs $3,795.00.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788.

MAGNETIC SENSING PROBE. By sensing the presence of magnetic fields, the *Lil Devil Mag-Probe* from *HMC* lets you test any electrical/electronic device for current-on/-off or glitches—and doesn't require in-depth training, schematics, or complicated hookups. The device makes it easy to accurately and safely identify and separate electrical from mechanical problems. The *Lil Devil* detects re-

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sidual magnetism and transient current pulses ("glitches") as fast as 10 milliseconds, and identifies north and south poles in AC- and DC-powered solenoids, relays, and any other devices that use a coil. When the instrument's probe tip is placed close to the coil in the device under test, the LED in the probe's handle lights if the device is energized. If the LED doesn't light, the device is de-energized. The probe works without having to make a direct electrical connection, unlike an oscilloscope or voltmeter.

Two models are available. The standard-sensitivity model tests large and standard-sized solenoids and relays. The high-sensitivity model tests the full range of devices, from subminiature to the largest, including most reed relays.

The standard- and high-sensitivity *Lil Devil Mag-Probes* have suggested retail prices of $28.50 and $33.75, respectively.—**HUB Material Company**, P.O. Box 526, Canton, MA 02021.

DISKETTE I.D. SYSTEM. A computer-disk identification system, the *ReMarkAble Label Ssytem* from *Weber & Sons*, eliminates the build-up of layers of labels on 5¼- and 3½-inch floppy disks. Special marker pens are used to write on a thin, self-adhesive, plastic surface affixed to the disk. As the data on the disk changes, old I.D.information is simply wiped off and updated notes can be added to reflect the changes. Ink removal doesn't require the use of any chemicals, alcohol, or erasers; ink is removed simply by wiping the surface with a dry tissue.

The *ReMarkAble Label System Kit* is available as the *RLS-200*, with 200 self-adhesive writing surfaces, or as the *RLS-100*, with 100 writing surfaces. Each kit also contains one marker pen and instructions.

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SPECTRUM ANALYZER/LAPTOP. For true convenience and portability, *Rapid System's R355* combination FFT spectrum analyzer and digital scope includes the versatile *Toshiba 3200 SX*, a 386 laptop personal computer. The complete system allows the user to view both the input signal and its frequency spectrum in real time on the computer. A two-channel, 12-bit, 267-K data buffer; 500-MHz bandwidth; and 1-MHz sampling rate are standard features in this turnkey, stand-alone testing system.

The 16-MHz, 40-B laptop features an IBM-VGA-compatible high-resolution gas-plasma display. The combined system offers two channels of simultaneous 1-MHz acquisition with 32-KB

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data buffers per channel, 1024-point FFT displayed at a rate of 10 per second, and 10 mV to 50 V per division with user-selectable gain scaling. The menu-driven software and features such as save (autosave) and retrieve data to/from disk make the system easy to use. Spectra can be stored either as magnitude or comples data.

The *R355/3200 SX* combination spectrum analyzer and laptop PC costs $8495.—**Rapid Systems, Inc.**, 433 North 34th Street, Seattle, WA 98103.

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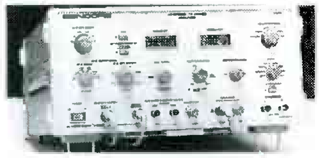

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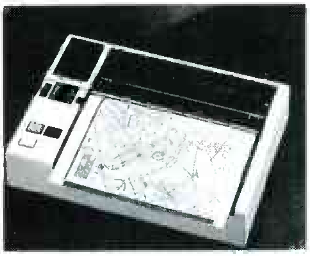
QUAM) and FM-stereo (MPX) analyzer. The digitally accurate instrument produces virtually noise- and harmonic-distortion-free RF, IF, and audio signals.

The *SC80* analyzer allows manufacturers and servicemen to thoroughly performance-test and troubleshoot AM-stereo/FM-stereo receivers for parameters such as sensitivity, selectivity, separation, and pilot threshold. The unit's innovative design includes RF, IF, C-QUAM, MPX, SCA, audio, tunable sweep, and marker generators. Special drive capability allows in-circuit troubleshooting, which highly accurate attenuator and impedance matching for 50-, 75-, and 300-ohm receiver inputs.

The *SG80* AM-stereo/FM-stereo analyzer—including test leads, manual, simplified operating guide, and "100% Made Right" lifetime guarantee—costs $3995.—**Sencore, Inc.**, 3200 Sencore Drive, Sioux Falls, SD, 57107; Tel. 1-800-SENCORE.

RADIO FACSIMILE TERMINAL. *ACE Communications' WX-1000* is a stand-alone radio facsimile terminal designed to produce hard-copy images from various radio facsimile services—including NOAA weather charts, NFAX, and press photos. The unit can even receive satellite weather pictures from NOAA, GOES, and METEOR. The *WX-1000* requires only audio output from a short-wave receiver or an S-band receiver capable of receiving facsimile signals. The built-in high-resolution, 24-pin thermal printer produces clear, crisp images. It also has the capability to produce gray scale, which is ideal for Automatic Picture Transmission (ATP) by weather satellite.



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The *WX-1000* radio-facsimile terminal has a suggested retail price of $845.00.—**ACE Communications, Inc.**, 22511 Aspan Street, El Toro, CA 92630-6321; Tel. 800-523-6366.

SOIC CLIP ADAPTERS. Six SOIC clip adapters, designed to provide test points for high-density, surface-mounted *S*mall-*O*utline *I*ntegrated *C*ircuits (*SOIC*), are being offered as kit *5514* from *Pomona Electronics*. The kit includes one each of the 8-, 14-, 16-, 20-, 24-, and 28-pin SOIC clips, all housed in a sturdy plastic case that is fitted with a contoured-foam interior to separate the enclosed adapters. The SOIC-clip test adapters securely hold both wide- and narrow-body SOIC's. Access pins are 0.025-inch-square gold-plated pins on 0.100 centers, and SOIC contacts are also gold plated.

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The model *5514* SOIC clip adapter kit costs $54.50.—**ITT Pomona Electronics, 1500 East Ninth Street, Pomona, CA 91766.**

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M. M. Newman Corporation, 24 Tioga Way, P.O. Box 615, Marblehead, MA 01945. **R-E**

NEW LIT

SK CROSS-REFERENCE GUIDE. *Thomson Consumer Electronics' SK Replacement Semiconductor Guide (SKG202F)* contains more than 3370 parts, including 228 recently introduced semiconductors. Its 329-page cross-reference section contains references to more than 217,000 original devices.

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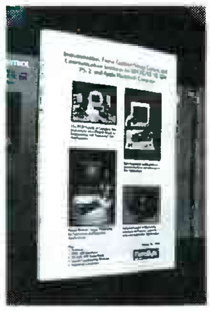
The SK devices cover a wide variety of both discrete components and integrated circuits with consumer as well as industrial applications. The guide contains expanded specifications in the discrete devices charts. Included in the SK line are thyristors, rectifiers, optoelectronics, microprocessors, and many other types of devices, all under warranty for one year.

The *SK Replacement Semiconductor Guide (SKG202F)* is available from Thomson distributors nationwide.—**Thomson Consumer Electronics**, Distributor and Special Products, 2000 Clements Bridge Road, Deptford, NJ 08096-2088.

DATA ACQUISITION AND CONTROL. *Volume 21* of *MetraByte's* product handbook includes comprehensive data on the company's complete line of data-acquisition, industrial-control and -monitoring, video-imaging, signal-conditioning, personal-instru-



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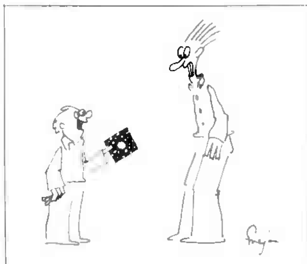
mentation, and communications products for IBM PC/XT/AT, PS/2, and Apple Macintosh II microcomputers. The 304-page color handbook features complete technical data on MetraByte's brand new *WORKHORSE* line of high-speed industrial-control and -monitoring products. Also included are the *PCIP-SCOPE*, a single-board digital-sampling oscilloscope; the *DAS-HRES*, a 16-bit data-acquisition board; the *VOS/DVOS* software, an Icon-based user interface for MetraByte's image-processing hardware; and the *MBIC* family of 19-inch rack-mounted IBM-compatible industrial computers. Product characteristics are presented in easy-to-use quick-selection guides, followed by complete technical and pricing information.

The *Volume 21* catalog is available at no charge.—**MetraByte Corp.**, 440 Myles Standish Blvd., Taunton, MA 02780. **R-E**



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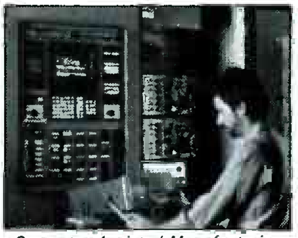

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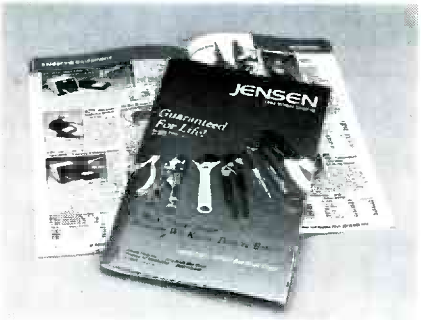

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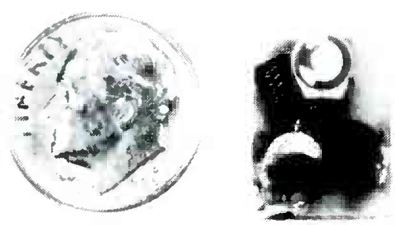

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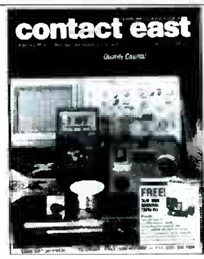

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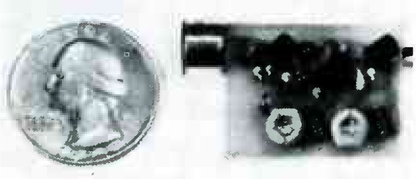

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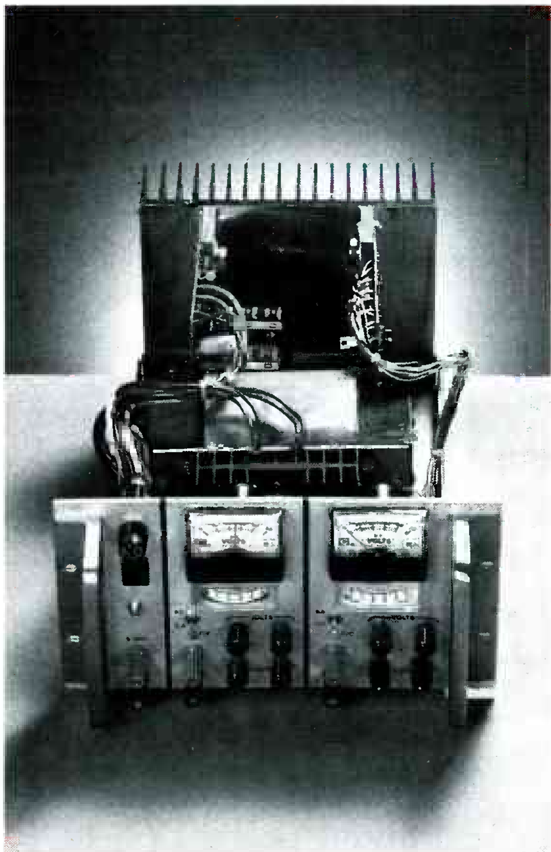


This universal power supply offers high performance and flexibility at low cost.

REINHARD METZ

WHILE NUMEROUS BENCH POWER SUPPLIES have emerged over the years, few combine the performance, flexibility, and low cost of the version described here. This article describes a well-regulated, modular, lab-grade power supply with dual 0–50-volt, 0–5-amp DC supplies, and a single 5-volt, 3-amp DC supply. It uses two identical custom PC boards, one for each 50-volt supply. There's also a customized heat sink with space for both PC boards that minimizes point-to-point wiring in the 50-volt supplies. However, because of the modular design, you can customize the configuration as needed. See Table 1 for a performance summary.

Circuit description

Figure 1 is the schematic of the power supply. The value of the design lies in the use of IC1, an LM317HVK adjustable series-pass voltage regulator, for broad-range performance. The "HVK" suffix specifies the high-voltage version of the regulator. The remainder supplies voltage-setting and current-limiting functions. The input to IC1 comes from the output of BR1, which is filtered by C1 and C2 to about +60-volts DC, and the input for current-sense comparator IC2 comes from BR2, which also acts as a negative bias supply for regulation down to ground.

The purpose of IC1 is to maintain the OUT terminal at 1.25- volts DC above the ADJ terminal. The current drain at the ADJ terminal is very low (nominally 25 μA) and, as a result, R15 and R16 (the coarse and fine voltage adjustments) and R8 form a voltage divider, with 1.25 volts appearing across R8. The bottom end of R16 connects to a −1.3-volt reference level generated by D7 and D8, letting the R8-R15 divider set the output voltage all the way down to ground when R15+R16=0 ohms. In general, the output voltage is determined by:

$$(V_{OUT} - 1.25 + 1.3)/(R15 + R16) = 1.25/R8.$$

Thus, the maximum value from each variable supply board is:

$$V_{OUT} = (1.25/R8) \times (R15 + R16) = 50.18 \text{ volts DC}.$$

Using potentiometers R15 and R16 to control the voltage, V_{OUT} ranges from 0–50 volts DC. As current demand increases, the drop across R2 increases, and at about 0.65 volts (which corresponds to about 20 mA), Q1 and Q2 turn on, becoming the main current path. Also, R3 and R4 ensure that Q1 and Q2 share the load equally. Current limiting is provided by IC2. Its noninverting input uses the output voltage as a reference, and its inverting input is connected to the

TABLE 1—PERFORMANCE SUMMARY

Characteristic	Capability
Number of supplies	2 (fully floating)
Voltage range	0—50 VDC
Current range	0—5 A
Coarse vs. fine control ratio (both current and voltage)	1:10
Voltage regulation	0.01% line, 0.1% load
Current limiter	0.5%

NOTE: (a) There's a current-limiting LED; (b) Has internal +5 VDC, 0—3 A supply.

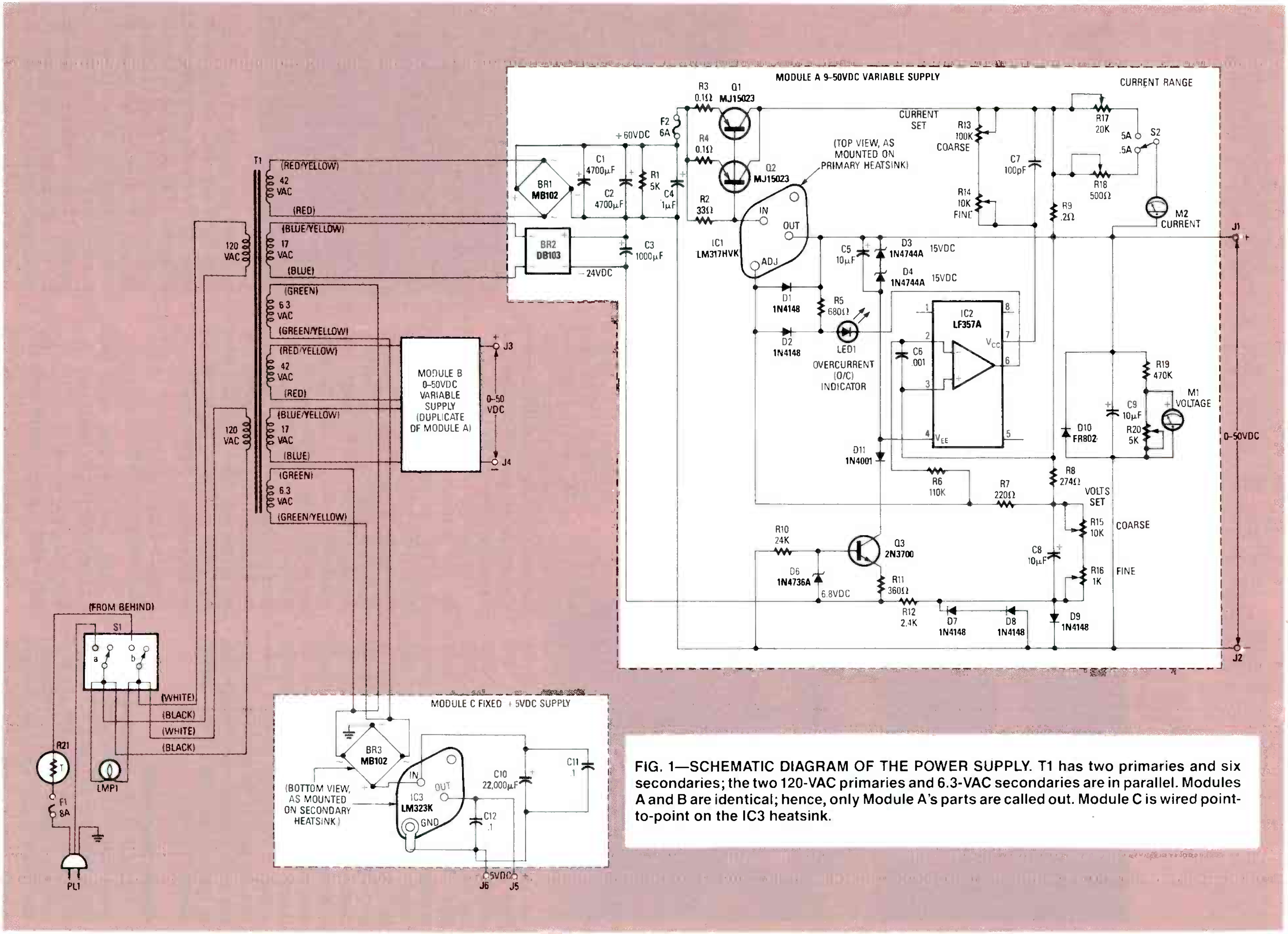


FIG. 1—SCHEMATIC DIAGRAM OF THE POWER SUPPLY. T1 has two primaries and six secondaries; the two 120-VAC primaries and 6.3-VAC secondaries are in parallel. Modules A and B are identical; hence, only Module A's parts are called out. Module C is wired point-to-point on the IC3 heatsink.

voltage divider created by R6 and current-limit potentiometers R13 and R14.

The drop across R6 is about 1.25 volts, the reference voltage mentioned above as being the difference between the OUT and ADJ terminals of IC1. Current from Q1 and Q2 flows through R9, creating a drop across R13 + R14. Thus, IC2 trips when the drop across R9 creates current through R13 and R14, causing the voltage at the non-inverting input to exceed V_{OUT}.

That sets the current limit point at: $(I_{OUT} \times 0.2)/(R13 + R14) = 1.25/100K$; $I_{OUT} = 0–5$ amps. That corresponds to a range of about 0–5 amps. At the current limit point, IC2's output goes low, pulling the ADJ lead down via D2 and lighting LED1. Additional current for D5 is provided by R5. As the ADJ lead is pulled low, the output follows, until the output current drops to a level corresponding to the setting of R13 and R14.

Since the output voltage can be anywhere from 0–50 volts, the power supply for IC2 must track that range using D3, D4, and Q3. Next, D9 ensures that the output voltage doesn't rise when the supply is shut off, while D10 protects against supply back-feeding. Finally, M1 monitors voltage and M2 monitors current. The power supply is modular; each PC board is used for one 50-volt supply, and includes all parts other than those for the front panel and the 5-volt supply. Since a dual 50-volt version may be popular, T1 accomodates two supplies and the 5-volt supply, and a custom heat sink for the two PC boards is available.

Construction

The transformer is mounted on a 6- × 5- × 1-inch L-bracket in the center of the supply, and the heatsinks for IC1 and BR1 go on the back of the transformer bracket. A 6- × 8- × 6- × 11-inch U-shaped cover of 1/16-inch aluminum completes the assembly. Complete all drilling and preparation before assembly, but install only the transformer and its bracket for now, to make wiring easier for you.

Next, assemble the PC board(s) for the 50-volt supplies; Fig. 3 shows the parts placement diagram. Install all components except Q1, Q2, and IC1. Check resistor values as you go, and mount the heat sink for BR1 before installation. Don't forget to observe polarities on all the electrolytic capacitors. Use the alignment holes with 6-32 screws for the PC board(s). Install Q1, Q2, and IC1, using mica insulators, heat sink compound, and 6-32 screws. Check for shorts from

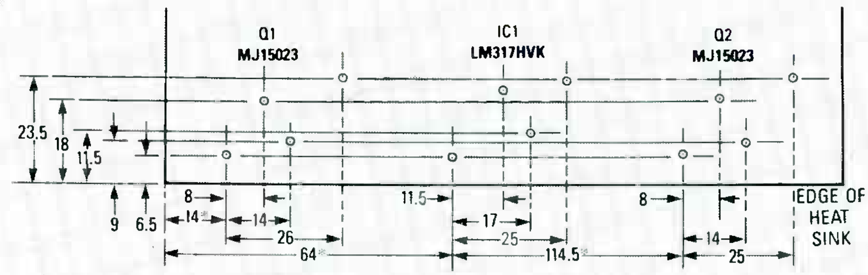


FIG. 2—POWER SUPPLY HEAT SINK LAYOUT. All marked dimensions are in millimeters, all mounting holes are 1/4-inch in diameter, all lead holes are 3/16-inch in diameter, and add 3 mm to all dimensions with an (*) to align the PC boards.

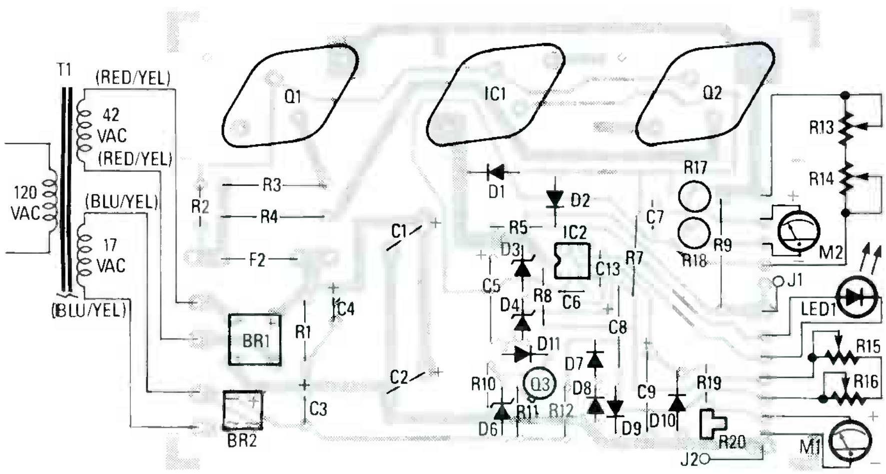


FIG. 3—PARTS PLACEMENT DIAGRAM FOR 50-volt supply. Only one primary and the two relevant secondaries of T1 have been depicted, for brevity.

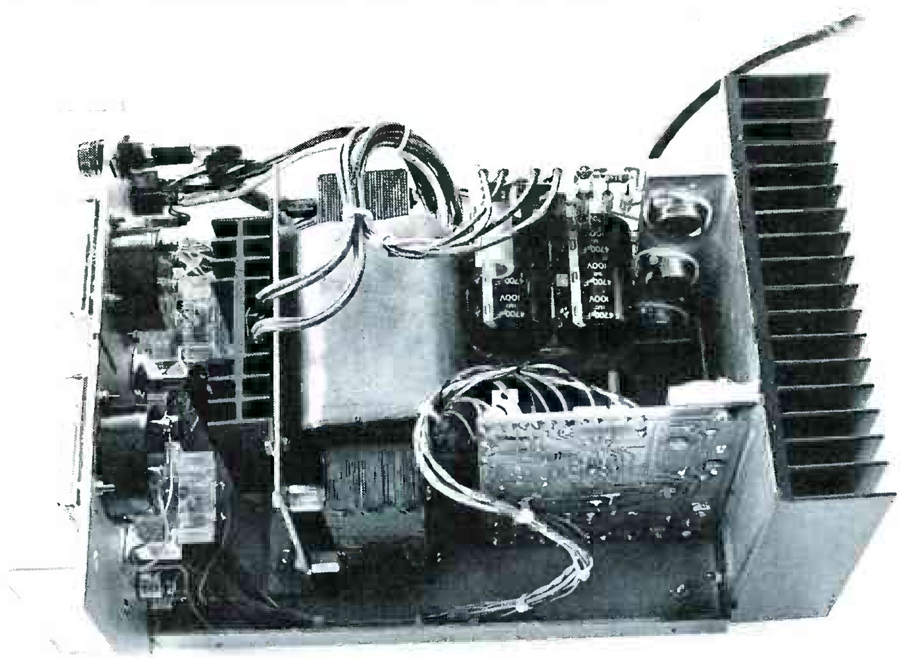


FIG. 4—PROTOTYPE OF THE POWER SUPPLY. Note the custom PC board heatsink at right, and how S1, F1, LMP1, and R21 are wired.

PARTS LIST

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

R1—5000 ohms, 1-watt
R2—33 ohms
R3, R4—0.1, 3-watt
R5—680 ohms
R6—115,000 ohms, 1%
R7—220 ohms
R8—274 ohms, 1%
R9—0.2 ohm, 5-watt
R10—24,000 ohms
R11—360 ohms
R12—2400 ohms
R13—100,000-ohm potentiometer
R14, R15—10,000-ohm potentiometer
R16—1000-ohm potentiometer
R17—20,000-ohm PC-board-mounted potentiometer
R18—500-ohm PC-board-mounted potentiometer
R19—470,000 ohms
R20—5000-ohm PC-board-mounted potentiometer
R21—thermistor in-rush protector (Keystone KC003L)

Capacitors

C1, C2—4700 µF, 100 volts (Panasonic P6430)
C3—1000 µF, 50 volts, Panasonic P6272
C4—1 µF, 63 volts
C5—10 µF, 500 volts
C6—0.001 µF, ceramic disc
C7—100 pF, mica
C8, C9—10 µF, 50 volts
C10—22,000 µF, 16 volts (Panasonic P6420)
C11, C12—0.1 µF, ceramic disc

Semiconductors

IC1—LM317HVK adjustable, series-pass, high-voltage regulator
IC2—LF357A JFET input, 8-pin DIP comparator
IC3—LM323K 5-volt DC regulator in TO-3 case
D1, D2, D7, D8, D9—1N4148 germanium diode
D3, D4—1N4744A, 15-volt, 1-watt Zener diode
D6—1N4736A, 6.8-volt, 1-watt Zener diode
D10—FR802 8-amp, 100-volt fast-recovery silicon rectifier (TO-220 package)
BR1, BR3—MB102 10-amp, 200-volt bridge rectifier
BR2—DB103 1-amp, 200-volt bridge rectifier
Q1, Q2—MJ5023 or ECG68 PNP silicon transistor
Q3—ECG128 or 2N3700 1 watt general purpose NPN silicon transistor
LED1—yellow light-emitting diode

Other components

F1—8-amp fast-blow fuse
F2—6-amp fast-blow fuse
T1—600 VA transformer; 120-volt AC primary; two 42-volt, 5-amp secondaries; two 17-volt, 250-mA secondaries; and one 7-volt, 3-amp secondary
PL1—120-volt AC pilot light
M1—50 mA meter (GC Electronics 20-1110)
M2—100 µA meter (Jewell 81T)
S1—120-volt, 1O-amp DPST switch
S2—SPDT switch
J1, J3, J5—red banana jack
J2, J4, J6—black banana jack

Miscellaneous: 8-inch wide × 6-inch high × 11-inch deep aluminum case with ⅛-inch predrilled aluminum plate as front panel (including holes for handles) and 8- × 11- × 3/32-inch steel plate with a 1-inch lip on the bottom, two front-panel-mounted case handles, 6- × 8- × 3-⅛-inch dual-supply main heatsink, heatsink for 5-volt DC regulator with TO-3 case, heat sink for BR1, 3-wire power cord, knobs, four rubber feet, panel-mounted fuse holder (for F1), two PC-board mounted fuse clips (for F2), PC board (Digi-Key #F040), three TO-3 transistor insulator kits, silicone grease, wire, solder, etc.

NOTE: The following parts are available from A&T LABS, P.O. Box 552, Warrenville, IL 60555; plated PC board with parts placement silkscreen, $19.00; 600 VA custom dual-supply transformer (T1), $66.00; custom dual-supply main heatsink, $42.00; LM317HVK (IC1), $8.00; MJ4502 (Q1 and Q2), $6.00; M1, $16.00. Send check or money order, except for COD orders via UPS in the U.S. If you don't order T1, add 5% shipping and handling for U.S., and 10% for Canada. If you order T1, add 12% for U.S., and 17% for Canada; Illinois residents add 6.75% sales tax.

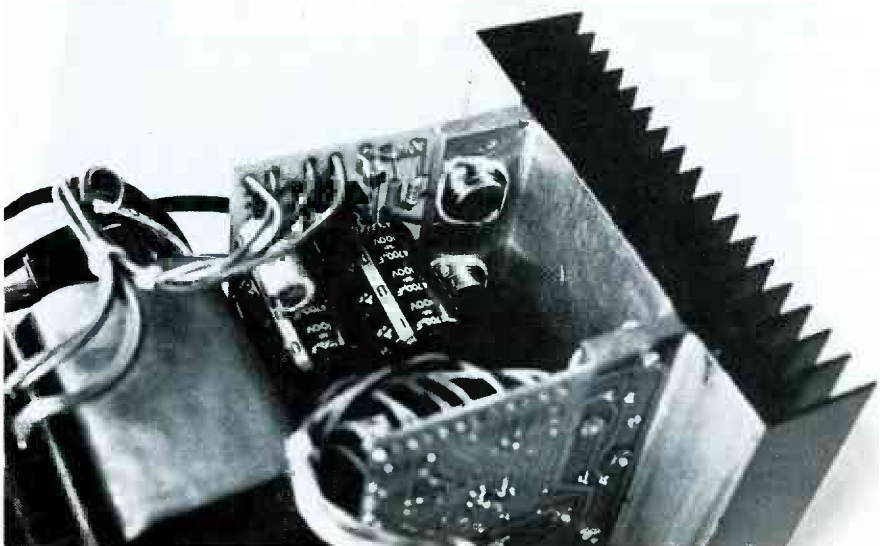


FIG. 5—PRIMARY HEAT SINK ASSEMBLY CLOSE UP. You can see how Q1 and IC1 are attached, the silicone grease used for heat transfer, and how the heatsink is attached to the PC boards. The mica insulators aren't clearly visible from this perspective.

Q1, Q2, or IC1 to the heatsink. Note that BR1 and BR3 have different pin connections than BR2.

A variety of meters can be used with this design. Sensitivity differences are compensated with PC-board-mounted resistors and potentiometers. The values in the parts list call for 50 µA/2500 ohms for M1, and 100 µA/700 ohms for M2. In most cases, panel meters require some faceplate disassembly or removal to mark them for 50 volts and 5 amps DC at full scale. Assuming sensitivities of I_V and R_V for M1 and I_I and R_I for M2, the resistor values are:

- $R19 = 25/I_V$, $R20 = 2 \times R_V$.
- $R17 = 2 \times (1.0_I - R_I)$, for 5 amps full-scale.
- $R18 = 2 \times (0.1/I_I - R_I)$, for 0.5 amp full-scale.
- $R18 = 2 \times (0.2/I_I - R_I)$, for 1 amp full-scale.

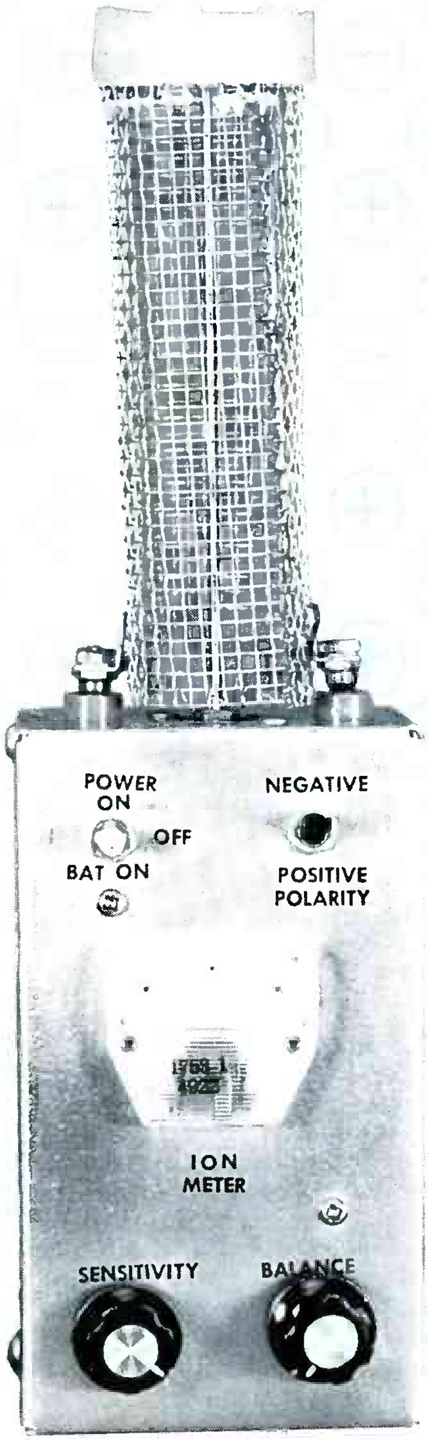
Proceed with the point-to-point wiring from the PC board to the front panel. Those wires should all termi-

continued on page 69

ION METER

Build this ion meter and keep track of the level of ions in your home.

By PETER A. LOVELOCK



A COUPLE OF DECADES AGO, RESEARCH scientists were examining how the population ratio of positive to negative ions in our atmosphere affect human behavior. Many theories were generated—among them, that positive ions cause irritability and erratic behavior, and that negative ions promote well-being. That theory still persists, as can be seen from the numerous products that are marketed to flood your home or office with negative ions.

Because of the interest, the electronics magazines of the time published articles on the properties of ions, how to produce them, and even how to build chambers to measure them. The device in one of the first articles, back in 1969, used a short detector-rod antenna in a cylindrical wire-mesh detector screen. The screen was polarized to plus or minus 60 volts DC, causing ions of the opposite polarity to that of the screen be attracted to it, pass through, and be collected by the detector rod. A special tube was used to amplify the minute voltage induced in the detector rod, which had a 100,000-megohm input impedance. The device used a 1.5-volt battery for the tube filament, a 9-volt battery for the circuit, and a 67-volt battery for the screen.

Circuit description

The schematic of an updated version is shown in Fig. 1. The tube was replaced with a dual-gate RCA 40673 or 40841 MOSFET with both gates tied together as the detector input. The input impedance isn't as high as was the case with the tube, but there's more than enough sensitivity without needing a 100,000-megohm grid resistor; and the gate impedance bleeds off ions without an external resistor. R1 prevents static-voltage buildup on the detector screen in dry weather and instability in M1.

The MOSFET drain feeds a balanced DC bridge using two 2N2222's coupled to M1, a zero-center, $\pm$150-μA meter. Since the MOSFET forms one leg of a bridge, any change in drain current caused by ions at the detector will unbalance it, deflecting M1. Since the device can indicate only relative negative or positive ion levels, the ion meter is balanced for zero, and reads increasing or decreasing levels for the selected polarity; don't interpret M1 as indicating a negative left-hand and positive right-hand scale. Besides filtering the ion type, the detector screen also shields the detector rod from static charge. If the shield is removed, body movements within a couple of feet of the detector rod can make M1 fluctuate, due to static charge that may be present on your clothes.

The ion meter can be powered from either a 9-volt battery, B1, or a 12-volt DC plug-in supply. Whichever supply is in use operates IC1, a 555 which generates a square wave that's fed to a 6-stage ladder multiplier composed of D1–D12 and C1–C14. Each stage acts as a voltage doubler, so the multiplier increases the applied voltage by 2×6, or 12. The +5-volt internal supply is boosted to plus or minus 60 volts at the detector screen, whereas using B1 the multiplier generates plus or minus 108 volts DC. The available current is a few microamps, and the output impedance is about 100 megohms, or R1. Also, R1 prevents loading the multiplier, dropping the detector-screen voltage and cutting sensitivity. The voltage polarizes the detector screen, as long as there's no load.

Measuring the multiplier's output voltage is difficult, since most multimeters, despite their high input impedances, will load the output of the ion meter. Typically, a multimeter with 10-megohm input impedance exhibits a false reading of 25–45 volts DC, when using the plug-in supply. The good thing about the very high impedance at the detector is that shorting the plus or minus 60 or 108 volts DC from screen to case won't generate much current, so a short won't damage the circuit. However,

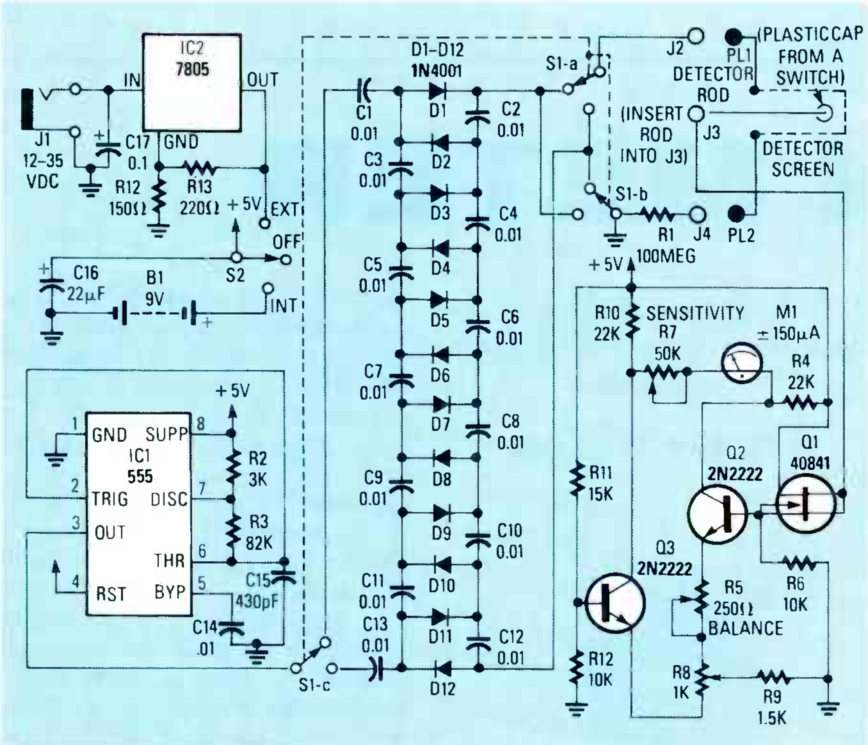


FIG. 1—SCHEMATIC OF THE ION METER; R5 controls the sensitivity of differential amplifier Q2-Q3, and R5 and R8 control the balance. Q1 is a very high input impedance dual-gate MOSFET, and IC1 is a 20-kHz astable feeding a ×12 voltage multiplier composed of D1–D12 and C1–C14.

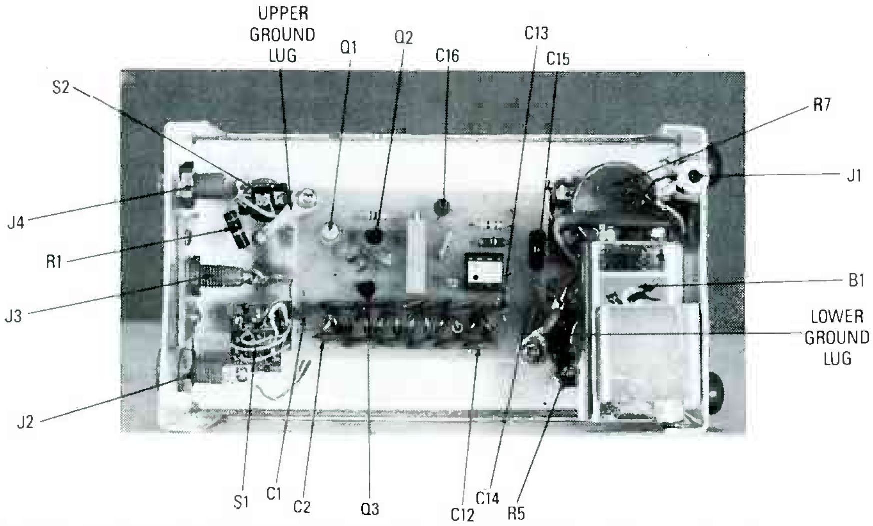


FIG. 2—PROTOTYPE OF THE ION METER, showing the rear internal view. The detector screen plugs into J2 and J4, and the detector rod plugs into J3. Note that the wiring for IC2 is fairly tight, and also that the jumper running under C12 is supposed to be run on the foil side of the PC board.

be very careful, regardless of the low current, when dealing with voltages of that magnitude. Switch S2 reverses the multiplier input-output connections, letting the detector screen voltage be either positive or negative, regardless of whether IC2 or B1 is used as the supply. The ion meter draws 4 mA at 9-volts DC, so a standard 70 mAh, 9-volt battery should be enough to give you 16 hours of continuous use.

Construction

The interior view of ion-meter prototype is shown in Fig. 2. You can build the circuit on a 2 × 3-inch piece of perforated circuit board, or you can etch a PC board using the pattern provided in PC Service. Before you use the foil pattern provided in PC Service, you may have to modify it slightly. Figure 3 points out two jumpers that must be added, and one that must be cut. The PC-board source in

PARTS LIST

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

R1—100 megohms (see text)
R2—3300 ohms
R3—82,000 ohms
R4, R10—22,000 ohms
R5—250-ohm, 2-watt, cabinet-mounted potentiometer
R6, R12—10,000 ohms
R7—50,000-ohm, 2-watt, cabinet-mounted potentiometer
R8—1000-ohm, 15-turn, PC-board-mounted, trimmer potentiometer
R9, R14—150 ohms
R11—15,000 ohms
R13—220 ohms

Capacitors

C1–C14—0.01 µF, 35 volts, disc ceramic
C15—470 pF, 50 volts, disc ceramic
C16—22 µF, 16 volts, tantalum
C17—0.1 µF, 16 volts, tantalum

Semiconductors

D1–D12—1N4001 silicon diode
Q1—RCA 40673 or 40841 dual-gate, P-channel MOSFET
Q2—2N2222 NPN transistor
IC1—555 timer
IC2—7805 5-volt DC regulator

Other components

S1—miniature 3PDT switch
S2—miniature SP3T switch
M1—±150-µA meter with centered needle
PL1, PL2—threaded banana plugs and nuts
J1—miniature monophonic jack
J2, J4—banana jacks without ground lugs
J3—miniature pin jack

Miscellaneous: Chassis box, 5-¼ × 3 × 2-⅛-inches, PC board standoff kit, TO-220-type transistor case insulated mounting kit for IC2, 120 VAC-to-12 VDC plug-in power supply, 4 × 5-inch piece of ⅛-inch grid metal screening, 8-pin DIP socket, two 3-pin transistor sockets, one 4-pin transistor socket, 9-volt battery clip, plastic cover from subminiature switch for detector rod, solder, wire, hardware, etc.

NOTE: The RCA 40763 dual-gate MOSFET is available for $2.00 plus $3.00 shipping and handling from Circuit Specialists, P.O. Box 3047, Scottsdale, AZ 85271-3047, (800) 528-1417 or (602) 966-0764; shipping time is normally about 10 days. The PC board is available from R.R. Assoc., 31066 Glendon, Los Angeles, CA 90034, for $4.50. That includes shipping and handling; California residents add sales tax.

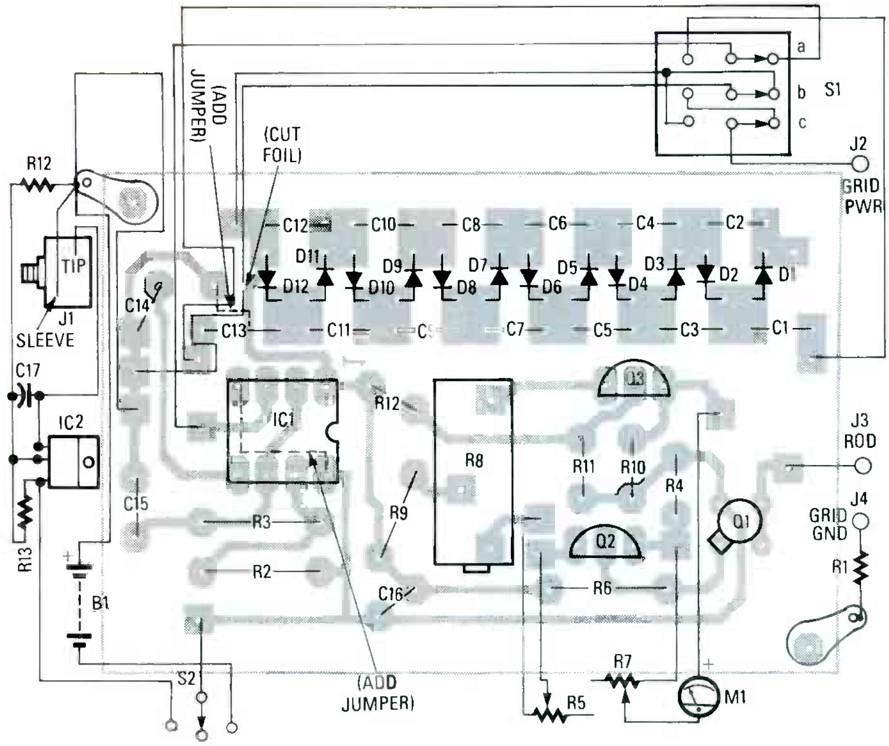


FIG. 3—PARTS-PLACEMENT DIAGRAM of the ion meter. Note the terminals used for J1, and the modifications to the PC board (all they involve is cutting a foil and adding two jumpers).

the Parts List will make every effort to make those changes for you in advance, but be aware of them anyway.

R1 may be hard to find; an alternative is ten ¼- or ⅛-watt, 10-megohm resistors in series. Potentiometer R8 is a 10–15-turn, PC-board-mounted version, while R5 and R7 are the case-mounted variety, and permit easy adjustment of M1. The parts-placement diagram is shown in Fig. 3. Mount the voltage multiplier first, being careful with C1–C13 and D1–D12. A mistake there can reduce detector-screen voltage, or result in no polarizing voltage at all. The resistance from the cathode of D1 to the anode of D12 should be about 300 ohms.

Install IC1 using an 8-pin DIP socket, then R2, R3, and C15. Next R4, R6, R8–R12, R15, and C16 are installed; R4, R10 and R15 are to be vertically mounted. Then, connect M1, R5, R8, S1, S2, and the detector. Leave plenty of extra lead length; you can trim off the surplus when the PC board is installed in the case. Install

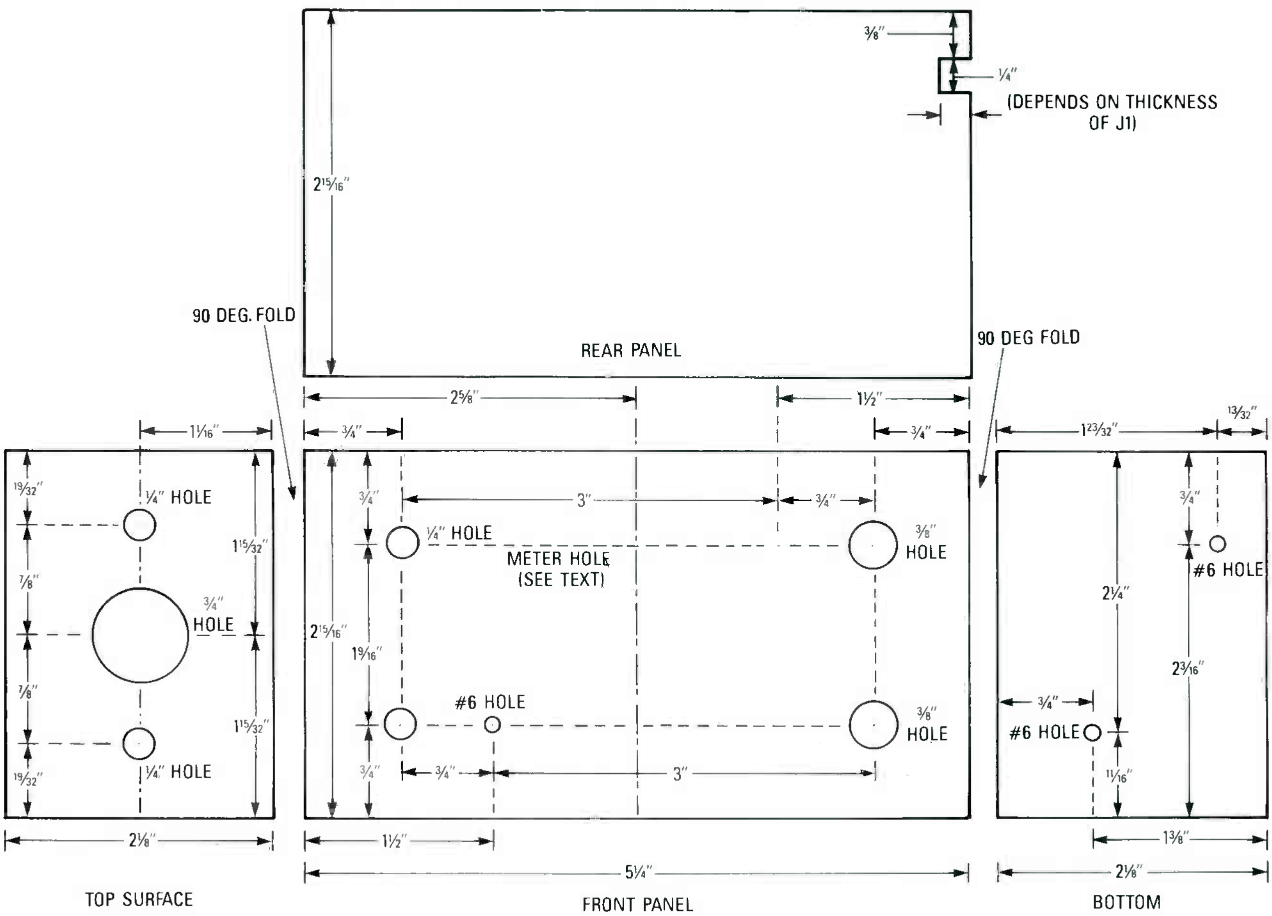


FIG. 4—ION METER CASE LAYOUT, consisting of top surface, front panel, bottom surface, and rear panel. Make sure that everything has been carefully measured before any drilling or cutting.

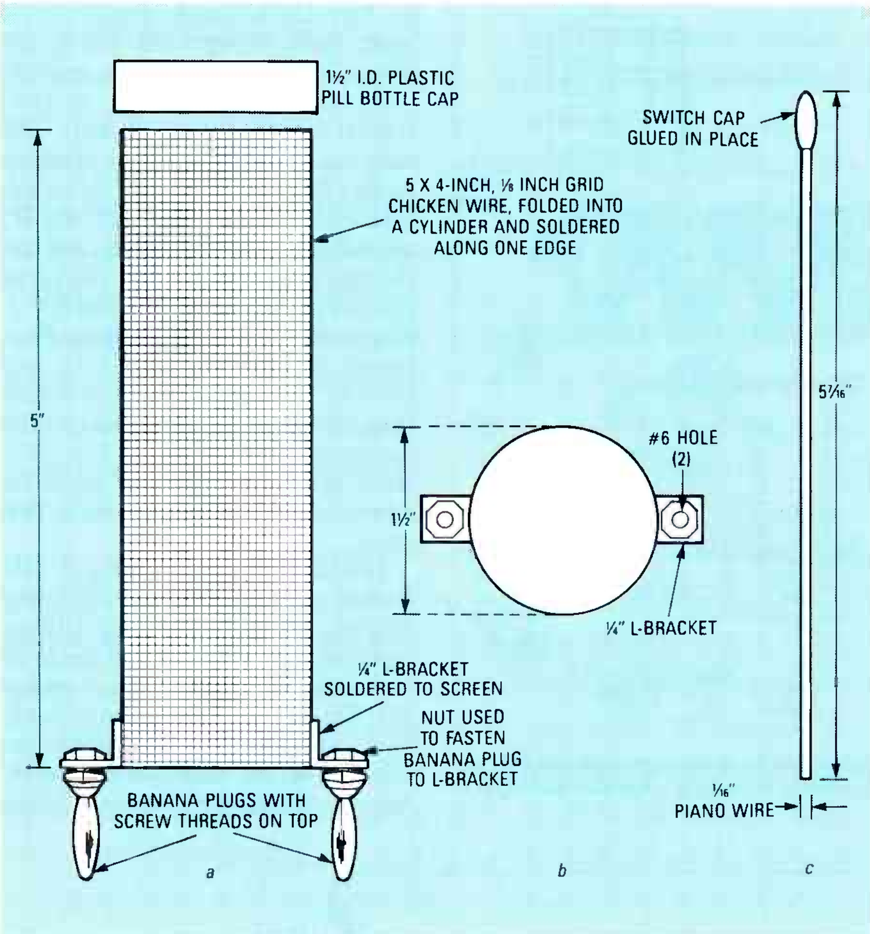


FIG. 5—DETECTOR SCREEN, SHOWING (*a*) the cage with the banana clips, and (*b*) the cap over the top of the cage, made from a 1.25-inch inner-diameter pill bottle cap.

Q1–Q3 with transistor sockets if possible; otherwise, use minimal soldering time and, preferably, a grounded soldering iron for Q1.

The case

All prototype components were mounted in a two-piece, 5-¼ × 3 × 2-⅛-inch box. One half serves as front panel for R5, R7, S1, S2, and M1. The top of that half supports the detector rod and screen as shown in Fig. 2-*a*. Figure 4 is the dimensioned case layout, showing the upper surface, front panel, lower surface, and rear panel. Use a straight-edge and pencil to locate the front-panel holes for S1, S2, R5, and R7, mark with a center punch, and drill. Check the shaft diameter of the parts you plan to use, and adjust the drill sizes accordingly.

The hole for M1 isn't dimensioned since yours may vary from that of the prototype. You'll need a ±150-μA zero-center meter for M1. A surplus FM-radio tuning meter should work nicely. Some meters are "D"-shaped, requiring modification of the hole with a small file, for an easy fit. If yours uses mounting screws, drill additional holes, and mount M1 on the front panel with screws, clips, double-sided adhesive tape, or rubber cement. Apply the latter to both the rear surface of the meter and the front panel, and let it dry. It'll act like contact cement, but you can still pry M1 off.

Drill a #6 hole for the heatsink of IC2 in the bottom surface of the top half of the case, as shown in the lower surface drawing of Fig. 4. For a case other than the one specified in the Parts List, modify the drilling dimensions. You can try a plastic case if you want to, but a metal one might provide better shielding. When all the holes are drilled, don't mount any components until you've applied the lettering using rub-on transfers.

Clean the front panel with steel wool or rubbing alcohol. Cut the lettering with an X-acto knife, hold with tweezers, and position on the front panel; don't mount the knobs, screws, or M1 until you're done. Press the lettering with a fingernail, run a pen over the surface, and lift the backing off with tweezers. Cover with pa-
ing off with tweezers. Cover with pa-
per, and rub firmly with a fingernail for a good bond. Let it dry for a day before applying varnish.

The detector

The detector screen is made from a 4 × 5-inch piece of ⅛-inch metal screening, as shown in Fig. 5. Roll it into a 5-inch long cylinder, hook the ends to form a seam, and solder. Solder small L-brackets with #6 holes to one end, and mount banana plugs PL1 and PL2 with nuts; they plug into J2 and J4. The opposite end of the detector-screen cylinder can be closed with a large plastic pill-bottle cap (1.5-inch inner diameter).

Figure 6 shows the detector-rod in-

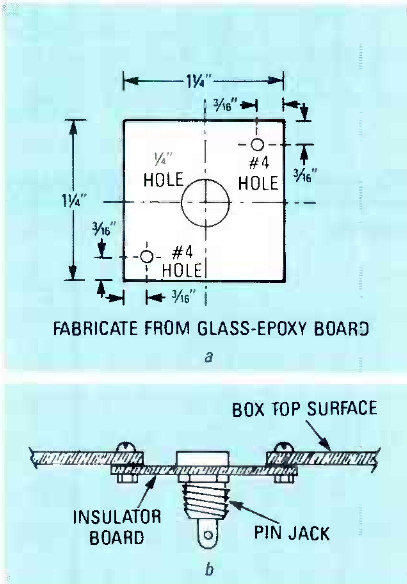


FIG. 6—DETECTOR-ROD INSULATOR BOARD, showing (*a*) physical layout and (*b*) assembly into the case.

sulator board, made from a 1.25- × 1-¼-inch piece of glass phenolic; the detector rod plugs into J3. As shown in Fig. 4-*b*, mark and punch the ¾-inch hole for the detector-rod insulator board. Drill two ¼-inch and two #6 holes as shown. Center the hole for J3 on the ¾-inch hole in the top of the case, and drill two holes in the insulator board through the mounting holes in the top of the case.

Attach the insulator board to the inside of the top of the case with #4 machine screws. Make the detector rod from a 5-5⁄16-inch piece of 1⁄16-inch piano wire, as shown in Fig. 4-*c*. Glue a rubber cap from a small subminiature switch handle on one end as a grip. That'll let you insert and re-

continued on page 70

Limit your audio volume to prevent clipping and distortion.

LOWELL D. JOHNSON

HAVE YOU EVER BEEN ANNOYED BY A PAGing system that makes the speaker difficult to understand, or by a stage-show performer who rattles the speakers by singing loudly into a microphone? Most people assume that the equipment is malfunctioning, and that repairs are needed. However, in many cases that's not so; and the real culprit that's causing the distortion is audio-level mismatching.

Basically, if the gain of an audio amplifier is adjusted for a small input signal, and a large signal is applied, then the amplifier is driven beyond its capabilities and distortion results, even though the amplifier is working perfectly. And, if the amplifier is adjusted for a strong input signal, and a weak signal is applied, then it is difficult to understand what the speaker is saying. In either case, it sounds awful, and the message doesn't get across. However, if you build the circuit described in this article, it will eliminate those kinds of problems; the circuit maintains a constant output-voltage level, regardless of the input signal.

The circuit produces no clipping, which would flatten the peaks of the signal, and virtually zero distortion, because the shape of the output signal is a true replica of the shape of the input signal. The circuit introduces little noise, so none is heard at the output. Pumping, or changes in amplifier gain that can be detected by the listener, is almost imperceptible. Transient spike handling is excellent—if it weren't, the limiter would not be fast enough to control instantaneous fast-rising spikes, such as a percussive sound.

Volume limiters aren't always desirable. For example, the circuit we'll present was installed in a church PA system to compensate for the different voice levels of the various members of the congregation who made short announcements. Everyone loved it—except the minister. After the sermon, he very strongly requested that a switch be installed that could disable the limiter. It seems that he preached fire-and-brimstone, and he *wanted* to rattle the speakers.

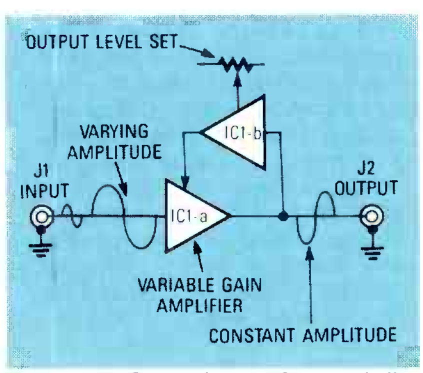


FIG. 1—BLOCK DIAGRAM of the audio limiter. The feedback loop of IC1-a controls the gain of the circuit.

Circuitry

Figure 1 shows the block diagram of the audio limiter. Amplifier IC1-a can change its gain from 1/100th to ×100, depending on the net effect of its feedback loop. That way, the overall gain of the circuit is such that the output level remains constant. If we put a potentiometer in the feedback loop of IC1-a that we could continuously adjust to maintain a steady output level, that would do the trick. However, that would be extremely impractical, as well as being boring; what we need is a resistor that can instantly change its value in accordance with the output voltage of IC1-a. An optically coupled *L*ight-*D*ependent *R*esistor, or LDR would do the trick.

An optocoupler is a device that contains both a light source (an LED) and some kind of light-sensitive device (in this particular case it happens to be an LDR) inside one package,

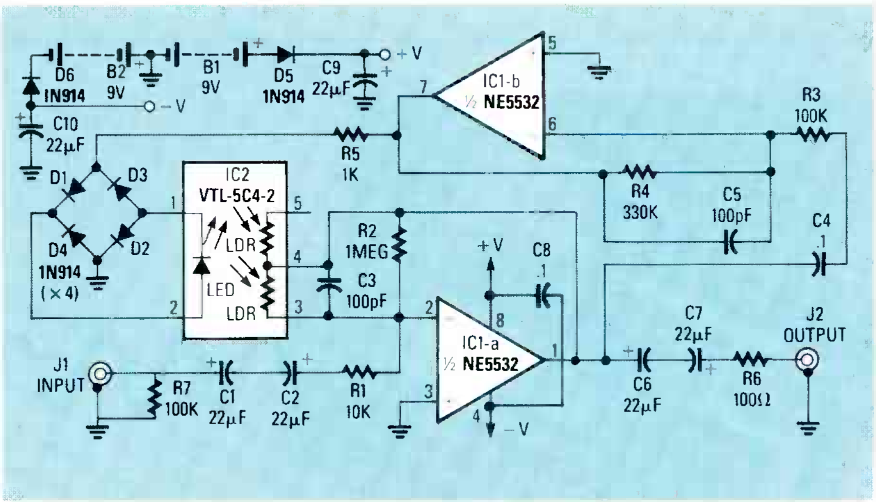


FIG. 2—SCHEMATIC OF THE VOLUME LIMITER. IC1-a is connected as an inverting amplifier whose gain is controlled by the LDR portion of an optocoupler.

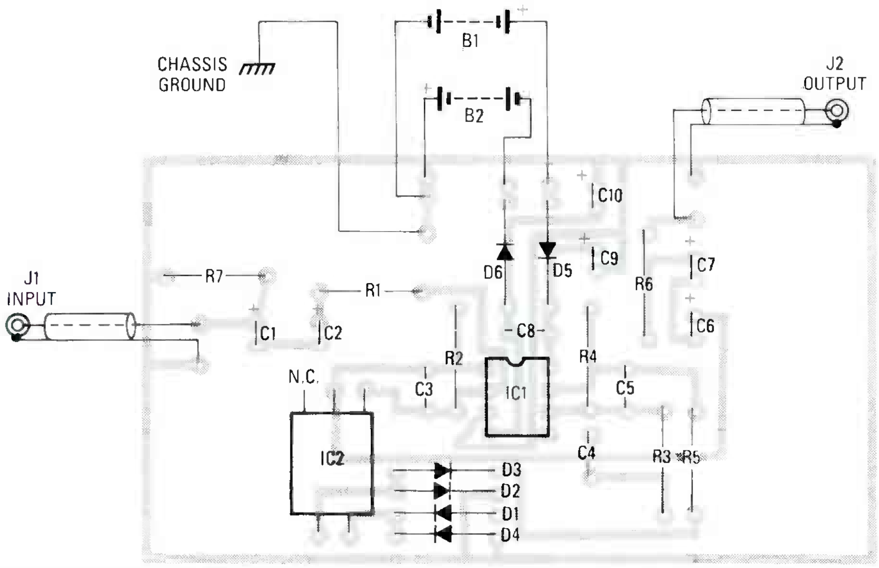


FIG. 3—FOLLOW THIS PARTS-PLACEMENT DIAGRAM if you are using the PC board.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—10,000 ohms
R2—1 megohm
R3, R7—100,000 ohms
R4—300,000 ohms
R5—1000 ohms
R6—100 ohms

Capacitors
C1, C2, C6, C7, C9, C10—22 μF, 35 volts, electrolytic (a larger value will also do)
C3, C5—100 pF, 50 volts
C4, C8—0.1 μF, 50 volts

Semiconductors
IC1—NE5532 low-noise audio amplifier (Signetics)
IC2—VTL-5C4-2 optocoupler device (Vactec)
D1–D6—1N914 diode

Other components
J1, J2—RCA jacks

Miscellaneous: power supply, project case, wire, solder, etc.

Note: A kit of parts, a PC board, and assembly instructions (power supply and enclosure not included) is available for $48.00, and a single PC board is available for $25.00, from Woods Electronics Inc., 4233 Spring St. #117, La Mesa, CA 92041 (619) 265-2551 (order # AVL-42889-K). An assembled and tested unit is also available for $57.00 (order # AVL-42889-A). Check or money order, only.

with the leads of both brought out to external pins, much like an IC. When the LED is turned on via an external input voltage, the LDR's resistance is very small, and when the LED is turned off, the LDR's resistance becomes very large. The resistance of the LDR can therefore be varied at a very fast rate, according to the intensity of the light from the LED. So let's use the LDR portion of an optocoupler in the feedback loop of our amplifier to produce a gain-controlling circuit.

Now, to be more specific, we need an optocoupler with an LDR that can reduce its resistance instantly when its input signal reaches the limiting threshold, thereby reducing the gain of the amplifier to just below the threshold. Then we'd like it to stay at that value until the input signal became weaker, and then gradually increase the gain until the threshold is reached. Fortunately, the VTL-5C4-2 from Vactec Inc. (10900 Page Blvd., St. Louis, MO 63132) has exactly those characteristics. When the light source is illuminated, the resistance decreases in a matter of microseconds (very fast with respect to audio frequencies), and when the light source is removed, the resistance increases over a period of seconds (very slow with respect to audio frequencies). Those combined characteristics can form a limiting circuit that produces a constant output level, but whose action is not easy—in fact, quite difficult—for the listener to detect.

Figure 2 shows the schematic of the volume limiter. IC1-a is connected as an inverting amplifier; ignoring the LDR (assume that its resistance is very high so that it doesn't affect the feedback loop), the gain is R2/R1, or 100. Standard low-impedance-microphone preamplifiers have a gain of 100. Thus, the output at IC1-a pin 1 will be about 2 volts p-p.

The second half of the amplifier, IC1-b, is connected to the output through C4, and its gain is R4/R3, or 3. The optocoupler's LED turns on when the voltage across it is about 2 volts. The higher the current through it, the brighter it illuminates. On positive peaks, it is in series with D1 and D2, and on negative peaks it is in series with D3 and D4. Since D1–D4 are silicon diodes, about 0.7 volts is dropped across each one before they begin to conduct. Therefore, the total positive voltage across the bridge required to illuminate the LED is 0.7V + 0.7V + 2V, or slightly less than 3.4 volts. The same voltage with a negative polarity appearing across the bridge will also illuminate the LED.

As the AC signal at IC1-b pin 7 approaches 6.8-volts AC, the LED receives short bursts of current, and the LDR instantly reduces in value to a point where it reduces the gain of IC1-a, thereby reducing the output of IC1-b pin 7 to less than 6.8 volts AC. Because of the slow recovery time of the LDR, it appears effectively as a fixed resistor and therefore produces virtually no distortion. The output voltage, 6.8-volts AC, when divided by the gain of IC1-b, is about 2-volts p-p, which is a standard line level. Since the LDR can go below 100 ohms, the gain of IC1-a can be reduced to LDR/R1, or 1/100th. That means that signals up to 200-volts p-p can be applied to the input (although you'll never have an input with that magnitude), while maintaining the output at a line level; any input signal ranging from microphone-level to 200 volts will produce a clean line-level output.

If R5 were left out of the circuit, the output level would be so constant that a monotone sound quality would result. By putting a little resistance in series with the bridge, the output voltage will be allowed to vary a little, and the sound is much more natural. A 1K resistor is a good choice for R5, but try out other values for yourself. You may also want to try other R2/R1 and R4/R3 ratios.

The NE5532 (IC1) is a relatively expensive dual op-amp with very-low-noise characteristics. If you can tolerate some noise, feel free to use a 741, 324, or any other general-purpose audio op-amp. If you do, note that the pin numbers may change. Also, C1, C2, C6, and C7 are used to block DC. If no DC exists in your design, then you may omit them. R6 is included for spike protection; if no dangerous spikes will exist, you may omit that resistor, too. Capacitors C3, C5, and C8 are included as standard practice, but if no undesirable effects occur, you may omit them. Use any regulated supply voltage, such as two 9-volt batteries or a ±12-volt DC supply. Just don't exceed the maximum voltage ratings of the IC that you decide to use. The current drawn by the circuit will depend on the op-amp that you decide to use for the project, but it will never be more than a few milliamps per op-amp section.

If you want to operate without a negative supply, then connect IC1 pin 4 to ground, and create a $V_{CC}/2$ supply with another unity-gain op-amp section and a voltage divider. Then connect all the ground connections except for the input and output grounds to that, and connect IC1 pin 8 to V_{CC} (just reference everything up to $V_{CC}/2$). Always use at least 15-volts DC—preferably 24-volts DC. Also, the optocoupler used for the project is a dual-element type; they are more versatile. However, you can use the VTL-5C4 (the single-element version) if you like.

Building the circuit

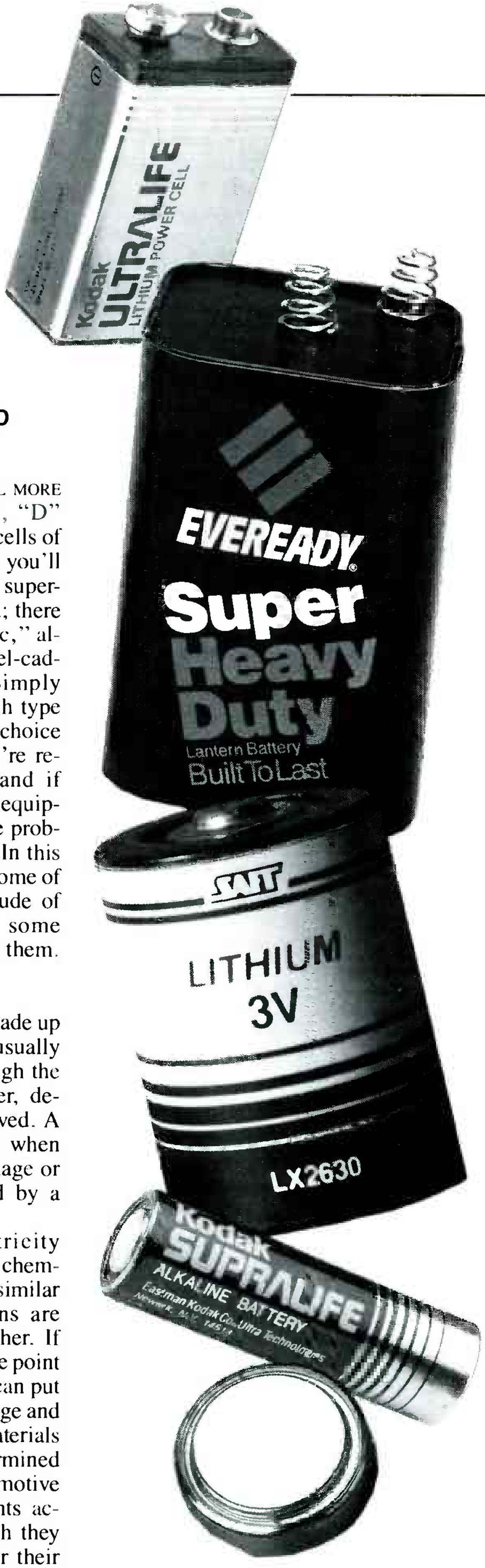
Because IC1-a may have a gain of up to 100, you must keep the leads short in that circuit. Ground loops can defeat any circuit, so keep all power-supply grounds together on one side of the board. Also, remember to use shielded wire on the input and output connections. You can use point-to-point wiring on perforated construction board, but it's best to use the foil pattern provided in PC Service to make a board and use that instead. A ready-to-use PC board is also available from the source mentioned in the parts list.

Figure 3 shows the parts-placement diagram for the audio limiter. Be sure to check for solder shorts and all of that other bad stuff before powering up and testing the circuit. RCA-type jacks are probably the best choice for J1 and J2, but use whatever best suits your application.

To test the circuit, simply connect a microphone, and observe the output on an oscilloscope, or listen to it through a headset (to cut out feedback). The output should remain at the same level, regardless of whether you whisper or scream into the microphone. A note of caution: Remember that the limiter works to correct the gain by looking at seldom-encountered maximum peaks. If you feed in a sine wave, you will notice that the output indeed remains constant, no matter what the input voltage, but a "blip" appears on each and every peak (which would imply high distortion). In a normal audio signal, not all peaks are the same amplitude, and only seldom-occurring maximum peaks are acted upon. Since they occur very infrequently (as compared to audio frequencies), the distortion of the limiter is actually very low—you won't even notice it. **R-E**

TECHNOLOGY

ALL ABOUT BATTERIES



JOSEF BERNARD

Selecting the right batteries for a particular application can be frustrating, especially when you have to choose between so many different types. This article will help you make your next selection.

BATTERIES, BATTERIES, AND STILL MORE batteries. There are "C" cells, "D" cells, "AA" cells, and button cells of all varieties. The assortment you'll find, even just hanging on a supermarket rack, boggles the mind; there are regular, heavy-duty, "classic," alkaline, lithium, mercury, nickel-cadmium, and air-zinc cells. Simply making a decision about which type to use, even when you have no choice about the size of the cell you're replacing, can be confusing; and if you're designing a piece of equipment for battery operation, the problem is magnified enormously. In this article we'll try to make clear some of the reasons behind the multitude of battery types, and present some guidelines for choosing among them.

A short course

To begin with, a battery is made up of *cells*. An individual cell usually outputs about 1.5 volts, although the figure may be higher or lower, depending on the materials involved. A battery of cells must be used when you need to produce more voltage or current than can be delivered by a single cell.

A battery produces electricity through an oxidation-reduction chemical reaction involving two dissimilar materials, in which electrons are transferred from one to the other. If you extract the electrons at some point along their path of travel, you can put them to work for you. The voltage and current that a given pair of materials will produce are largely determined by their places in the electromotive series, which lists the elements according to the degree to which they react with oxygen. The greater their separation along the series, the greater the potential they will produce.

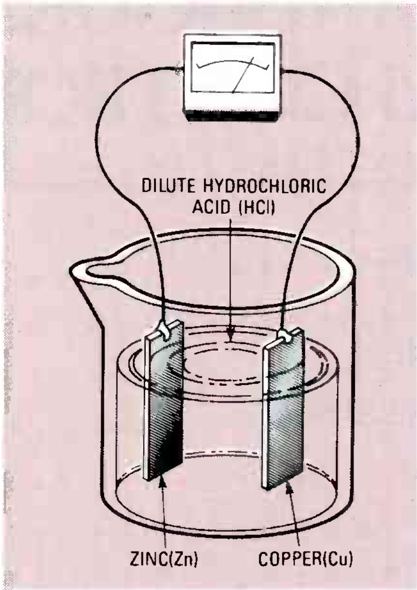


FIG. 1—A SIMPLE ENERGY-PRODUCING cell can be constructed from two dissimilar metals such as copper and zinc immersed in an acid electrolyte.

Any high-school chemistry book can provide you with detailed information on how the electron-producing reactions work. And, if you have fillings in your teeth and have ever bitten down on a coin or a piece of gum-wrapper foil, you have experienced (and tasted) firsthand how a simple battery works.

A simple, lab-experiment energy cell is illustrated in Fig. 1. In principle, all energy-producing cells have the same three principal components. They are:

Anode: the material that is oxidized and gives up electrons during the chemical reaction. The anode is usually marked with a " – ."

Cathode: the material that is reduced (releases oxygen) and accepts electrons during the reaction. It is usually marked with a " + ."

Electrolyte: the conductor through which electrons travel from the anode to the cathode as ions. The electrolyte is usually a "wet," or at least a damp material.

Note that, contrary to customary usage in electronics, the anode is the *negative* electrode of an energy cell and is indicated with a " – ." The positive electrode, marked with a " + ," is the *cathode*. In a rechargeable device, the functions of the electrodes are reversed during charging however, and conventional terminology then applies.

Cells and batteries are divided into two types: *primary* and *secondary*. Primary cells, which include the common throw-away "flashlight battery" types, expend their energy and, when their chemicals are exhausted, they must be discarded. Secondary cells are rechargeable (the chemical action is reversed by forcing a reverse flow of electrons), and include nickel-cadmium types and the lead-acid batteries used in automobiles.

Leclanche cells

Figure 2 shows the construction of an ordinary carbon-zinc D-size cell. The anode, cathode, and electrolyte are just a few of the components of a modern-day dry cell. Many of the others, though, such as the paper separator, serve just to "fine-tune" the performance of the device. That type of dry cell belongs to a class called "Leclanche cells" (sometimes pronounced Le-clan-SHAY) cells. They are named after Georges Leclanche, the Frenchman who produced the first carbon-zinc cell in 1866.

Because carbon-zinc cells are in

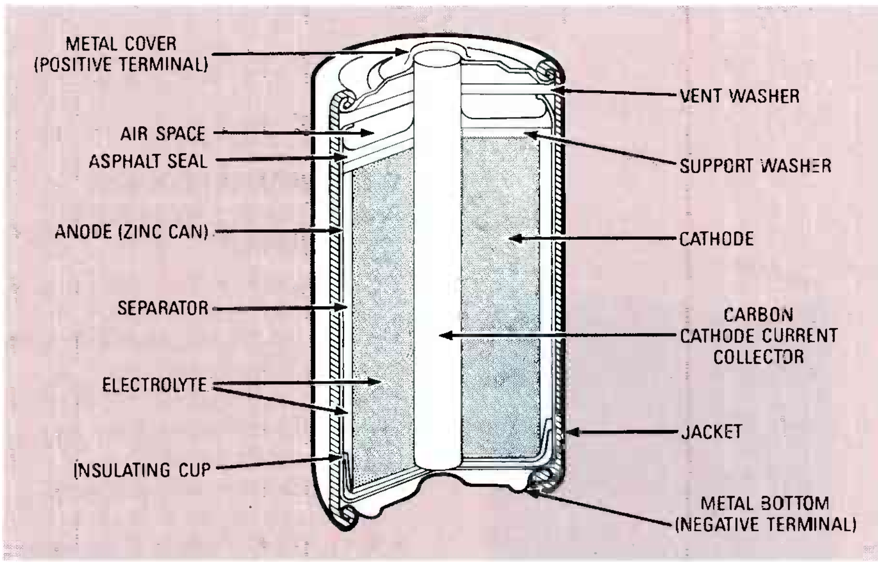


FIG. 2—THE "CLASSIC" DRY CELL uses a zinc can as anode, an ammonium/zinc-chloride electrolyte, and a manganese-dioxide cathode mix. The carbon rod plays no active part in the electron-producing reaction.

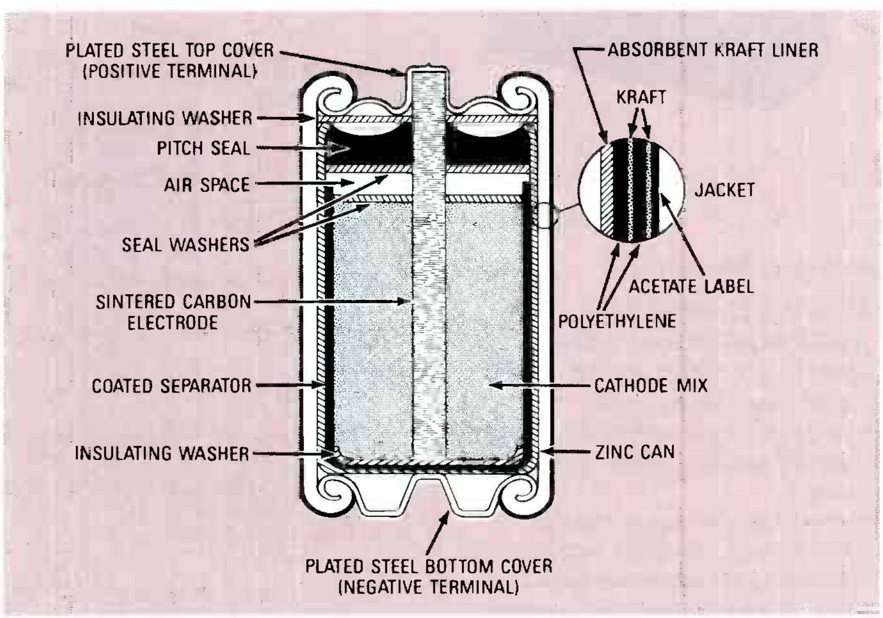


FIG. 3—THE PAPER SEPARATOR used in more recent dry-cell designs requires less space than the older paste-type, thus allowing the inclusion of more cathode mix and making possible a greater energy density.

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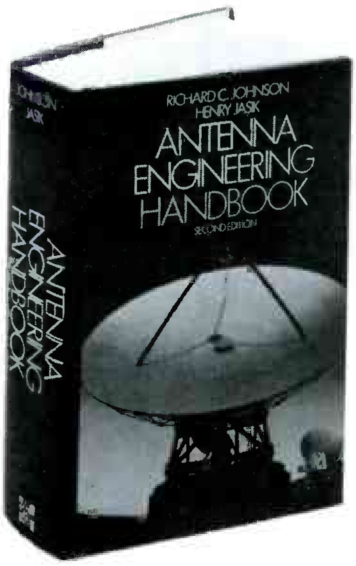

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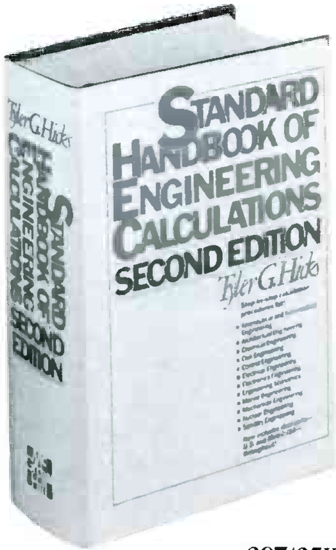

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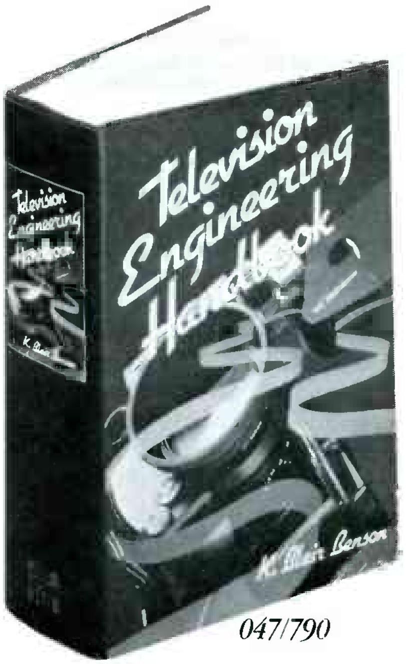

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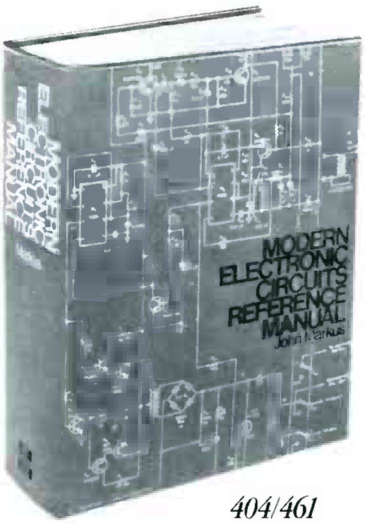

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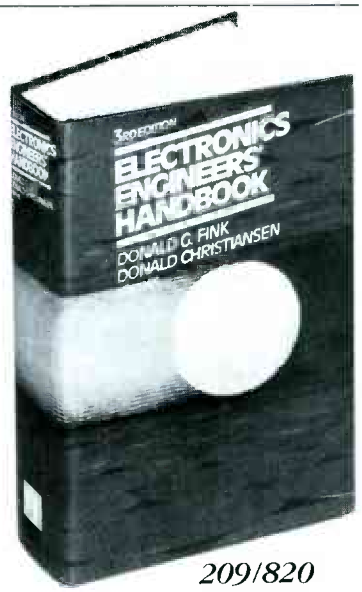

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such widespread use, it will pay to devote a paragraph or two to a discussion of the elements of which they are comprised. Figures 2 and 3 show carbon-zinc cells using paste and paper separators, respectively. (Because a paper separator occupies less space than the paste type, paper-separator cells can contain more reactive materials and produce about ten percent more power.)

The anode is a zinc can, zinc being one of the two reactive materials in the cell. The can also serves as a container for the other cell materials. Today, zinc cans are usually enclosed in a steel jacket, which increases durability and helps to contain leakage, should that occur.

Lining the inside of the can is the paste or paper separator. Its purpose is to physically and electrically isolate the positive and negative electrodes while permitting electrolytic or ionic conduction to take place through the electrolyte. The paste contains electrolyte and a gelling agent such as starch or flour. The paper-type separator is coated with a gelling agent and impregnated with electrolyte that is squeezed out of the cathode material during manufacture. Ordinary general-purpose Leclanche cells use an electrolyte made of ammonium chloride (NH_4Cl), zinc chloride ($ZnCl_2$), and water. In "heavy-duty" cells, the electrolyte is almost entirely zinc chloride and water.

The bulk of the cell consists of the cathode mix, also known as the "bobbin," "black mix," or "depolarizer." Its constituents are manganese dioxide (MnO_2), carbon black, and electrolyte. The purpose of the carbon is twofold: it holds the electrolyte and adds electrical conductivity to the mix. Some cells use a very pure electrolytically derived form of MnO_2 known as EMD (*E*lectrolytic *M*anganese *D*ioxide). Although that makes them more expensive, it also makes for an extra-heavy-duty device. A carbon rod is inserted at the center of the bobbin, which is the cell's current collector (electron source). The semi-porous rod also acts as a vent for hydrogen gas.

Note that although the Leclanche cell is frequently called a carbon-zinc (or zinc-carbon) type, carbon does not take part in the chemical reaction that produces electricity. The active ingredients are zinc and the manganese compound(s).

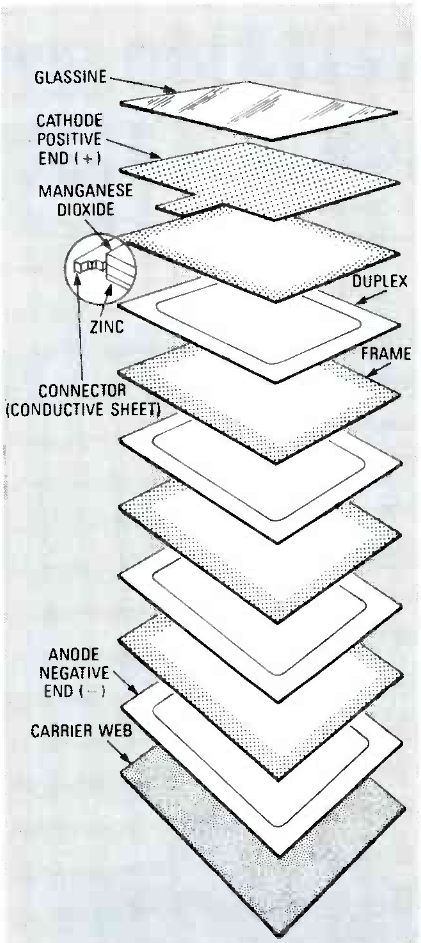

FIG. 4—THE LARGE ELECTRODE area of the *Polapulse* battery gives it the power to deliver enormous quantities of current.

The no-load voltage developed by a carbon-zinc cell is nominally 1.5 volts, although a brand-new one may be measured as high as 1.75–1.8 volts. A general-purpose Leclanche cell has an energy density of about 30 watt-hours per pound.

A special form of the carbon-zinc design is the *Polapulse* battery (Fig. 4) used to power Polaroid instant cameras. Its thin, flat construction makes possible electrodes with large surface areas. That, in turn, gives it a large capacity—as much as 19 amperes of instantaneous current! A Polapulse experimenter's kit is available from Powercard Corporation, 391 Totten Pond Road, Waltham, MA 02154 (617) 890 6789. The P100 Designer's Kit contains five P100 batteries and a special holder for them; it costs $17.50, and Massachusetts residents must add proper sales tax.

Alkaline cells

Alkaline cells derive their name from the fact that their electrolyte is the highly caustic base, potassium hydroxide (KOH), rather than a slightly acidic one containing a salt such as ammonium- or zinc-chloride. The design of an alkaline cell, although superficially similar to that of a carbon-zinc one, is really significantly different, as can be seen in Fig. 5.

The cathode material of an alkaline cell is EMD, the electrolytically derived manganese dioxide sometimes used in carbon-zinc cells to improve performance. It is mixed with water,

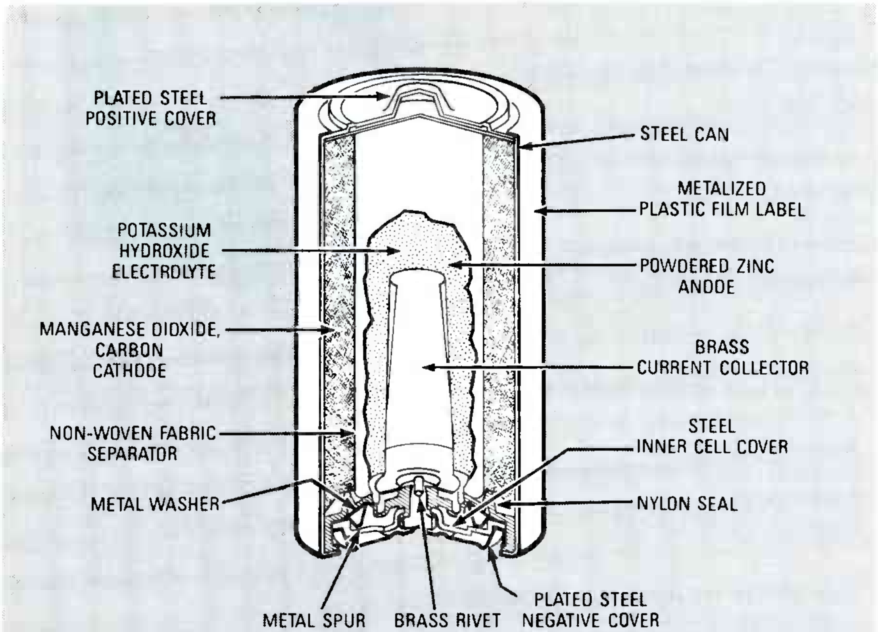

FIG. 5—TYPICAL OF MANY alkaline cells is "inside-out" construction, where the cathode material is exterior to that making up the anode.

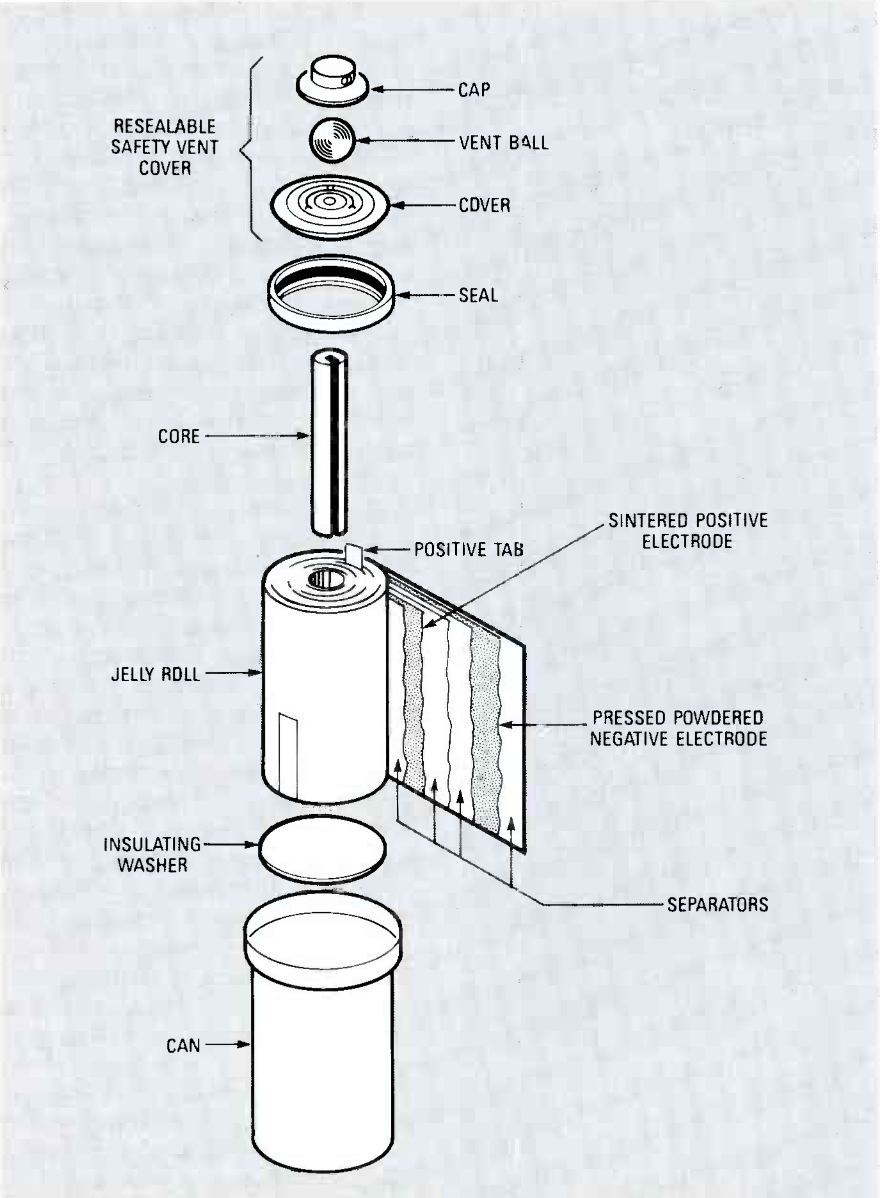

FIG. 6—THE "JELLY ROLL" construction of a typical nickel-cadmium cell gives it a large electrode area. Note the vent mechanism to protect against cell rupture resulting from the generation of gases during charging.

carbon or graphite (ten percent or a bit more), and some potassium-hydroxide electrolyte. As in a Leclanche cell, the anode is made of zinc, but the metal is in finely powdered form and the cell is contained in a steel jacket. The highly purified zinc powder is treated with mercury to form an amalgam; that greatly reduces the production of hydrogen, caused by the metal reacting with the potassium hydroxide electrolyte that pervades it. The separator that is used is made of a porous woven, felted, or bonded material.

In a cylindrical alkaline cell, the central element is the anode collector, not the cathode collector used in carbon-zinc cells. That piece, which may be made of brass, is mechanically and electrically connected to the bottom (−) terminal of the cell. That sort of "inside-out" construction is frequently used in dry-cell designs.

Alkaline cells have an open-circuit rating of about 1.52 volts, and an energy density of about 45 watt-hours per pound. Their performance at temperature extremes exceeds that of carbon-zinc types. Their low-current-drain performance is also better, but where alkalines are best where moderate-to-high currents are drawn over an extended period.

Making a choice

Carbon-zinc and alkaline cells are available in a wide variety of packagings and voltages. Fortunately, if it's just a replacement battery you're looking for when you walk into the store, you don't have to worry too much about your decision. The equipment into which the replacement cell or battery will be inserted can take only a particular size, and that size is usually keyed to the voltage. What you have to concern yourself with is the way the replacement performs—its behavior at various temperatures and, more important, its ability to deliver the current that your application requires. The literature provided with a dry-cell-operated device frequently recommends a specific type of cell or battery, but does not explain why that particular sort is called for. The next few paragraphs will help you to make a more informed decision about replacement cells, and in choosing a power source for something you may be designing.

Although alkaline cells have largely replaced carbon-zinc types in most applications, there are still some places where the latter will give a better price-performance ratio than the more glamorous type. Such situations are typically those where current drain is light but constant (no surges of current are called for by the device) and the operating temperature is a comfortable one. Carbon-zinc cells have a relatively short shelf or storage life, so they are best suited to applications where they will be used immediately; not where they will be expected to remain quiescent for long periods awaiting emergency use.

In a C-cell-powered wall clock it may prove more economical to install a regular carbon-zinc cell than an alkaline one; while the alkaline cell may last a bit longer, its extra cost will offset any economy that might be gained from its somewhat longer life. Heavy duty carbon-zinc cells made with somewhat higher-quality materials can even be used to power small transistor radios, provided not too much demand is made of them.

Alkaline cells, with their ability to source heftier currents than carbon-zinc ones and to depolarize, or recover, more quickly after heavy use, are better suited for the workload presented by much of today's consumer-electronics equipment; cassette players, boom-boxes, portable TV's, and the like. Devices that might suck carbon-zinc cells dry in twenty minutes can run for several hours on alkalines.

An Eveready brand called the "Conductor" promotes itself as being best for audio applications. While that was the case when it was first introduced, due to the use of premium components, the design of "ordinary" alkaline cells is today virtually identical to that of the Conductor brand, and there is little, if any, difference in performance.

Other properties of alkaline cells may also make them the better choice in certain applications. They have a longer shelf or storage life, and their output voltage falls off less rapidly than does that of carbon-zinc cells. Incidentally, you can extend the storage life of carbon-zinc cells by keeping them refrigerated to slow the chemical reactions that take place in them even when they are not being used. Because those reactions take place much less actively when alkaline cells are not in use, alkaline cells do not benefit as much from refrigerated storage.

Low temperatures cause voltage drop-offs in all types of energy-producing cells and batteries. Again, alkaline cells provide greater reliability over a greater temperature range than do carbon-zinc ones. As the temperature of a carbon-zinc cell drops below freezing, its voltage, and particularly the current it is capable of delivering, fall rapidly to unusable levels. While alkaline cells are similarly affected by low temperatures, their performance is better than that of even the best carbon-zinc cells.

Don't be swayed by those commercials that say things the likes of "Ours last 30 percent longer than..." The comparison is probably being made between the manufacturer's current production and the same product as he formulated it several years ago—not between his and somebody else's products. Virtually all alkaline cells produced today by the major manufacturers are considerably longer-lasting than those of a few years back due to the fact that changes in the construction of the shell (namely, reducing it to a single steel container with a thin plastic overcoating) has resulted in the ability to cram more reactive material inside. The voltage, of course, doesn't change, but the ability to deliver current does.

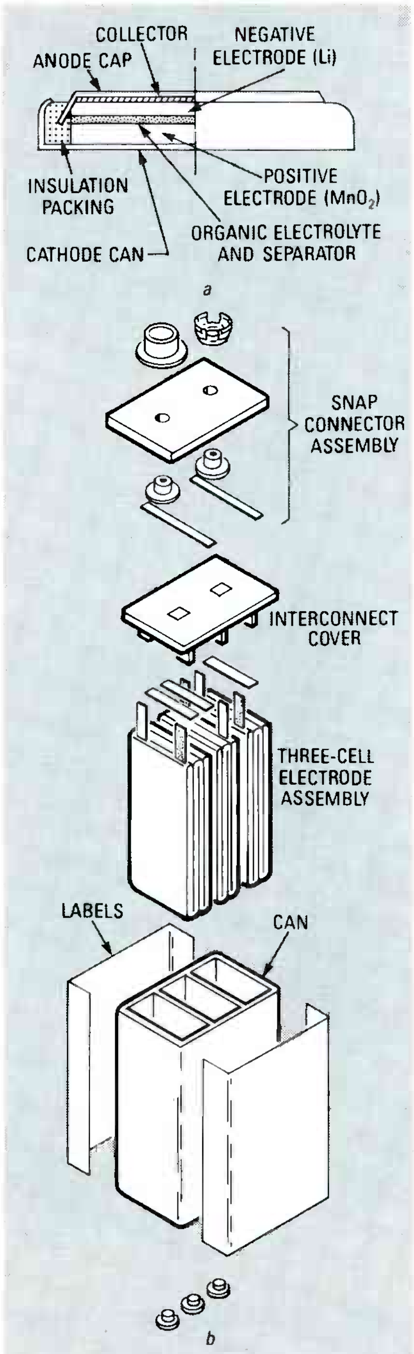

FIG. 7—LITHIUM CELLS have extremely high energy densities. The button-style packaging shown in *a* provides a large electrode area. Three 3-volt lithium cells are connected in series to make a 9-volt transistor-type battery (*b*).

Rechargeable cells

Are you tired of replacing worn-out dry cells all the time? Maybe you're tempted to replace them entirely with rechargeable nickel-cadmium cells. But nickel-cadmium cells (commonly called "Nicads," although that's actually a trademark owned by one manufacturer, Saft) have their pros and cons.

The internal details of a typical nickel-cadmium cell are shown in Fig. 6. The active materials are nickel oxide (NiO), which forms the cell's positive plate; cadmium (Cd) for the negative plate; and the highly caustic potassium hydroxide (KOH) electrolyte. Several different manufacturing techniques may be used but, in general, the positive and negative electrodes form a "sandwich" with the potassium-hydroxide-saturated separator in the middle. Those three layers are wound into a jelly-roll-like spiral. The separator can be either nylon or a polypropylene material; the latter makes possible greater cell capacities. A safety vent is provided to prevent cell rupture resulting from pressure buildup during extremes of charge or discharge.

Normal-rate recharging is performed at the rate of one-tenth the rated current of a cell. For example, it takes 60 milliamperes to charge an AA-size cell rated at 600 mAh, for 14 to 16 hours. Quick-charge cells can be recharged in four to six hours, and fast-charge devices can be charged in as little as one or two hours, at much higher currents. Safeguards in the form of voltage or temperature sensors must be provided to prevent cell rupture or internal plate damage due to the high internal pressures and temperatures that may be generated during the fast-charge process.

The differences in charging rates are made possible by a number of different factors, including electrode design, and the choice of reactive materials; they are still nickel and cadmium, but in different formulations. Aside from a reduced charging time, the differences between regular-, quick-, and fast-charging cells are more or less transparent to the user. There is, however, a slight reduction in internal resistance in fast-charging cells, resulting in a nominal (on the order of millivolts) voltage increase, and the ability to better provide surge current.

Nickel-cadmium cells have a much flatter voltage-drop curve over their working life than do Leclanche and alkaline designs—a fact that may be worth considering. Immediately after charging, their open-circuit voltage is about 1.4 volts, which drops almost immediately to about 1.25 volts, a level that is maintained until their charge is nearly depleted. They can provide very large amounts of current when needed, and hold up well under conditions of continuous drain. Nickel-cadmium cells also provide good power output under extremes of tem-

FIG. 8—RECHARGEABLE lithium cells are intended principally for maintaining the contents of solid-state memories.

perature range.

Nickel-cadmium cells perform best when worked hard. If discharged just shallowly and then charged immediately, they will develop a "memory" for that sort of use and eventually lose some of their capacity. However, because of slight changes in cell chemistry, that's far less of a problem than it was just a few years ago. Most manufacturers insist that memory effects no longer exist. The working life of a nickel-cadmium cell on a single charge is only about 70 percent of that of an equivalent-size alkaline cell.

Nickel-cadmium cells are most useful where they can be built into a device and the charging current supplied from the outside through a jack, or internally, directly from it. If rechargeables are used as replacements for throwaway primary cells, you generally face the inconvenience of removing them from the device for charging, and then removing them again from the charger and replacing them in their compartment for use. When replacing old or worn-out cells in a nickel-cadmium battery pack, replace them all at once—mixing old and new ones can lead to the weakest of them reversing its polarity and affecting the life and performance of the entire pack.

Rechargeable lead-acid cells and batteries (similar to the one in your car, but smaller) use lead, lead oxide, and sulphuric acid, and come with a gelled electrolyte that allows them to be used in portable equipment without fear of spillage. Lead-acid technology is also available in the form of sealed D-size cells. The nominal voltage of a lead-acid cell is 2.0 volts, and it is capable of sustaining very high rates of discharge. The performance of lead-acid cells falls off at cold and very warm temperatures. Unlike nickel-cadmium cells, lead-acid cells must be kept well-charged if you expect them to perform efficiently over a long lifetime.

Lithium cells

Lithium is an extremely reactive metal, and its high place in the electromotive series makes it an excellent candidate for inclusion in energy cells. Unfortunately, its high degree of activity (it reacts violently with water, for example) makes it difficult to work with. Many of the difficulties have been overcome, however, and lithium-based cells are now found widely in watches, cameras, calculators, and in situations where a small trickle of current is required to maintain the contents of solid-state memory in a standby state. Lithium cells are very efficient, with energy densities on the order of 90 watt-hours per pound. The major reason lithium cells are not more widely used (although that is changing) is the difficulty in manufacturing large-size ones that are safe to use.

Although there are a number of lithium-cell formulations, the one using lithium, manganese dioxide (MnO_2) and a lithium perchlorate ($LiClO_4$) electrolyte in an organic solvent (water cannot be used, remember) makes up about 70 percent of the lithium-cell market. Carbon monofluoride is also used. Much of the remaining portion consists of cells made using a lithium-carbon-thionyl chloride ($SOCl_2$) formulation. Figure 7-*a* shows the construction of a typical lithium "button" cell; Fig. 7-*b* shows how Kodak combines three manganese-dioxide-type lithium cells in one package to produce a nine-volt, "transistor-type" battery.

The output of a lithium/MnO_2 cell is nominally three volts; in some applications it may be possible to replace two 1.5-volt carbon-zinc or alkaline cells with one lithium one. By using a lithium/ferric-sulphide (FeS_2) combination, a lightweight and powerful 1.5-volt cell can be produced. One of the great benefits of using lithium cells is their extremely long shelf life; five years or even ten. Under conditions of low drain, their useful working life may almost equal that figure.

A rechargeable lithium/MnO_2 button cell has recently been introduced by Sanyo (see Fig. 8). It is intended primarily as a replacement for the Ni-Cd cells and large-value capacitors used in keeping memory circuits alive.

Other types

While the types of energy cells already described can fill most electronics needs, actual and anticipated, there are a few additional kinds that bear mentioning.

Mercury cells have long been used as a compact power source in devices such as hearing aids and cameras. They use a mercuric-oxide cathode, powdered-zinc anode, and a potassium hydroxide (KOH) or sodium hydroxide (NaOH) electrolyte. The output voltage is 1.3 volts, and remains stable over a long life of storage or use. Silver-oxide cells are also used for similar applications (see Fig. 9).

FIG.9—THIS SILVER OXIDE battery is often used in cameras.

Another type of energy cell found in hearing aids and watches is the zinc-air, or just plain "air," cell. It uses atmospheric oxygen to produce electrochemical energy. Zinc-air button cells use a powdered-zinc-with-potassium-hydroxide-electrolyte anode and have a very thin cathode region incorporating a catalyst. Oxygen in the air provides the cathode material. Although they are not able to output large amounts of current, zinc-air cells have very high energy densities. Because air is kept out by a pull tab until a zinc-air cell is ready to be used, its shelf life is extremely long. A zinc-air cells's output voltage of about 1.4 volts remains stable over a working life of several hundred hours before falling rapidly to an unusable level.

There are, of course, still many more types of energy-producing cells, primary and secondary. Some are being produced today, some are still in the experimental stage, and others have been abandoned either for practical reasons or because they have been rendered obsolete by newer battery designs. **R-E**

RAY MARSTON

WORKING WITH AUDIO POWER AMP IC'S

Building your own amplifier circuits for audio applications doesn't have to be difficult. In this article we show you how easy it is to use several of the more popular audio-amplifier IC's.

AN IDEAL AUDIO POWER AMPLIFIER CAN BE simply defined as a circuit that can deliver audio power into an external load without generating significant distortion, and which does so without overheating or consuming excessive quiescent current. In practice, circuits that come very close to that ideal can easily be built using modern integrated circuits.

Simple audio-power amplifiers with outputs up to only a few hundred milliwatts can be easily and cheaply built using little more than a standard op-amp and a couple of general-purpose transistors. For higher power levels, a wide range of special-purpose "single" or "dual" audio-power amplifier IC's are available, which can provide maximum outputs ranging from a few hundred milliwatts to roughly 20 watts. The specific IC chosen for a given application depends mainly on the constraints of the available power-supply voltage and on the required output power. This article will look at a wide selection of practical IC-based audio-power amplifier circuits.

Low-power circuits

The ever-popular general-purpose 741 operational amplifier can supply peak output currents of at least 10 mA, and can provide peak output-voltage swings of at least 10 volts into a 1K load when powered from a dual power supply of plus- and minus-15 volts. The IC can supply peaks of about 100 mW into a 1K load. Among the reasons for the 741's popularity is that it can easily be used as a simple low-power audio amplifier, as shown in Figs. 1 and 2.

Figure 1 shows how to use the 741 with a dual power supply. There, the external load is direct-coupled between the op-amp output and ground, and the two input terminals are ground-referenced. The op-amp is operated in the non-inverting mode, and has a voltage gain of × 10 (R1/R2) and an input impedance of 47K (R3).

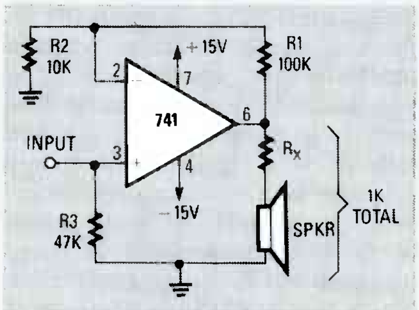

FIG. 1—LOW-POWER AMPLIFIER using dual power supplies.

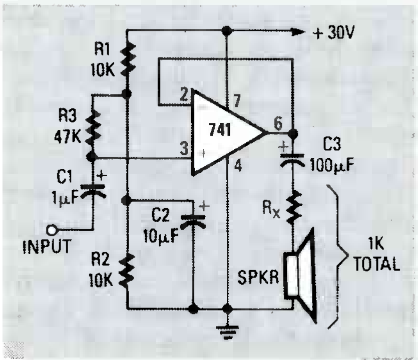

FIG. 2—LOW-POWER AMPLIFIER using a single-ended power supply.

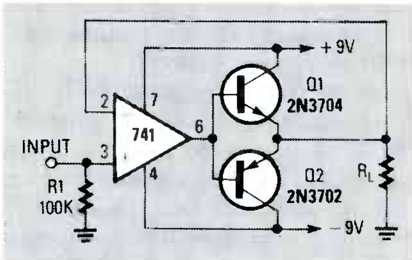

FIG. 3—BASIC BOOSTED-OUTPUT-current unity-voltage-gain op-amp circuit.

Figure 2 shows how to use the circuit with a single-ended power supply. In that case, the external load is AC-coupled between the output and ground, and the output is biased to a quiescent value of half of the supply voltage (to give maximum output-voltage swing) via the R1-R2 divider. The op-amp is operated in the unity-gain non-inverting mode, and has an input impedance of 47K (R3).

In Figs. 1 and 2, the external load must have an impedance of at least 1K. If the external speaker has an impedance lower than that, the resistor R_X must be connected as shown to the schematic to raise the load to a total of 1K; R_X inevitably reduces the amount of power that actually reaches the speaker.

Boosted-output circuits

The available output current (and thus the power) of a standard op-amp can easily be boosted by wiring a complementary emitter-follower between its output and its non-inverting input terminal, as shown in Fig. 3. Note that the circuit is configured to give an overall unity voltage gain, but that the base-emitter junctions of Q1 and Q2 are both wired into the negative-feedback loop of the circuit, so that their effective forward-voltage drops (approximately 600 mV) are reduced by a factor equal to the open-loop voltage gain of the op-amp. So, if the open-loop gain is 10,000, then the effective forward voltage drops of Q1 and Q2 are each reduced to a mere 6 μV, and the circuit generates negligible signal distortion.

In practice, the open-loop voltage gain of an op-amp actually falls off at a rate of about 20 dB/octave, so that although the signal distortion of the circuit in Fig. 3 may be insignificant at 10 Hz, it may become quite objectionable at 10 kHz. That problem can

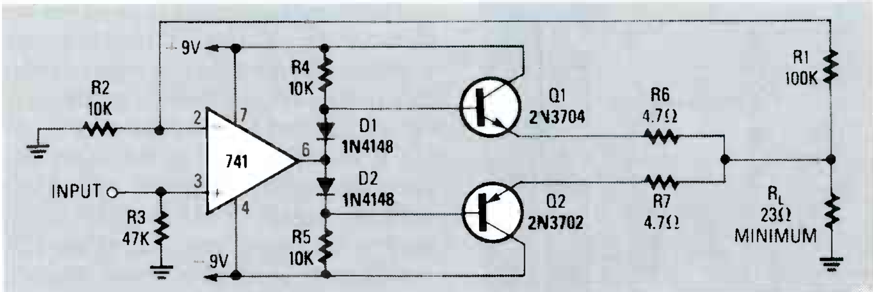

FIG. 4—OP-AMP POWER AMPLIFIER using dual supplies; output power is about 280 mW, maximum.

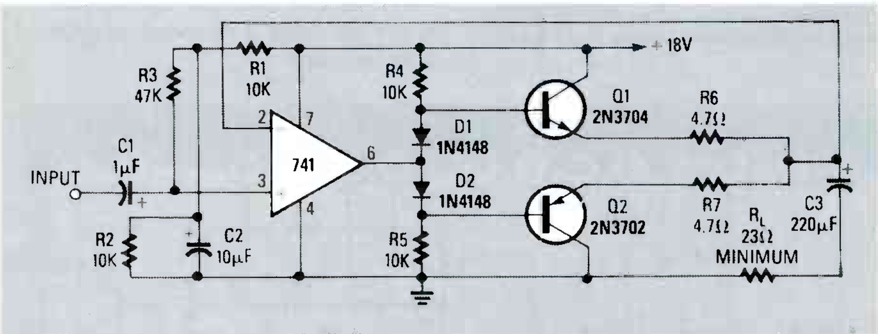

FIG. 5—OP-AMP POWER AMPLIFIER using a single-ended supply.

be overcome by applying a small amount of forward bias to Q1 and Q2, as shown in Figs. 4 and 5, so that their forward-voltage drops are reduced to near-zero and the result is that the distortion is minimized.

The circuits of Figs. 4 and 5 are designed to produce output currents up to 350 mA peak, or 50-mA RMS into a load of at least 23 ohms, thereby producing up to 280 mW RMS. The limitations are determined by the current/power ratings of Q1 and Q2, and by the power-supply voltage. The Fig. 4 circuit is designed for use with dual power supplies, and gives a voltage gain of 10. The Fig. 5 circuit uses a single-ended supply, and has unity voltage gain.

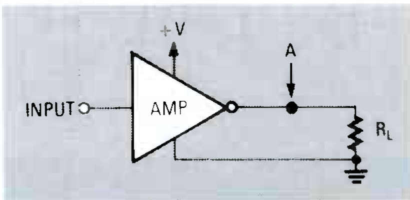

FIG. 6—AN AMPLIFIER CONNECTED in the single-ended output mode gives a peak output of V^2/R watts.

Power-amplifier basics

If output powers in the approximate range from 200 mW to 20 watts are needed, the most cost-effective way of getting them is to use a dedicated IC to do the job. A wide range of such IC's are available, in either "single" or "dual" form. Most of them take the effective form of a simple op-amp with complementary emitter-follower output stage (like Figs. 3–5); they have differential input terminals and can provide high output current/power, but consume a low quiescent current.

When a power amplifier is connected in the single-ended configuration of Fig. 6, the peak available output power equals V^2/R, where "V" is the peak available output voltage. Note, however, that the available output power can be increased by a factor of four by connecting a pair of amplifier IC's in the "bridge" configuration shown in Fig. 7, in which the peak available load power equals $2V^2/R$. That power increase can be explained as follows:

In the single-ended amplifier circuit of Fig. 6, one end of R_L is grounded, so the peak voltage across R_L equals the voltage at point A. On the other hand, in the circuit in Fig. 7, both ends of R_L are "floating" and are driven out of phase; and the voltage across R_L equals the difference between points A and B. Figure 7 also shows some waveforms when the circuit is fed with a 10-volt p-p square wave. Although the waveforms at points A and B have peaks of 10 volts relative to ground, the two signals are 180° out of phase. Therefore, during period 1, point B is 10-volts positive with respect to point A. Consequently, if point A is regarded as the reference point, it can be seen that the point B varies from +10 to −10 volts between periods 1 and 2, giving a total swing of 20 volts across R_L.

The load in the 10-volt bridge-driven circuit sees a total 20-volts p-p, or twice the single-ended input-voltage,

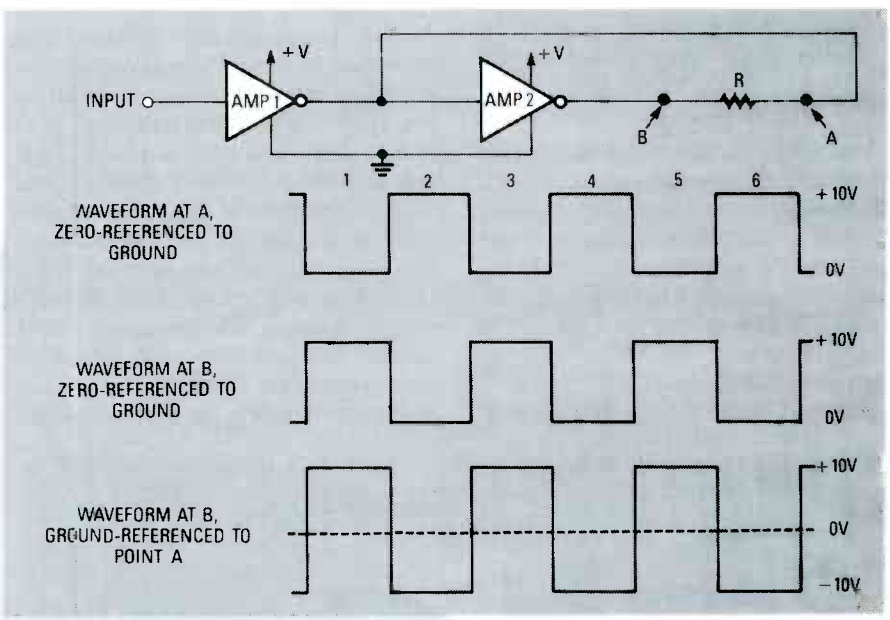

FIG. 7—A PAIR OF AMPLIFIERS connected in the bridge configuration gives a peak output of $2V^2/R$ watts; four times the power of a single-ended circuit.

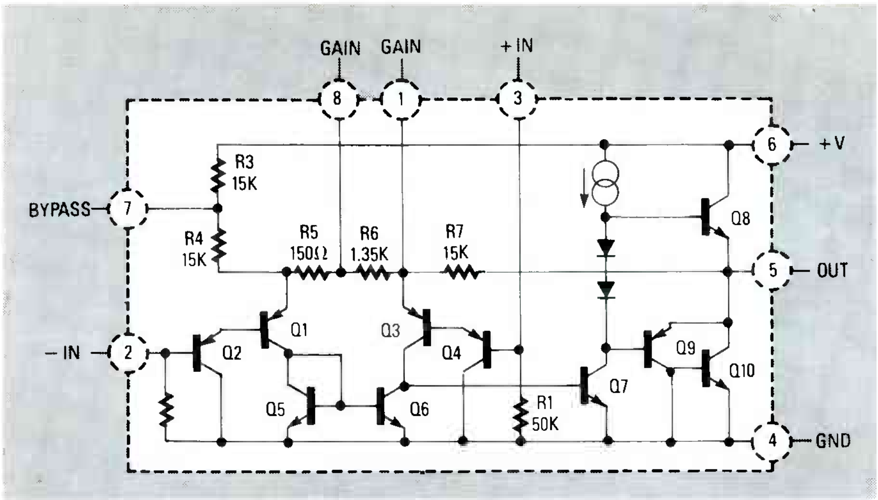

FIG. 8—INTERNAL CIRCUIT and pin connections of the LM386 low-voltage audio-power amplifier.

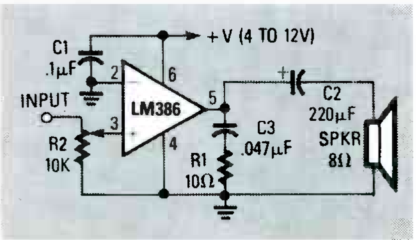

FIG. 9—A MINIMUM NUMBER OF PARTS are needed for this LM386 amplifier with $A_V = 20$.

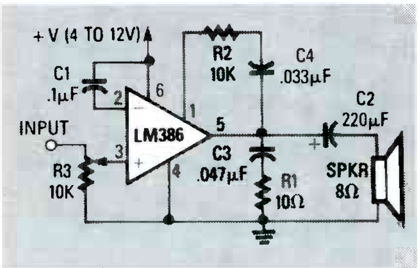

FIG. 10—LM386 AMPLIFIER with 6 dB of bass-boost at 85 Hz.

as indicated in the diagram. Since doubling the drive voltage results in a doubling of drive current, and power is equal to the current times the voltage (P = IV), the bridge-driven circuit produces four times more power than a single-ended circuit.

LM386 basics

The LM386 audio-power amplifier (manufactured by National Semiconductor) is specifically designed for operation with power supplies in the 4–12-volt range. It is housed in an 8-pin DIP, consumes a quiescent current of only a few mA, and is ideal for use in battery-powered applications. The voltage gain of the IC is variable from 20 to 200 via external connections, and its output automatically centers on a quiescent value of half-supply voltage. The device can feed several hundred milliwatts into a 8-ohm load when operated from a 12-volt power supply. Its differential input terminals are both ground-referenced, and have typical input impedances of 40K.

The internal circuit of the LM386 is shown in Fig. 8. Here, Q1 to Q6 form a differential amplifier in which both inputs are tied to ground via 50K resistors (R1 and R2) and the output of Q3 is direct-coupled to the input of common-emitter amplifier Q7. The collector signal of Q7 is direct-coupled to the output terminal of the IC via Class-B unity-gain power amplifier stage Q8-Q9-Q10 which, to minimize the internal volt-drops and maximize the available output power, is not provided with overload protection circuitry.

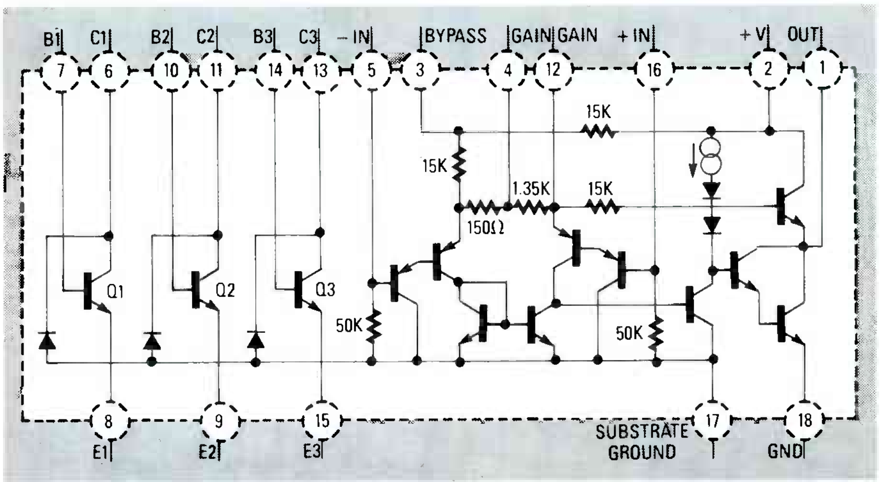

FIG. 12—INTERNAL CIRCUIT AND PIN CONNECTIONS of the LM389 low-voltage audio-power amplifier with NPN transistor array.

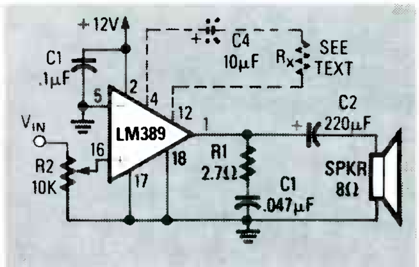

FIG. 13—BASIC CIRCUIT CONNECTIONS of the LM389 IC.

LM386 applications

The LM386 is a very easy IC to use. The voltage gain of the IC is equal to the value of the pin-1-to-pin-5 impedance (15K in Fig. 8), divided by the impedance between the emitters of Q1 and Q3 (R5 + R6 in Fig. 8). Thus, the IC can be used as a minimum-parts amplifier with an overall voltage gain of 20 by using the simple connections shown in Fig. 9. In that circuit, the load is AC-coupled to the IC output via C2, and the input signal is connected to the non-invert-

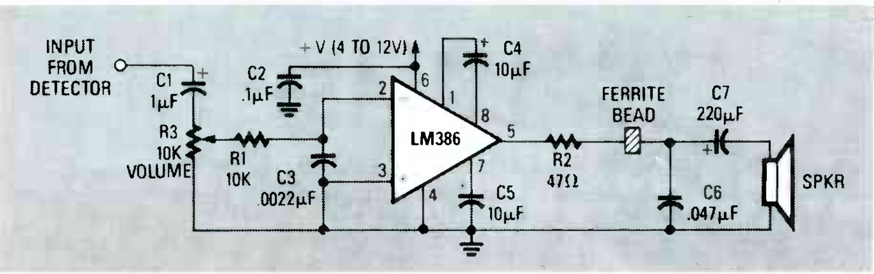

FIG. 11—AM-RADIO POWER AMPLIFIER.

ing terminal via R2. Note that C1 is used to RF-decouple the +V supply (pin 6), and R1-C3 is an optional Zobel network that gives HF output-loading stability.

Note that in Fig. 9, pins 1 and 8 are not used. However, if you connect a 10-μF electrolytic between pins 1 and 8 (the positive end connected to pin 1), you can change the overall gain of the circuit to 200; that's because the capacitor effectively shorts out the IC's internal 1.35K resistor. If a 1.2K resistor is wired in series with a 10-μF electrolytic between pins 1 and 8, the overall gain will be 50.

The voltage gain of the LM386 can also be varied by shunting the effective value of the internal pin-5-to-pin-1 15K feedback resistor. Fig. 10 shows how to shunt that resistor with C4-R2, to give 6-dB of bass boost at 85 Hz, to compensate for the poor bass response of commonly used inexpensive speakers.

Figure 11 shows how the LM386

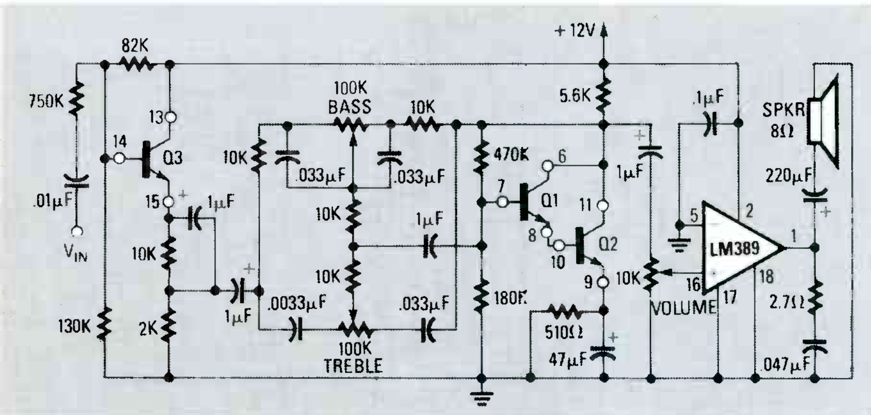

FIG. 14—CERAMIC PHONO AMPLIFIER with tone controls, using an LM389.

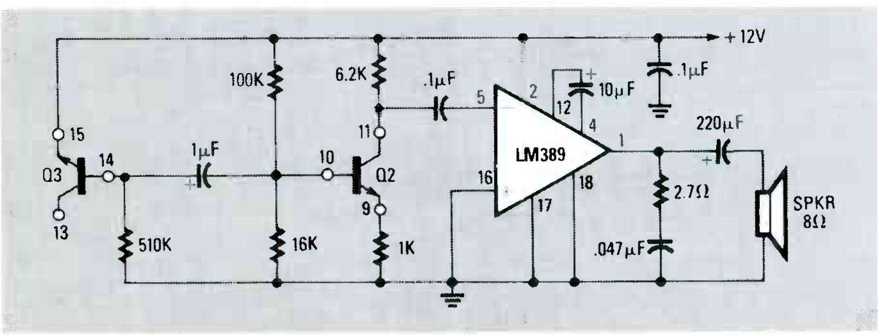

FIG. 15—LM389 WHITE-NOISE sound generator.

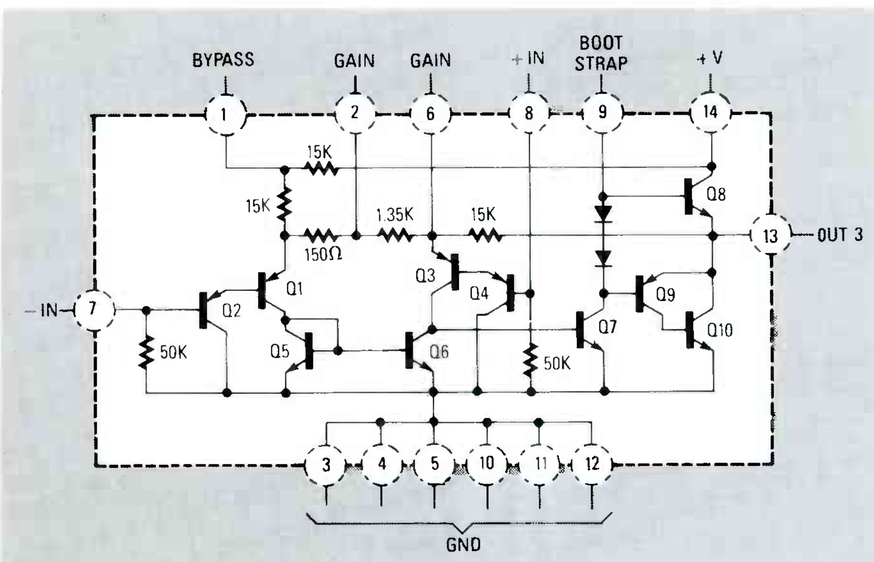

FIG. 16—INTERNAL CIRCUIT and pin connections of the LM388 1.5-watt audio-power amplifier.

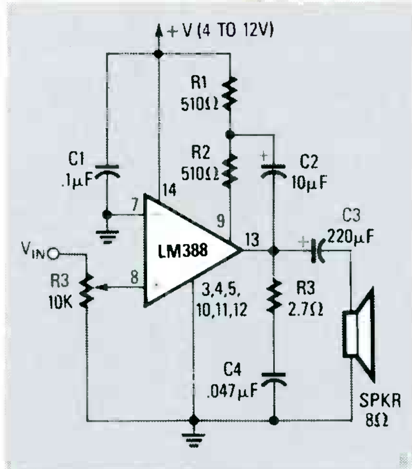

FIG. 17—LM388 WITH A GAIN OF 20 and load returned to ground.

amplifier can be modified for use as a built-in amplifier in an AM radio. Here, the detected AM signal is fed to the non-inverting input of the IC via volume-control R3, and is RF-decoupled via R1-C3; any residual RF signals are blocked from the load via a ferrite bead. The voltage gain of the amplifier is set at 200 via C4. Note that the circuit is provided with additional power-supply ripple rejection by wiring C5 between pin 7 and ground, and that the ripple-rejection capacitor can also be used with Figs. 9 and 10 if required.

LM389 circuits

The LM389 (Fig. 12) contains an array of three wide-band and independently accessible NPN transistors on the same substrate as an audio-power amplifier that is almost identical to that of the LM386. The IC can be used with any power supply in the 4- to 12-volt range. The three NPN transistors have closely matched characteristics, can be operated with collector currents in the range from 1 μA to 25 mA at frequencies up to 100 MHz, and each have typical current gains of 275. Also note that Q1, Q2 and Q3 are independently accessible.

Figure 13 shows the LM389 in a basic circuit. The internal power amplifier is used in the same way as the LM386; the gain of the amplifier is controlled by C4 and R_X, between pins 4 and 12. If those two components are absent, the voltage gain is 20. If the two components are in place, and R_X has a value of 1.2K, the gain is 50. If R_X is replaced with a short-circuit, the gain rises to 200. Note that the power amplifier can be used as either an inverting or non-inverting amplifier by connecting the external signal to the appropriate input terminal.

Figures 14 and 15 show practical applications of the LM389, making

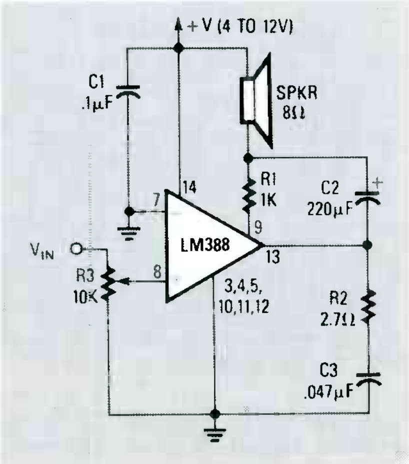

FIG. 18—LM388 WITH A GAIN OF 20 and load returned to +V supply.

use of the internal transistors. In the phono amplifier of Fig. 14, which is intended for use with a ceramic pickup, Q3 acts as a voltage-following input buffer giving an input impedance of about 80K, and Q1 and Q2 are used to make an active tone-control network with its output feeding to the non-inverting input of the power amplifier via the volume-control potentiometer. In the white-noise generator circuit of Fig. 15, Q3 is wired as a noise-generating Zener diode; the noise signal is amplified via Q2 and then fed to the inverting input terminal of the power amplifier, which is wired in the 200 voltage-gain mode.

LM388 circuits

The LM388 (Fig. 16) can be regarded as a slightly modified version of the LM386. The device is housed

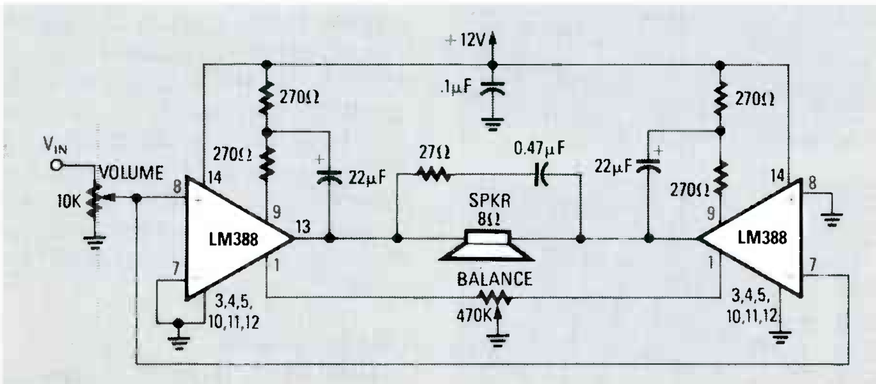

FIG. 19—LM388 BRIDGE AMPLIFIER delivering 4 watts to an 8-ohm load.

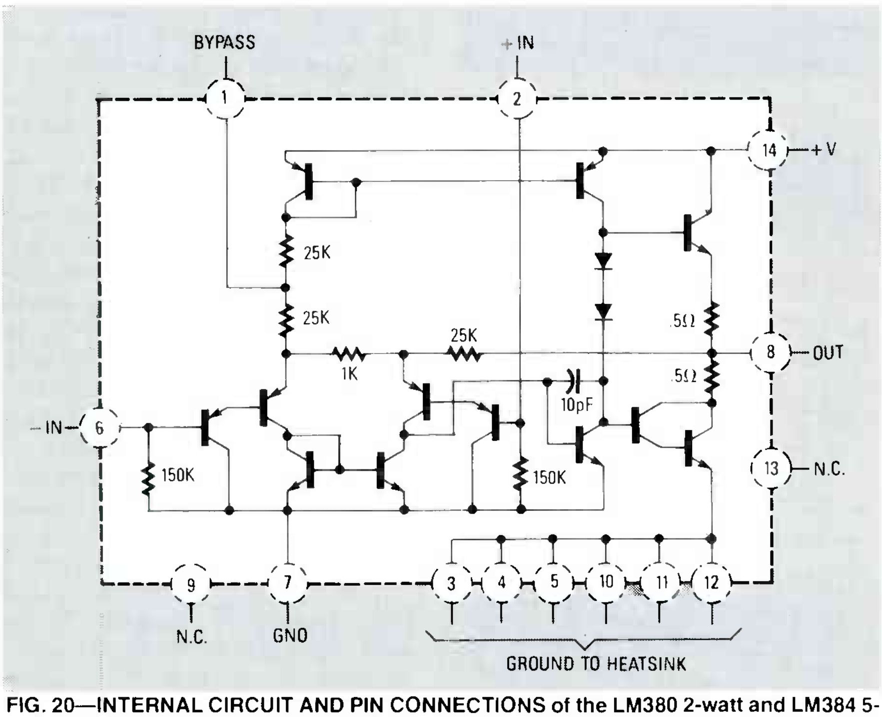

FIG. 20—INTERNAL CIRCUIT AND PIN CONNECTIONS of the LM380 2-watt and LM384 5-watt audio-power amplifier IC's.

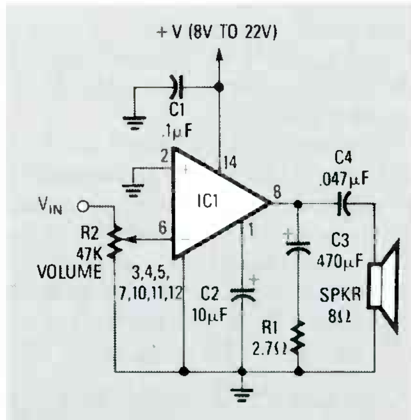

FIG. 21—IN THIS CIRCUIT, IF IC1 is an LM380, powered from 18 volts, the circuit will produce 2 watts, and if IC1 is an LM384, powered from 22 volts, it will produce 5 watts. The circuit also has simple volume control and ripple rejection.

in a 14-pin DIP with an internal heat sink, and can feed 1.5 watts into an 8-ohm speaker when powered from a 12-volt supply. The most significant internal difference between the LM388 and the LM386 concerns Q7, and an internal constant-current collector load in the LM388. That "external load" feature greatly increases the versatility of the IC.

Figure 17 shows one way of using the LM388. Here, R1 and R2 are wired in series between the positive supply line and pin 9, to provide collector current to the internal Q7. Note that the R1-R2 junction is bootstrapped from the output of the IC via C2, to raise the AC impedance of R2 (and thus the voltage gain of Q7) to a value far greater than its DC value. The overall voltage gain of the LM388 is determined in the same way as in the LM386, and equals 20 in Fig. 17. Pins 2 and 6 were not used in Fig. 17, but if you wire a 10-µF electrolytic between those two pins (with the positive end connected to pin 6), the gain can be increased to 200.

Figure 18 shows an alternative way of using the LM388 where direct current (DC) is fed to pin 9 via the speaker and R1. Note, however, that the "low" end of the speaker is AC-driven by the output of the amplifier, thereby bootstrapping R1 and providing R1 with a high AC impedance. The circuit therefore gives a performance that is somewhat similar to that of Fig. 17, but does so with a saving of two components.

Finally, Fig. 19 shows how to connect a pair of LM388 IC's in the

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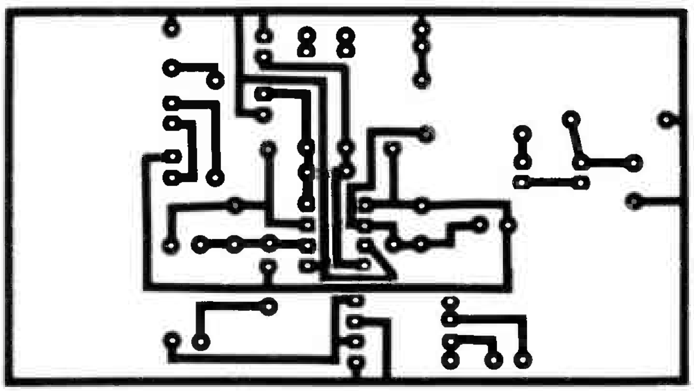
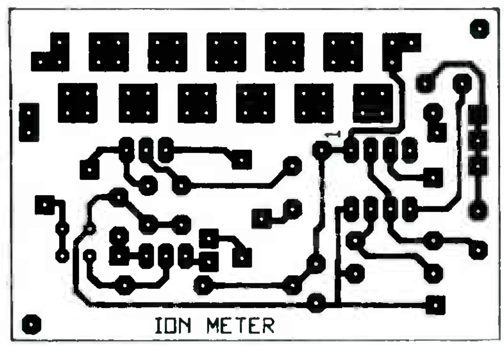
PC SERVICE



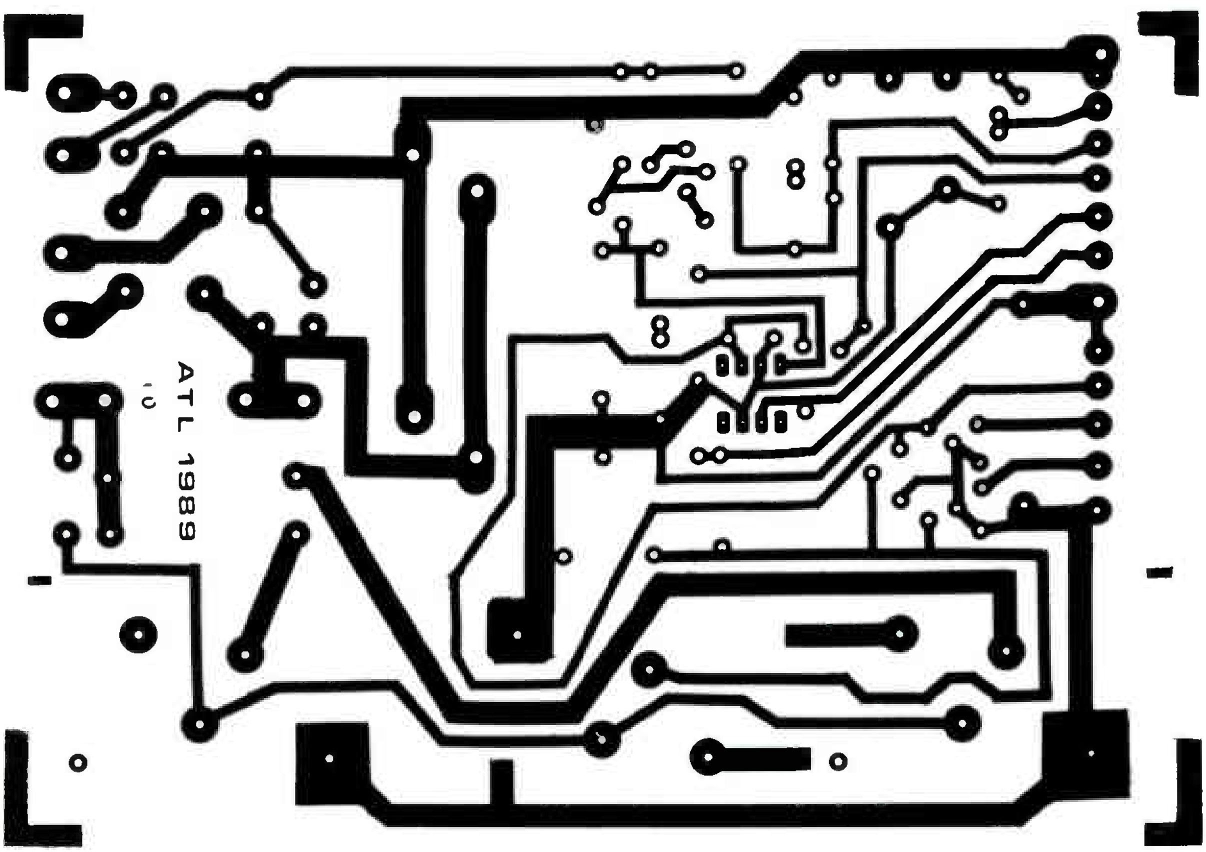
3½ INCHES

AUDIO VOLUME LIMTER FOIL PATTERN.



2³⁄₁₆ INCHES

ION METER FOIL PATTERN.



6 INCHES

UNIVERSAL POWER SUPPLY FOIL PATTERN.

HARDWARE HACKER

LVDT position detectors
Treasure finding circuitry
Switchable analog inverter
Synchronous demodulators
Desktop accessories contest

Synchronous demodulation

DON LANCASTER

THIS MONTH, I FIGURED WE'D LOOK AT a rather mis-named integrated circuit that has an unbelievable future hacker potential. But first, as usual, let's pick up some background...

Programmable analog inverter

Figure 1 shows you my favorite "sleeper" circuit found in my *CMOS Cookbook*. It's a single-ended and simple op-amp circuit that gives you a choice of a +1 or −1 gain under manual or electronic control.

You can analyze most any op-amp circuit by treating the (−) and (+) input sources separately. By a fundamental electronic law called *superposition,* you can get a combined final result.

Assume that we have a fairly low-impedance input source which also provides a resistive path to ground. Suppose we close the switch; the (+) input sees only the resistor to ground and the (−) input acts as an amplifier with a gain of −1, since the input resistor and the feedback resistor are identical.

As with any op-amp, the (−) input can be treated as a *virtual ground,* since any deviation from the grounded (−) input will cause an output change that reaches back around through the feedback resistor to continually seek a zero difference between the (+) and (−) op-amp inputs.

What if we open the switch? Well, we still have one input signal along the top that still has a gain of −1. But now there's a new input-signal path along the bottom, which has a gain of +2. Because of the feedback action, the (−) input of a properly connected op-amp will be a virtual ground "short circuit," while the (+) input will be a high impedance "open circuit."

Hmmm...the gain along the top is (−1). The gain along the bottom is +2. And, the last time I checked, (−1)+(+2) = +1. So, close that switch and you'll get a gain of −1. Open the switch and you get a gain of +1. Presto! A programmable linear inverter.

Your switch can be a manual one, or else a higher-speed electronic one. A quarter of a CMOS 4066 is often an ideal choice for that sort of thing.

As we will shortly see, there are zillions of uses for the circuit. One obvious place is as a *video inverter,* used to create negative video images for special needs. To create a video inverter, you take the circuit and add a sync separator, such as the *National* LM1881, and set things up to invert only your video portions but not the sync portions. Naturally, a video-quality op-amp would be needed for that use. Additional bias current can be switched in as needed to get the correct signal levels. But we'll save that for some other time, because what I really want to get into here are the secrets behind...

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Synchronous demodulation

The switch in Fig. 1 could be turned on and off at very slow rates compared to your input-signal frequency. Or at equal rates. Or even at much higher rates. Now, if you turn the switch on and off at precisely the same speed as your input signal, you create a beastie that is known as a *synchronous demodulator.*

Synchronous demodulators form a super-important electronic concept used just about everywhere. A sync demod's name can change all over the place, being otherwise known as an *autocorrellator,* a *lock-in-amplifier,* a *doubly balanced modulator,* a *phase-sensitive detector, I-Q demodulator, synchronous rectifier,* a *phase-locker*, or, going back to some really ancient history, as a *homodyne detector.*

Figure 1 can also be used as a modern and handy sync demod circuit. What is especially nice is that it's a single-ended circuit which needs no transformers of any kind.

In general, any synchronous demodulator demod is an electronic multiplier that extracts the *sum* and the *difference* between your input-frequency signal and your reference switching frequency.

For instance, Fig. 2 shows you what happens if we keep the input and switching frequencies identical, but shift their phases. Let's first assumethat ther e is a zero phase difference between signal and reference.

The amplifier's gain will be (+1) for the positive signal peaks, and

(−1) for the negative signal peaks, giving us a plain old full-wave rectifier. The "DC term" here will be a direct current level equal to the strength or amplitude of the input signal. The "lumps" will be a double-frequency and higher "AC term" that is usually filtered out. Thus, the zero-phased synchronous demodulation should extract only the *amplitude* of an input signal.

Suppose we next shift the phase by 180 degrees. This time, your gain is (−1) for the positive lumps and (+1) for the negative lumps of the signal. We get a *negative output*, and we could conclude that any 180 degree phased synchronous demodulation extracts only the *negative of the amplitude* of the input signal.

Now, let's get interesting. Suppose we shift the phase to 90 degrees. What happens? Well, *nothing at all*. During the time that the switch is closed, we have half of a positive cycle and half of a negative cycle, so our net (or average) DC output is zero. Very handily, any synchronous demodulation at a 90-degree phasing produces a *zero* output. And, since nothing upside down is still nothing, a similar cancellation happens at −90 or +270 degrees.

But wait a minute. If we get zero output at a 90-degree phase, can't we *double* the information placed on a carrier, simply by having an in-phase term and a 90-degree, or *quadrature* term? We sure can, and it gets done all the time.

For instance, the color information on an NTSC (Never The Same Color) television is placed onto a magic sub-carrier of 3.57545 Megahertz. The *hue* of the color is the *phase angle*, while the *saturation* of the color sets your amplitude. At the receiver, a *phase-locked loop* does an in-phase "I" and a quadrature "Q" demodulation. After further processing, all the separate amplitudes are extracted for the red, blue, and green guns in the display tube. Thus, we have used a pair of synchronous demodulators to extract both the amplitude and phase of a complex signal at the same time.

Let's look at some additional uses for synchronous demodulation. If you hard limit the input

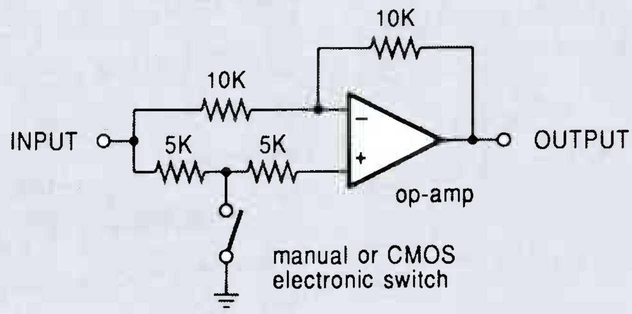

FIG. 1—A PROGRAMMABLE GAIN AMPLIFIER. When the switch is closed, the gain is −1. When the switch is opened, the gain is +1. One important circuit use is for synchronous demodulation.

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signal to your sync demod so that it's a clean square wave, then you will provide *phase detection*. Go through the math, and you will find that the output voltage is a triangle which linearly equals the phase angle between the input and the reference. You can then use your sync demod to measure the phase angle between two input signals.

Suppose we would synchronously demodulate one signal and, at the same time, apply an interfering signal of a different frequency. Your "wanted" signal will always be in phase and will always produce a DC output equal to its amplitude. The "unwanted" signal will create a sine wave as it "slips cycles" with respect to the wanted one. Any sine wave averages to zero over a long enough time. We apparently have a way of detecting one signal while rejecting an interfering one.

Certain types of sync demods are called *lock-in amplifiers*. They can form an extremely narrow *bandpass filter* that automatically centers on the frequency of interest, and can yield tremendous improvements in signal to noise ratios.

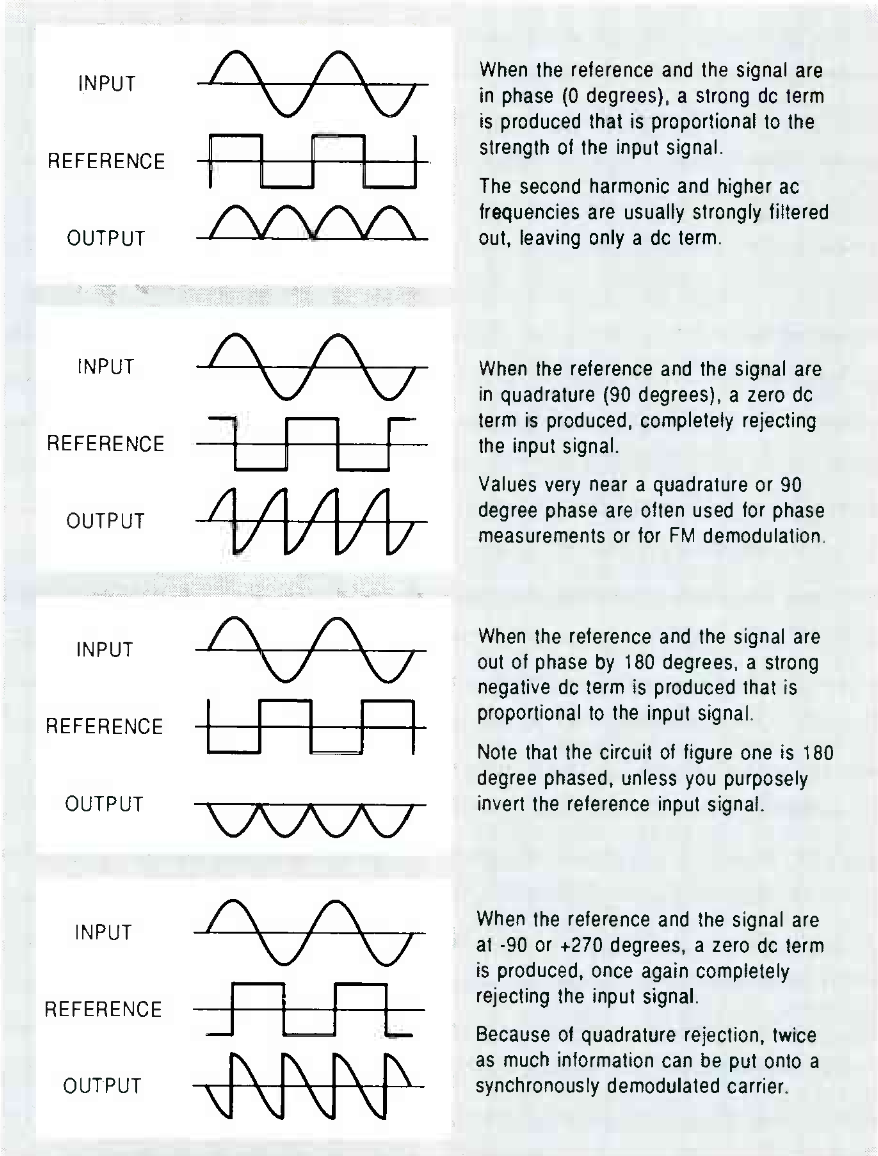

FIG. 2—SYNCHRONOUS DEMODULATOR WAVEFORMS. At 0 degrees reference phasing, the "DC" portion of the output is proportional to the input amplitude, and interfering signals are strongly rejected. At 90 degrees, the "DC" portion is zero, and the input signal itself gets strongly rejected.

As an example, it is not unknown for your lock-in amplifier to cleanly extract a signal that is buried in noise that can be as much as 120 decibels *stronger* than the signal you want. Important uses here include extracting data from deep-space probes, and doing any laboratory and medical instrumentation that measures very weak signals in the presence of much larger interfering noise and AC hum.

A not-quite synchronous demodulation will output a sine wave equal to the *difference* between the reference and input frequencies. That is a simple example of a *downconverting*, or *mixing* of one signal against another to get a frequency difference.

By using a pair of sync demods, you can not only extract the frequency difference, but also determine *which* of the frequencies are higher.

The doppler signal extraction in a side-looking radar is one major use. Separately, synchronously demodulating a shaft encoder can give you both speed and direction information. Flangers for electronic music synthesizers use a similar principle.

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For a really strange use of a sync demod, high-power rectifiers always have a forward drop associated with them of a volt or more that can cause all sorts of inefficiencies, especially with low-voltage solar-panel power conversions. But power transistors can have significantly lower forward drops if they are properly

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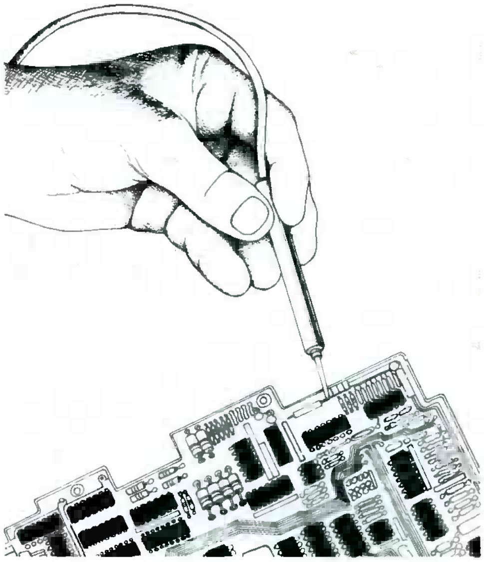

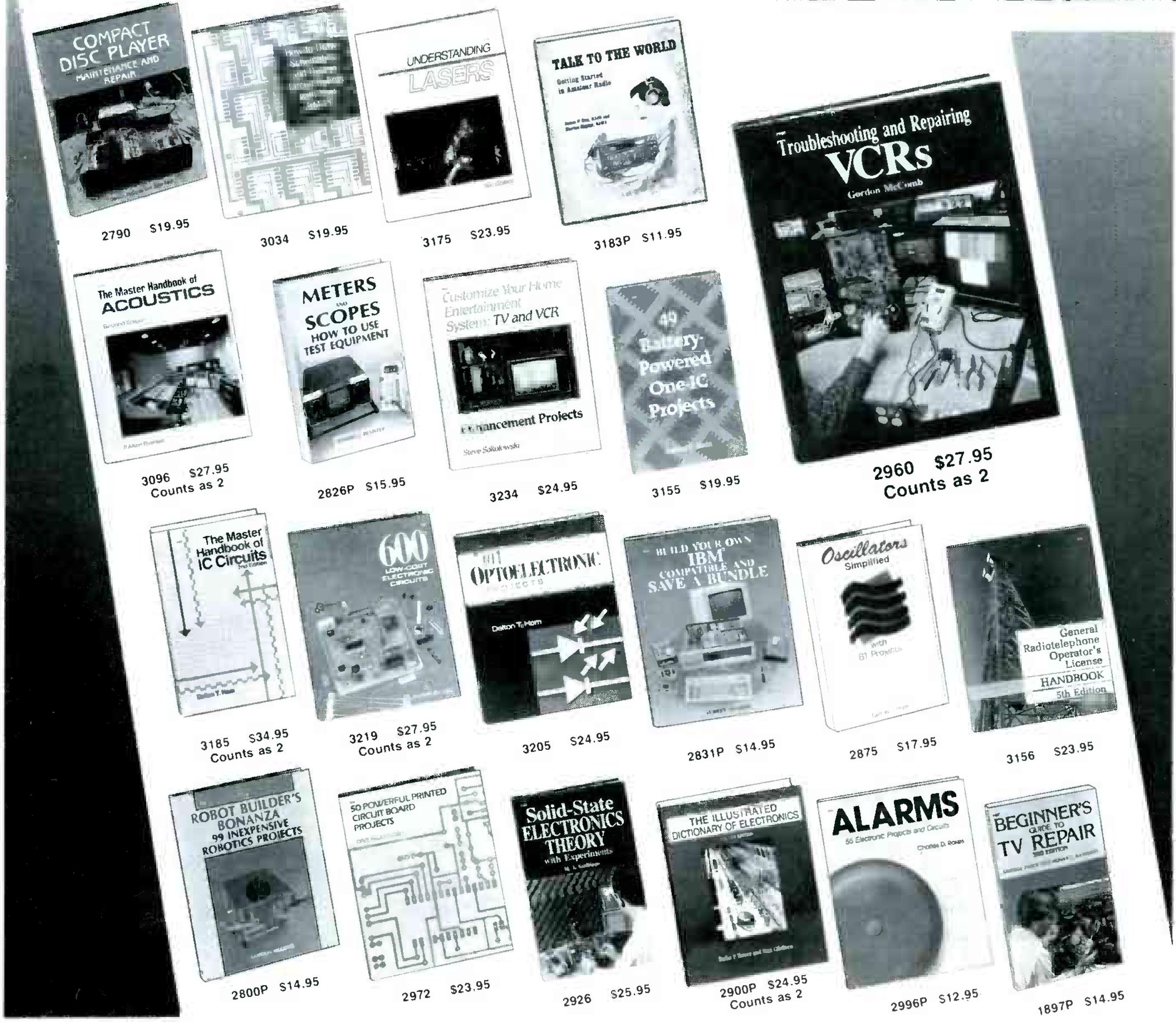

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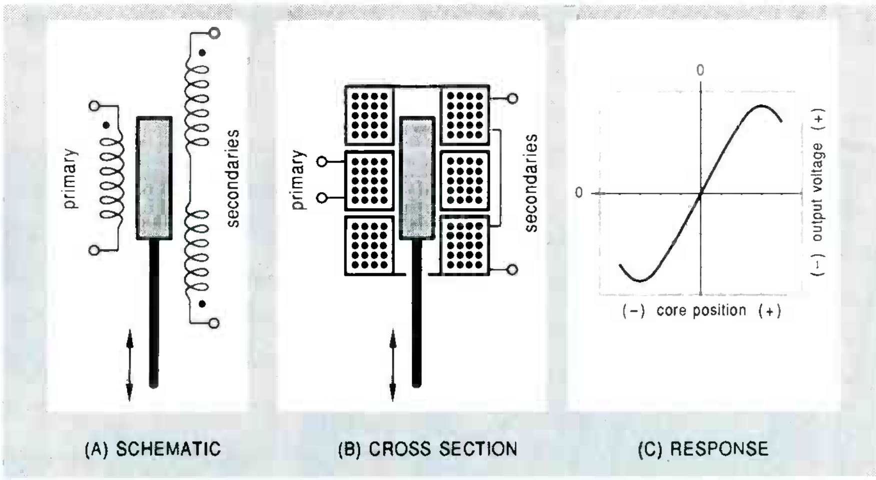


FIG. 3—LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS, or LVDT's for short, can be used for extremely precise position-to-voltage transducers. The output voltage is proportional to the core position. Microweighing is one use.

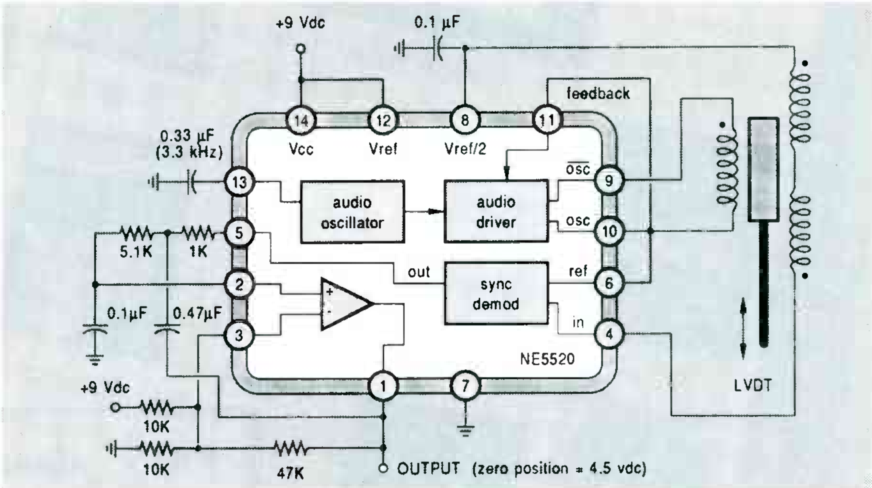


FIG. 4—THE PHILLIPS/SIGNETICS NE5520N has an internal precision sine-wave generator, a sync demod, and an extra op-amp that gets used here as an output filter. This is how to apply it as an LVDT signal conditioner. Since the chip can do so much more, it does seem a shame to waste it on LVDT uses.

overdriven as a switch. To improve the efficiency of a solar power conversion system, you create a *synchronous rectifier* that uses a sync demod and a pair of power transistors to replace your inefficient power diodes normally used.

Finally, one early way of detecting an AM radio station was known as a *homodyne detection*. Here you would synchronously demodulate your incoming signal against a reference of the same frequency as the transmitter carrier and then directly extract your audio in a single step. Unfortunately, they howled a lot as they were tuned and tended towards instability, so they were flushed in the late 1920's in favor of *superheterodyne* circuits that used intermediate frequency amplification, often at 455 kilohertz. Today, the old homodyne deserves a fresh new look, especially when combined with digital synthesis, and the ability to put highly stable audio gain and good filtering into very small packages.

So, sync demods are easy to build and can be amazingly versatile. But, before we explore a great sync demod chip and more real-world uses, let's briefly look at some little-used hacker components known as...

LVDT's

An LVDT, or a *L*inear *V*oltage *D*ifferential *T*ransformer, is shown in Fig. 3. An LVDT is a transformer which has a movable core, a single winding on the primary, and a pair of secondary windings. The secondary windings are connected in *opposition*, so that the output voltage will be the *difference* between the two.

When the movable core is in the center, equal and opposite voltages are induced in the secondaries, and the output voltage is zero. As your core moves up, a 0-degree phased sine wave appears in your output. As it moves down, a 180-degree phased sine wave appears instead.

With careful design, you can get a linear sine-wave output voltage whose amplitude changes with position, and whose phase is (0) degrees for positions above center and (180) degrees for positions below center.

In short, an LVDT is a very precise and ultra-sensitive *position-to-voltage transducer.* Some LVDT devices can easily sense any motions or position changes as small as a thousandth of an inch or less. They can also be made large enough to measure distances of several feet or more.

Unfortunately for hackers, LVDT's are rather pricey, since they are both low-volume and precision components. One useful surplus source is *AST Servo,* while others advertise in the *Sensors* and *Measurement and Control* trade journals.

Several LVDT uses? Weigh scales, especially for microweighing; torque sensing; accelerometers; distance measurement; inclinometers; pressure transducers; for seismometry; load cells; micropositioners; and anywhere else where you want to convert a very small motion or distance change into a useful electrical signal.

For precision results, your LVDT must get driven from a pure audio sine wave of a fixed and known amplitude. Distortion could lead to bad harmonics which will in turn create output errors and other difficulties.

To further up the LVDT precision, you can use an LVDT in its *servo mode*. Here, you'd use feedback to move, balance, shove, or otherwise continually coerce the *LVDT* back to its null position. That is known as *null seeking* and, because of the feedback, many nonlinearities can be greatly reduced if not canceled outright.

While LVDT's are usually super-precise, there's no reason you can't throw one together on your own to create a low-cost position sensor. Be sure to let me know what you do come up with on that.

By another of those astounding coincidences that infest this column, it looks like we need a sync demod to extract the position info from an LVDT. But, if we have a simple and cheap circuit that does that, why limit it to LVDT uses, when so much more can be done so much better with it? Which brings us around to...

The misnamed chip

Sometimes a manufacturer might simply put the wrong name on one of their integrated circuit chips. For instance, which of these two has the greater hacker potential: a *Signetics* NE5520N LVDT Signal Conditioner, or a *Phillips* NE5520N Universal Single Chip Treasure Finder?

As you might guess, *Signetics* is *Phillips* and, of course, the NE5520N is the NE5520N. Figure 4 shows details. What we have is a

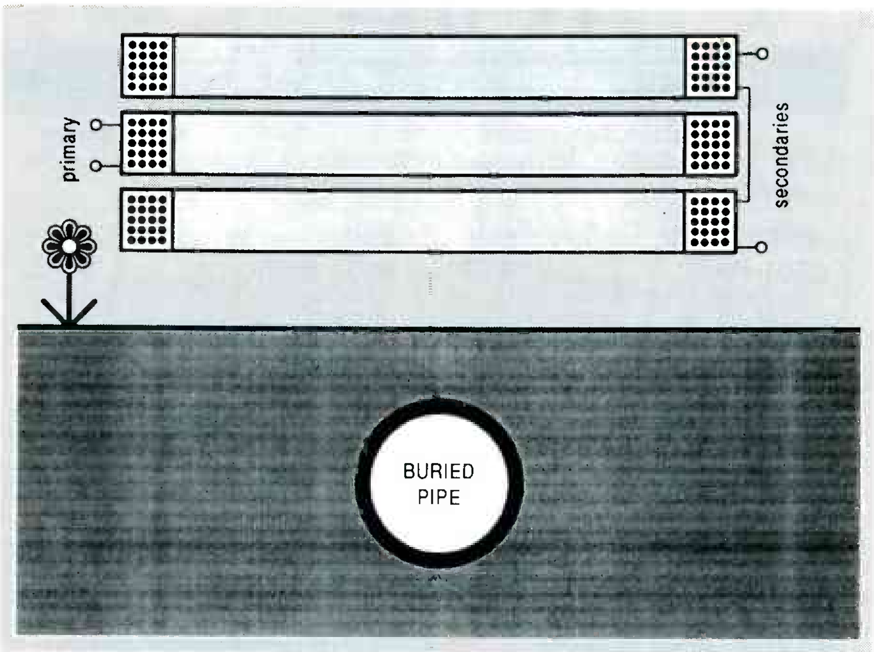


FIG. 5—THE SENSING HEAD of an induction-balance treasure finder or a metal locator can be thought of as an LVDT in disguise. The target acts as a movable core. Synchronous demodulation can separate metal from mineral detection.

precise amplitude and low-distortion audio sine-wave generator, a synchronous demodulator, and one uncommitted op-amp you can use for output filtering, meter driving, or in-phase to quadrature conversions. The circuit shows you how to power and sense the output of an LVDT.

While you actually could use one of those chips with an LVDT, the beast should work well for an extremely wide variety of hacker stuff. Where else could we use an audio source and a sync demod?

One place could include modulated infrared alarms and communicators that can ignore both sunlight and room lighting. A second might be in the fluxgate magnetometer used in solid-state digital compasses.

How about treasure finding? I can think of at least a dozen uses here. Figure 5 shows us how the search head of an induction balance metal locator is really an LVDT in disguise.

In the absence of a buried object, the voltages induced into the output sensing coils are equal and opposite. A buried ore or a metal object will distort the transmitted field, and unbalance the output voltages.

Now for the neat part; any "metal" objects return an in-phase component to the output signal, while "mineral" deposits, such as a well-rusted can, returns us a quadrature signal. Nicely separating the goodies from all the grunge and garbage.

Thus, the NE5520N circuit can be used for in-phase discrimination of metal objects, or for quadrature discrimination of mineral objects.

To do the quadrature synchronous demodulation, just shift the phase of your reference by 90 degrees. Add a second NE5520N, and you can also add such advanced features as automatic ground tracking and the "native" soil background cancellation effects featured on the higher priced locators.

Similarly, over in those receiver-transmitter styles of metal locators often chosen for pipe finding, fiber optics can be used to optically couple from the transmitter to the receiver, minimizing any field distortions an actual cable might create. A sync demod at the receiver could then be used for improved sensitivity and for metal/mineral discrimination.

The NE5520N costs around $7 in smaller quantities. Supply current is around seven milliamperes, easily provided by a 9-volt battery. While you can run the chip at +5 volts, its stability will not be as good.

For additional NE5520N circuit details and bunches of applications info, see the *Industrial Linear Data Manual II* offered by *Phillips*. Check out the NE5521N as well.

Printing resources

As you know, each month I try to feature a *Resources Sibebar* which shows you where to go for the real insider stuff on unusual topics of hardware hacking interest. Sources that are difficult or impossible to quickly pin down on your own. Be sure to tell me what you want to see in future sidebars.

This month's sidebar gives you a rundown of the major sources of information on printing and printshops. What does that have to do with hardware hacking? Just this: there's a total desktop-publishing revolution going on out there, and traditional printing equipment and machinery is so utterly and outrageously priced that it simply won't hack it.

What we need instead is for all you hackers to come up with low-cost and low-end, do-it-yourself hardware kit solutions for desktop printing and book-on-demand publishing needs. To do that, hacking skills and a hacker mentality are essential. And the opportunities are pretty nigh unlimited.

What's needed? Well, for openers, here's a tiny part of my wish list:

(1) A low-cost *Kroy Kolor* machine that doubles as a laminator and as a printed circuit direct-toner transfer processor.
(2) A true perfect binder that gives fully professional cold-glue results for under $99.
(3) A sanely priced clamping paper cutter which can accurately trim 200 sheets at a time.
(4) A die punch that, in one whomp, cuts out twelve business cards from a single sheet of cover stock.
(5) A low-cost padding press.
(6) An economical and programmable folder.
(7) A simple-to-use pad printer for the "real" printing of pens, golf balls, mugs, keyholders, and such.
(8) A cheap corner rounder.
(9) A workable paper drill.
(10) Automated conversions from

Continued on page 78

POWER SUPPLY

continued from page 34

nate in a row on one end of the PC board. Figure 4 shows the general chassis layout, and Fig. 5 shows the juncture between the PC boards and the custom heatsink close up. Use 16-gauge or heavier wire for the leads to J1–J4, and twisted pairs to R13-R14 and R15-R16. If you're including the 5-volt supply, install BR3, C10, C11, and IC3 with the secondary heatsink using point-to-point wiring. Connect T1, wire the primaries, and mount the primary heatsink and front panel. You should now be ready to turn on the supply.

Checkout

Install F1 and F2, apply power, and check for +60 volts DC across C1 and C2. Check for a bias supply of −25 volts DC across C3. Vary R15 and R16, and observe the output voltage change. When the current limiter is fully counterclockwise, the output voltage may be zero, regardless of adjustments. When current limiting occurs, LED1 should glow.

R-E

ION METER

continued from page 38

move the detector rod with ease; it should fit snugly into J3.

Assembly

Mount S2, R5 and R7 on the front panel. Prewire S1 before mounting it, since access after mounting the PC board is difficult. Leave enough lead length to mount the PC board and S1 without strain. Install two metal PC-board standoffs on the back of the front panel, and connect M1 to the PC board. Mount the PC board on the standoffs, and install S1. Use solder lugs between the mounting screws and the PC board as grounds.

Wire the power leads to S2, making sure that the PC board +5-volt DC lead goes to the center terminal. Switch S2 is an SP3T version, so the up position connects to B1, and the down position to IC2. Solder two wires from the PC board to R5, the balance control; the orientation doesn't matter, since that's just a fine adjustment for R8. Solder the positive battery lead to the bottom terminal of S2, and the negative lead to the upper ground lug. Solder two leads to sensitivity-control R7 so that it's shorted when fully clockwise.

Install shoulder washers in the two ¼-inch detector-screen mounting holes and use #6 screws to attach the detector-screen L-brackets. Also, solder one end of R1 to J4, and the other end to the upper PC-board ground lug. If you can't find any shoulder washers to insulate the detector screen from the case, use ¼-inch plastic grommets in the case mounting holes. Attach the 9-volt-battery clip to the left rear of the bottom surface with a ⅛-inch #4 screw.

Mount IC2 in the case hole shown in Fig. 4-*c*, using a TO-220 insulator kit. Solder R13 between the OUT and GND pins. Solder R12 from the IC2 GND pin to the lower PC-board ground lug. Solder the positive side of C17 to the IN pin of IC2, and the other end to the lower ground lug. Solder a wire to the OUT pin of IC2, and the opposite end to the upper terminal of S2. To avoid attaching J1 to the rear of the box and preventing its removal, cement it to the right rear edge. Connect a wire from the "tip" terminal to the IN pin of IC2, and from the "sleeve" terminal to the lower ground lug (see Fig. 3).

Checkout

Set R7 fully clockwise, R5 to center, S1 to positive, and turn on S2 using either B1 or IC2. With a high-input-impedance multimeter, the voltage from the detector screen to the case should be +35–45 volts DC. Switch S1 to negative, which should give –35–45 volts DC. If no voltage is present, check with an ohmmeter for a short from the detector screen to the case. Check pin 8 of IC1 for 9-volts DC, and pin 3 for 20 kHz. A small AM radio tuned to either end of the broadcast band should pick up harmonics when physically close to IC1.

When you turn the ion meter on, M1 should be nearly centered, and rotating R7 should swing the needle left or right; adjust for full scale either way. Next, adjust R8 until M1 is centered. Repeat until R7 is fully clockwise, and M1 is centered; that represents maximum sensitivity for positive ions. Then, set S1 to negative; M1 should deflect sharply to one side, so reduce sensitivity, rotating R7 counterclockwise until M1 fully deflects. Adjust R8 for center balance with full sensitivity as before; that represents maximum sensitivity for negative ions.

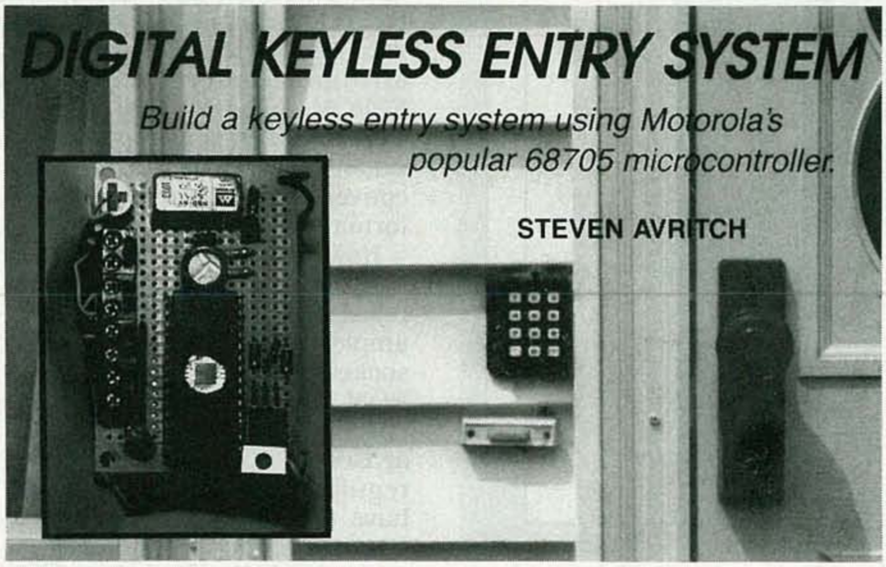
The ratio of negative to positive ions constantly changes. Thus, to balance both positive and negative readings at the center of M1 with full sensitivity is almost impossible. The ion meter reacts only to the immediate ion population.

To balance the ion meter, adjust R7 and R8 until equal readings on each side of zero are obtained for both settings of S1. They may or may not be full scale, but should be adjusted to be within scale using R7. When the ion polarity under observation is changed by switching S1, the detector takes about 20 seconds to stabilize, by bleeding off ions of opposite polarity. A little readjustment of balance vs. sensitivity should let you zero the ion ratio for both polarities, a basic reference level. When adjusted, carry the ion meter rapidly from room to room, and watch M1 swing. **R-E**

DIGITAL KEYLESS ENTRY SYSTEM

Build a keyless entry system using Motorola's popular 68705 microcontroller.

STEVEN AVRITCH



Keyless entry systems have long been commercially available, but the costs associated with the systems usually preclude their use in homes and small businesses. However, by using a readily available and inexpensive microcontroller, a full-featured digital keyless entry system can be built from just a handful of components at a fraction of the cost of commercial units.

The digital keyless entry system presented in this article is a simple yet highly flexible design requiring approximately a dozen components. It costs less than $75, most of which (about $45, depending on where you get it) goes for the electromechanical door latch.

How it works

The digital keyless entry system consists of three major components: the microcontroller, a keypad, and the electromechanical door latch (see the block diagram in Fig. 1).

To unlock the door, the user simply punches a three-digit entry code on the keypad. The microcontroller compares that code with the valid codes stored in its battery-backed RAM. If it matches, the latch is energized, and the door may be opened. In a power failure, the user can bypass the code-entry scheme and open the door with a key.

The keyless entry system may be programmed to recognize three distinct entry codes, each

continued on page 74

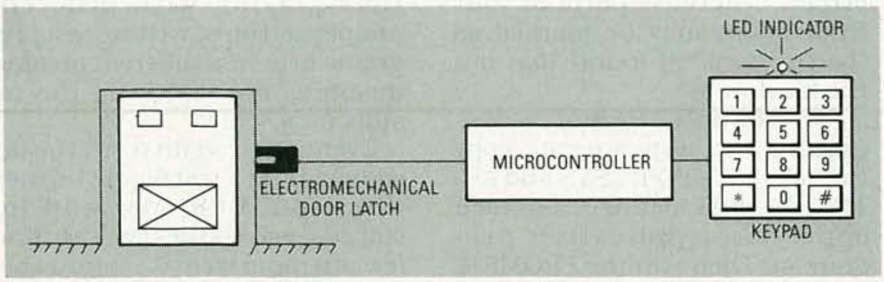


***Fig. 1.** A 68705 MICROCONTROLLER accepts keypad input and then energizes an electromechanical door latch after the proper entry code has been entered.*

EDITOR'S WORK-BENCH

Boot from ROM

Industrial controllers typically suffer from lack of a standard development environment—or, if one is available, it's expensive. The PC is ubiquitous; why not use it to develop real-time control systems?

One reason is cost: a full-blown PC may be too expensive for field use in many applications. Even if cost is not a major consideration, another problem is reliability; disk drives (hard or floppy) typically don't fare well in industrial environments.

Of course, disk drives aren't absolutely required; there are diskless LAN workstations, and some laptops boot from DOS in ROM. But putting DOS in ROM requires special expertise with device drivers and BIOSes—or does it?

It doesn't have to; Annabooks (the company famous for selling a C-language BIOS in source-code form) has done all of the dirty work for you. With their PROMKIT you insert the diskette to be emulated in a disk drive, run a one-line batch file, burn the resulting code into EPROM, and you're done.

How it works

When a PC with a standard BIOS boots, it scans the memory area above the video adapters (C000:0000—E000:FFFF) look-

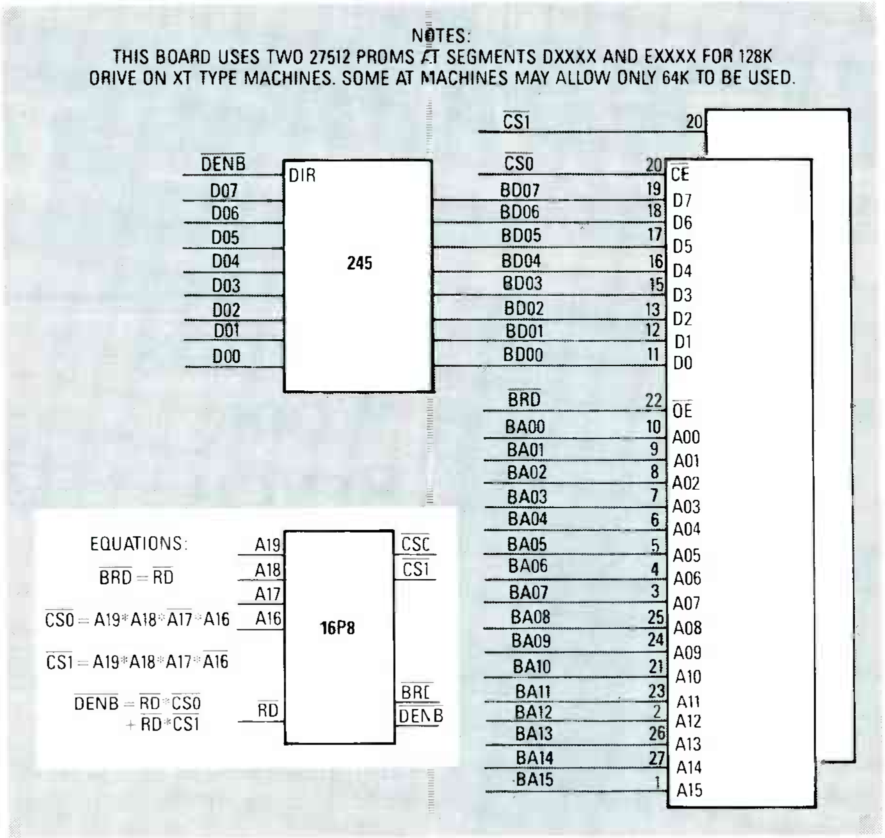


FIG. 1

ing for the "signature" word 55AAh every 2K. If the scan routine finds the signature, it picks up the third byte, which specifies the number of 512-byte blocks contained in the routine. The maximum value of the size byte is FBh (251), allowing a total of just under 128K (251 × 512) bytes. The scan routine next computes a checksum over the specified number of blocks. If the checksum equals zero, the BIOS then executes a far call to the fourth byte, which is where user code should start. The user code should perform its initialization and then terminate with a far return, which will allow the scan routine to continue at the next available block.

There's nothing magic or even particularly obscure about that procedure; IBM has used it at least since the introduction of the XT, whose hard-disk controller contains a BIOS extension allowing orderly access to one or two hard disks. The same technique is used by EGA and VGA video cards, network adapters, even some "intelligent" floppy-disk controllers, and more.

What Annabooks did was to tap into that potential by creating a set of programs that link user code into the floppy-disk drive control system of the PC—so that whenever a program tries to access an emulated drive, contents come from an EPROM rather than a physical drive. In addition, with the proper supporting hardware, static RAM's can be used to provide a fully solid-state read/write capability, and it all happens transparently at the DOS level. PROMKIT also supports multiple-drive emulation.

You use the software by creating a floppy disk with an *exact* image of the disk you wish to emulate. Make sure that you use a fresh floppy with no formatting errors, otherwise parts of your ROM image may be marked as "bad sectors." (I found that out the hard way.)

For example, format a disk (putting the system on it), copy the desired CONFIG.SYS and AUTOEXEC.BAT files to it, and then copy your application program(s). Then run the PROMKIT program (PK.EXE), specifying the drive letters of the source and emulated drives, the name(s) of the file(s) that will receive the object code, number and type of EPROM's, etc. PK then builds a set of files containing both the ROM-scan loader that copies your files from ROM to RAM, and your application program. The number of files that PK creates, as well as their size, depends on the number and size of EPROM you use. The file format is a straight binary image; some EPROM programmers require a hex/ASCII format. So, Annabooks includes a utility that converts the binary file to Intel format.

How you address the burned EPROM's depends on your application. Older XT clones, for example, often have several unused sockets allowing 56K of add-on ROM. Some AT system boards have a pair of sockets addressed at E000:0000. Otherwise, in a regular PC environment you'll have to use an add-on memory card. In addition, there are PC-on-a-card solutions, including Intel's Wildcard and others, that would allow more compact solutions.

For purposes of testing, Annabooks was kind enough to loan me the *U*niversal *M*emory *C*ard (UMC) card made by Sealevel Systems. The half-length card contains eight 28-pin sockets that allow various combinations of EPROM's and static RAM's, and even includes provision for a lithium backup battery. The board can be addressed at any 256K boundary in the PC's address space; I used it at the C000:0000 bound. You have to set several jumpers to select device type and capacity, and the documentation is minimal. To figure out the necessary decoding for my tests, I spent some time playing with different jumper settings, writing test programs to access different areas of memory, and watching the results on a scope.

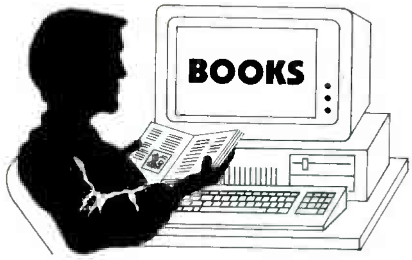
Eventually I figured out the decoding, built a test floppy, burned three 32K EPROM's, and installed them on the UMC. My first few attempts were disastrous because I didn't have the decoding jumpers set right, and then I didn't understand which sockets on the board to use. I also found that a *clean* floppy is necessary.

Hardware options

The PROMKIT documentation comes with several hardware designs for addressing various types of memory. One simple design (shown in Fig. 1) uses a single bus buffer and a PAL, and allows you to address two 27512 (64K) EPROM's in the D000 and E000 segments. Another two-chip (plus memory) design allows you to emulate a full 360K drive using only a 64K data window occupied by a standard 27128 (16K) EPROM for the driver module, and three 27011 paged EPROM's for data. The latter are organized as 16K × 8 bits × 8 pages, for a total of 128K each. The 27011's are somewhat expensive and hard to find, however. Another two-chip design allows read/write access to an emulated drive; another gives you 1MB of emulated disk using only a 32K window. The company also has information on commercial units like the Sealevel board I used.

The PROMKIT works with the company's BIOSKIT, so that you can combine the BIOS and the driver code in a single EPROM. The PROMKIT also comes with full source code (in C), heavily commented and well structured, so you can customize operation to your heart's content.

The PROMKIT is built on a foundation called the OBJEX Core Library, which provides a set of low-level data structures and routines (mostly in C, some in assembler, source included). You use OBJEX to access memory and I/O ports, manipulate 80xxx family segment registers, etc. PROMKIT is built on OBJEX; and Annabooks plans to release other system tools, including a "mini-DOS" that could be useful in situations where a full licensed copy of MS-DOS would be undesirable or cost-prohibitive. (Digital Research's DR-DOS is also available for ROM-based applications, and Microsoft recently responded to DR's growing popularity with an announcement of some support for a ROM-based DOS.) ◗CD◖



C and Pascal programming

Obect-oriented programming (OOP) may be just another fad, but it may not be. The first wide-scale implementation was on the Macintosh; now the PC world has caught up, so Microsoft and Borland are engaged in a war to define and control the market. The latest version (5.5) of Turbo Pascal adds object-oriented extensions. If you don't know what OOP is, Turbo Pascal 5.5 contains an excellent little book introducing the subject. If you feel the need for more hands-on experience, check out the *Turbo Pascal DiskTutor* by Werner Feibel. That book/disk combination consists of two parts. The first nine chapters teach you the basics of programming in Pascal and in using the tutorial environment. Chapter ten deals with units (libraries of object code), and serves as a bridge to the next two chapters, which deal with OOP. The final chapter deals with bit manipulation and using DOS services.

If C is more to your taste, check out *Microsoft C, Secrets, Shortcuts, and Solutions* by Kris Jamsa. It's a tutorial starting at square one. No compiler is included, and the examples are all geared toward Microsoft C. The book consists of four parts; the first discusses basics of the language and the Microsoft environment. Part II goes into pointers, arrays, and file processing. Part III continues with command-line processing, accessing the DOS environment, I/O redirection, low-level file I/O, and dynamic memory allocation. Part IV discusses optimizing compiler usage, LIB and MAKE, memory models, critical error handling, and other advanced topics. I do wish that I could take a couple of months off and study the book in depth. ◗CD◖

ITEMS DISCUSSED

- PromKit ($179), Annabooks, Suite 250-262, 12145 Alta Carmel Court, San Diego, CA 92128. (619) 271-9526.
  CIRCLE 40 ON FREE INFORMATION CARD

- Universal Memory Card ($199), Sealevel Systems, Inc., P.O. Box 1808, Easley, SC 29641. (803) 855-1581.
  CIRCLE 41 ON FREE INFORMATION CARD

- *Turbo Pascal DiskTutor* ($39.95), Werner Feibel, Borland-Osborne/McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710.
  CIRCLE 42 ON FREE INFORMATION CARD

- Microsoft C, Secrets, Shortcuts, and Solutions ($24.95), Kris Jamsa, Microsoft Press, Microsoft Corp., 16011 NE 36th Way, Box 97017, Redmond, WA 98073-9717. (206) 882-8080.
  CIRCLE 43 ON FREE INFORMATION CARD

KEYLESS ENTRY

continued from page 71

of which consists of three digits. You change the entry codes from the keypad by entering a special three-digit "function" code, discussed in detail later. An LED indicates system status.

It should be noted that the digital keyless entry system is not a complete security system in and of itself; however, it can function as an integral component of a complete security system.

Circuit description

The heart of the system is the Motorola MC68705P3 microcontroller discussed in detail in the September 1989 **Radio-Electronics** (page 82). To summarize its features, the microcontroller has 64 bytes of RAM, 2K of EPROM, a built-in clock oscillator, and 20 I/O ports.

You can program the 68705 with some off-the-shelf EPROM programmers; you may also want to consider building the programmer described in the earlier article.

The keypad used in this design is a standard four-row by three-column keypad with a common ground, as shown in Fig. 2. Each of the seven keypad outputs is pulled up by a resistor (R1–R7) and is connected to ports A0–A6 of the microcontroller, as shown in Fig. 3. The microcontroller uses a software scanning routine to determine when a key is pressed.

When the microcontroller has recognized a valid entry code, it sends port PB0 high, which turns on power MOSFET Q1, which in turn enables relay RY1. Current for the door latch then flows through the relay contacts. Diode D1 is wired across the coil of the relay to prevent voltage spikes caused by the instantaneous change in current through the relay coil.

Port B7 of the microcontroller drives LED1 (STATUS) directly. A logic low on port B7 completes the circuit to ground and lights the LED.

When the EXTAL and XTAL inputs (pins 4 and 5) are connected to-

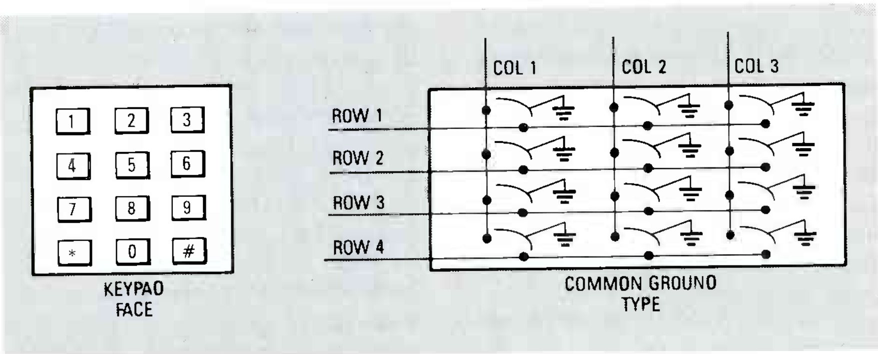


***Fig. 2.** THE KEYPAD consists of four rows by three columns. Pressing a key grounds the intersection of the corresponding row and column.*

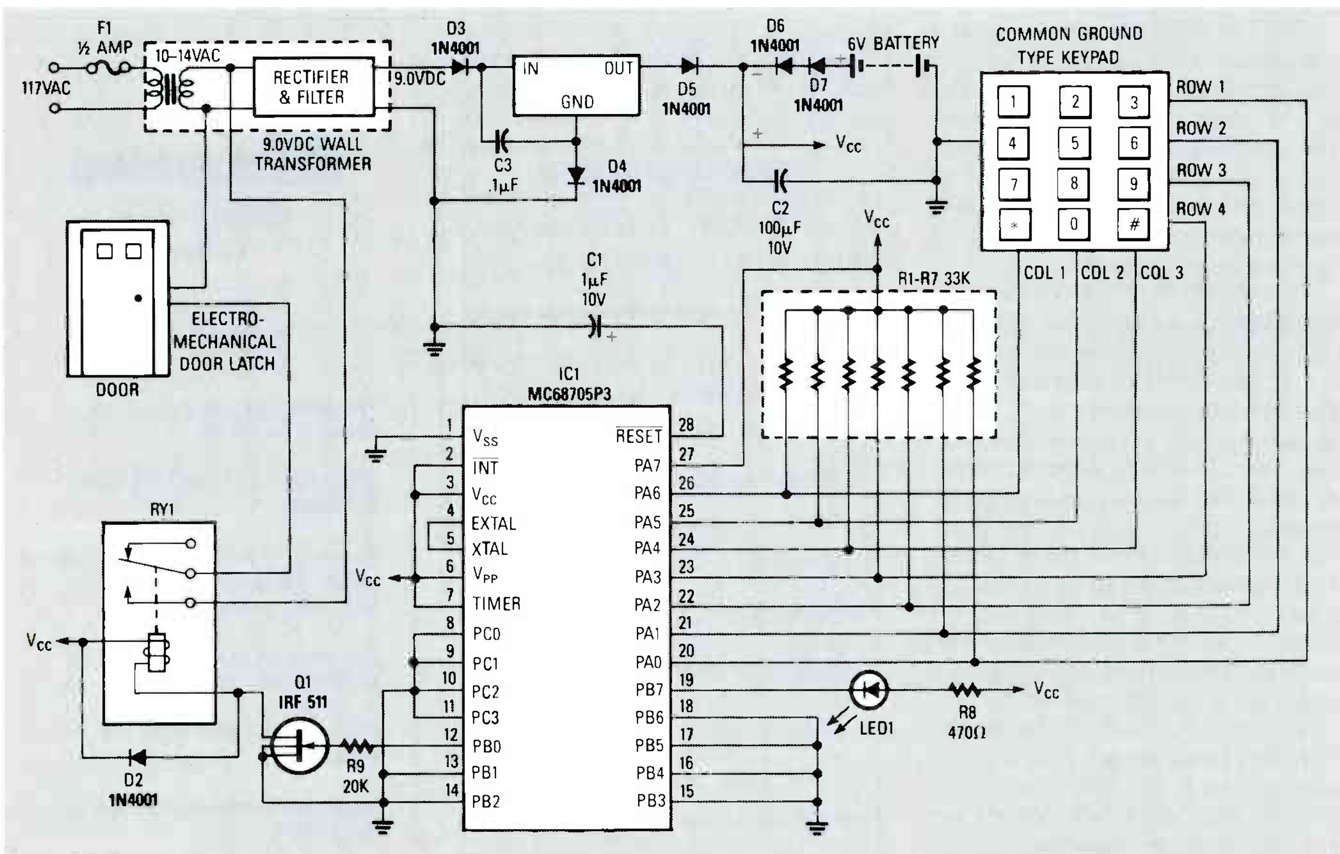


***Fig. 3.** COMPLETE SCHEMATIC of the digital keyless entry system. You can eliminate diode D4–D7 if you don't want battery backup. However, you'll be limited to the access codes burned into the microcontroller's EPROM.*

Parts List

Resistors

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

R1–R7 .... *33,000 ohms*
R8 .... *470 ohms*
R9 .... *20,000 ohms*

Capacitors

C1 .... *1 μF, 10 volts, electrolytic*
C2 .... *100 μf, 10 volts, electrolytic*
C3 .... *0.1 μF, ceramic disc*

Semiconductors

IC1 .... *MC68705P3 microcontroller*
IC2 .... *7805, 5-volt DC regulator*
Q1 .... *IRF511, power MOSFET*
LED1 .... *standard red*
D2–D7 .... *1N4001, 100 volts, 1 amp*

Miscellaneous

Keypad .... *common ground*
Door latch .... *(see text)*
Relay .... *SPST, 5-volt coil, 50 ohms, 100 mA*
Fuse .... *1/2 amp (and holder)*
Transformer .... *9-volt DC, wall-mount*
Batteries .... *4 AA cells (and holder)*

Ordering Information

The following are available from Simple Design Implementations (SDI)
P.O. Box 9303
Forestville, CT. 06010

....

Preprogrammed & tested MC68705 .... $25 + $2.50 S/H

Electromechanical door Latch .... $45 + $4 S/H)

Complete kit of parts as shown in Parts List .... ($75 + $6 S/H)

Software on 5.25" disk ... $25 + $3 S/H)

gether as shown in Fig. 3, the microcontroller's internal oscillator circuit runs at about 800 kHz, providing a cycle time of about 1.25 μs. The accuracy of a crystal oscillator is not important for this project.

The microcontroller pulls up the $\overline{\text{RESET}}$ input (pin 28), thereby eliminating the need for an external resistor. The 1-μF capacitor (C1) connected from that pin to ground gives the power supply time to stabilize before allowing the microcontroller to start up.

The external-interrupt input ($\overline{\text{INT}}$, pin 2) is tied high because interrupts are not required for this project. V_{PP} (pin 6) is also tied high per the manufacturer's specifications.

Power considerations

The power supply bears some explanation; it provides an optional battery-backup system. If you want, you can hard-code the desired entry codes into EPROM. That way, you won't need to provide battery backup. But you won't be able to change codes without changing the contents of the EPROM.

The 7805 voltage regulator (IC2) maintains the supply at five volts, and filter-capacitor C2 removes any noise from the DC supply voltage. A reversed-polarity protection diode (D3) is included to protect against misapplication of power. Diode D4 serves to "lift" the 7805's output voltage by about 0.7 volts to provide an output of 5.7 volts, which is then dropped by D5 back to 5.0 volts. Diodes D5, D6, and D7 isolate the battery and the power supply from one another, preventing current from flowing from whichever source happens to be active into the other. The batteries supply about $6.0 - 0.7 - 0.7 = 4.6$ volts. Four AA batteries supply plenty of power to keep the micro-

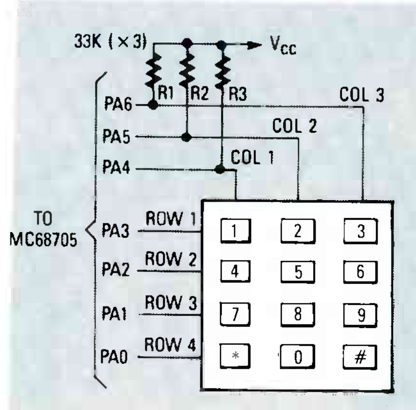


***Fig. 4.** AN UNGROUNDED KEYPAD may be used, but you'll have to change the keypad scan routine. An excellent opportunity to get started in 68705 programming!*

controller's memory active (and your entry codes intact), but they can't operate the door latch, so in case of a power failure, you will have to use a key to open the door.

If the system encountered a battery failure and a main power failure simultaneously, the microcontroller's memory would be lost. When power was restored, the entry codes would be initialized to the default values stored in EPROM. Diodes D4–D7 may be removed if the battery-backup option is not used.

Software design

The following describes the software running on the microcontroller; with the information provided, it should be easy to customize operation to your liking. Complete source and object code have been posted on the RE-BBS (516-293-2283, 300/1200 baud, 8N1) in the file DIGKEY.EXE, a self-extracting compressed file. The compressed file consists of about 20K; run it on a disk with at least 50K of free disk space.

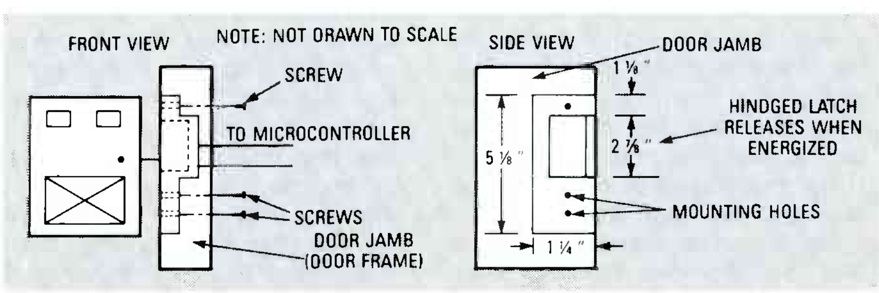


***Fig. 5.** MOUNTING DIMENSIONS for the prototype door latch. This is only a guide: measure your own unit carefully.*

The system can recognize as many as three distinct entry codes. Each entry code is three digits long. The three entry codes can be independently changed and independently enabled or disabled. The system also recognizes a fourth three-digit code that puts the system into the "function" mode mentioned earlier; the function mode allows the user to change the entry codes or enable/disable the entry codes.

The three entry codes and their functional status are initialized on power up to default values stored in the EPROM. The function code, on the other hand, always starts up enabled, because if it started up disabled, the user would never be able to get into the function mode to enable it!

During normal operation, the LED flashes to indicate that the microcontroller is active and ready for input. The microcontroller stores the incoming keypad data in a buffer and constantly compares that buffer to the three valid entry codes. If a match is found, the microcontroller checks to see if that particular entry code is enabled. If the entry code is enabled, the electromechanical latch is energized for seven seconds.

If the microcontroller detects too many digits before a valid match is detected, the system enters a security mode prohibiting further input until the "*" key is pressed. While in security mode, the LED stops flashing, and remains off, indicating an improper access attempt.

The microcontroller purges the input buffer three seconds after the last key was pressed. Therefore, if the user enters one, two, or three incorrect digits, he must wait at least three seconds from the last entry before reentering the correct code. If the user does not wait three seconds, the incorrect digits remain in the buffer, a correct match cannot be made, and the system will enter security mode on the fourth digit.

The microcontroller enters the function mode when the correct three-digit function code is entered. Upon entering the function mode, the LED will turn on for 1.5 seconds, turn off for 1.5 seconds, and then remain on. The microcontroller will now accept an entry-code change. The user enters the number of the entry code he wishes to change (1, 2, or 3) followed by the three new digits, followed by a zero (0) if the code is to be enabled or a one (1) if the code is to entered but not yet enabled. If an entry code already contains the desired three digits and the user simply wishes to activate or deactivate the code, then he must hit "*" (deactivate) or "#" (activate), following the function code and the entry code number. The user is not required to enter the three digits of the entry code when enabling or disabling it.

Construction/installation

The prototype was built on a small piece of perfboard using point-to-point techniques. Be sure to observe the polarity of all polarized ports.

You could use a standard row/column connect type of keyboard; doing so would allow you to eliminate four of the seven keypad pullup resistors. Figure 4 shows the basic idea. However, you'd have to implement a different keyboard scan routine.

The only change to the existing lock assembly involves removing the latch receptacle in the door jamb and replacing it with the electromechanical latch.

The latch in the prototype was obtained at a local safe and lock store. Although the physical dimensions of the latches were fairly uniform (as shown in Fig. 5), drive potential varied from three to twenty-eight volts, either AC or DC. The author recommends driving the latch with an AC voltage because the latch will buzz when energized. DC drive voltages work just as well, but the latch will make only one faint click when energized. ◆CD◆

AUDIO UPDATE

LARRY KLEIN,
AUDIO EDITOR

National sound preference?

LONG-TERM READERS OF THIS COLUMN may have noticed that I've been less than kind to those audiophiles who harbor strange, semi-magical beliefs about sound quality and the "mysterious" factors that supposedly influence it. It's not generally appreciated that many of the strange audio attitudes and peculiar belief systems originated in the same place that most of the equipment comes from—Japan.

I can remember my first encounter with Japanese audiophilia, about 15 years ago. A number of Japanese audio-magazine editors were visiting the U.S. and wanted to meet with me and other American audio editors to "exchange views." I was certainly pleased at the opportunity to meet my Japanese counterparts and looked forward to discussing technology, the audio-magazine business, the comparative natures of Japanese and American hi-fi audiences, and so forth. After a tour of the *Stereo Review* offices and sound room, we proceeded to a large local restaurant. As I recall, the first question put to me (during an excellent minestrone soup) was whether I preferred speakers with "East-Coast" or "West-Coast" sound.

I seems that the Japanese had observed that the leading U.S. west-coast speaker manufacturers of the time—Altec Lansing and JBL—produced high-efficiency systems with overly strong middle and upper midrange response, sometimes accompanied by a heavy upper bass. (Altec and JBL systems no longer sound that way.) On the other hand (or coast), there were the New England manufacturers—Acoustic Research (AR), KLH, and several others—whose acoustic-suspension systems had a smooth and extended frequency response that was relatively free of peaks and dips. (Incidentally, at that time AR systems accounted for fully one-third of U.S. speaker sales, a feat that has never been equaled.)

Bi-coastal disclaimer

I tried to explain that I did not find it helpful to characterize speakers by their area of origin, since I had heard systems from opposite sides of the country with similar sound qualities and systems manufactured on the same coast that sounded different. But my Japanese friends were not content with what they obviously thought was a cop-out. "What kind of sound do the Harman Kardon speakers have?" they persisted. "Long Island sound," I quipped, hoping to end the discussion. (For those readers unfamiliar with New York geography, the Long Island Sound separates Long Island, where Harmon Kardon is located, from Connecticut.) My reply had no effect on the Japanese, but caused one of the U.S. editors to choke on his soup.

In any case, our discussion ultimately turned to other matters, and I learned that their concern about East-Coast/West-Coast sound had world-wide implications. It seems that my Japanese colleagues believed that there were national tastes in sound: The Germans liked one kind of tonal balance, the English another, the Japanese a third, and so forth. Subsequently, I even saw a manufacturer's newsletter that attempted to correlate national speaker tastes with local environmental factors, such as high or low humidity levels.

On my subsequent trips to Japan, most of the engineers that I spoke to simply accepted the variations in national tastes as a given, and were prepared to export to each country the kind of sound that they believed its natives preferred. Incidentally, the speakers that came to the U.S. were of the "West-Coast" variety, because that was also the kind of sound that the Japanese liked. As a result, for many years *no* Japanese speaker ever received a good review in the American or British press, even from those publications that loved Japanese electronics.

Insrutable ears

Here's where the story really gets confusing and mysterious. One of the American representatives (let's call him Bill) of a major Japanese manufacturer asked me to have *Stereo Review* test a new two-way bookshelf speaker system. He assured me that it was a cut above the typical Japanese speaker. I agreed to submit it to our test lab, which, to my surprise, gave it a very favorable review. A month or so after the test report appeared in print, I got a call from Bill, who asked if I would be willing to visit his company's Long Island City plant and do a little critical listening for him. He suggested that I bring my own test

continued on page 87

HARDWARE HACKER

continued from page 68

a laser-printed image onto T-shirts, for rubber stamps, and for CAD/CAM machining of a plastic mockup or even actual hardware.
(11) A super scungy vacuum packer and/or shrink wrapper.
(12) A method to convert an orbital jitter sander into a paper jogger.
(13) A new combination scoring, perforating, and die-cutting machine, possibly with a hot foil die-stamping capability, as well.
(14) A very low-cost power stapler strong enough to handle *Jiffy Bags*.
(15) Solutions to economical custom glass etching.
(16) Vinyl hot-knife sign cutters and PostScript driven wood and/or aluminum routers.

Once again, your projected final cost to the end user on any and all of those should end up in the $25 to $99 range, or under *one-tenth* of the sales commissions of the "real" print machinery that all this stuff is inevitably going to shoot out of the saddle.

Your hacker abilities are obviously needed to hold the costs down. And lots of electronics and power control does seem to be involved. This is one hot topic right now, with a potential market in the millions of units.

Two contests

Let us have two contests for this month. As usual, there will be an *Incredible Secret Money Machine* for the dozen or so best entries, with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two awarded to the very best of all.

Either (A) show to me a new and unique hacker circuit involving the NE5520N with some unusual synchronous demodulation use, or else (B) show me a low-cost solution to some desktop publishing peripheral hardware of one sort or another.

As usual, send your entries directly to me at *Synergetics,* and *not* to **Radio-Electronics**. Let's hear from you.

New tech literature

Those *Phillips* folks have recently bought out *Amperex* and several other companies. They've now released a wheelbarrow full of fat, new, and free data books. Check out their *Light Emitting Diode; RF Power Transistor; High-Voltage Transistor; RF Power Module; Thyristor; Small Signal Transistor; Surface Mounted Semiconductor;* and the *PowerMOS* data books for openers. There's bunches more where those came from. *Linear Technology* has issued a great new *1990 Linear Data Book* that is crammed full of great hacker integrated circuits.

Free software this month includes the latest *Specs in Secs Discrete Data* from *Motorola,* and the *PCBII* printed circuit layout demo from *OrCAD*. And unusual free samples for this month include the MC33034 *Brushless Motor Controller,* again from *Motorola,* the *Advanced Bus Interface Product Samples* from *Texas Instruments,* and the various low-cost jellybean integrated circuits from *Calogic*.

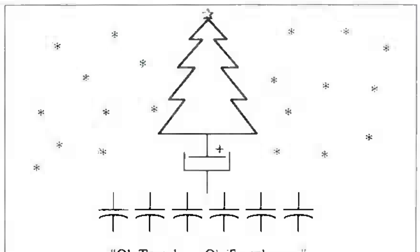
Our reminder here that *Midnight Engineering* is a great new hacker magazine aimed at all small-scale hardware and software productions. Free samples are available.

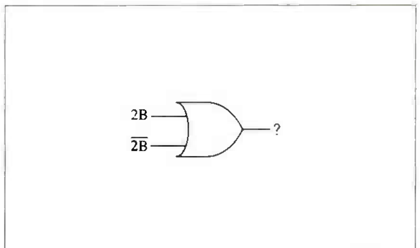
Rounding out the selections, the *Chomerics* folks have new *Cho-Flex 440-X* line of force-sensitive inks. *Car Audio* is an interesting slick magazine for high-power mobile music buffs. *American Design Components* has a new surplus catalog that includes $14 ultrasonic radars and $15 gyroscopes, among scads of other goodies. And *Chips and Technologies* has a new 82C235 single-chip AT motherboard out, along with a free data book.

Turning to my own stuff, for the fundamentals of digital integrated circuits, check out my million-selling *TTL* and *CMOS Cookbooks*. I also have a new and free mailer for you which includes dozens of insider and top hardware-hacking secret sources. Do write or call for your copy.

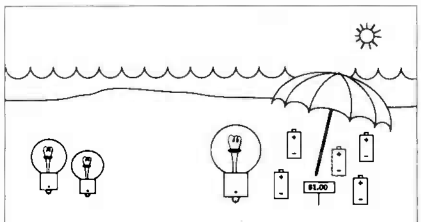
As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8–5, *Mountain Standard Time*. Let's hear from you. **R-E**

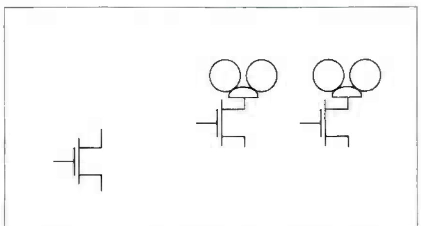
SHORT CIRCUITS


"Oh Tantalum, Oh Tantalum...."
John Q



John Q


"She Sells C-Cells Down By The Sea Shore."
John Q


"What is this....Some Kind Of *Mickey MOS* Outfit?"
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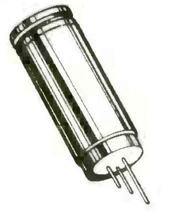

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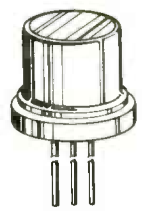

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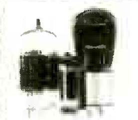

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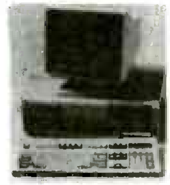

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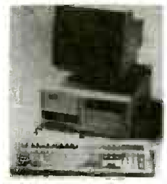

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AUDIO POWER AMP IC's

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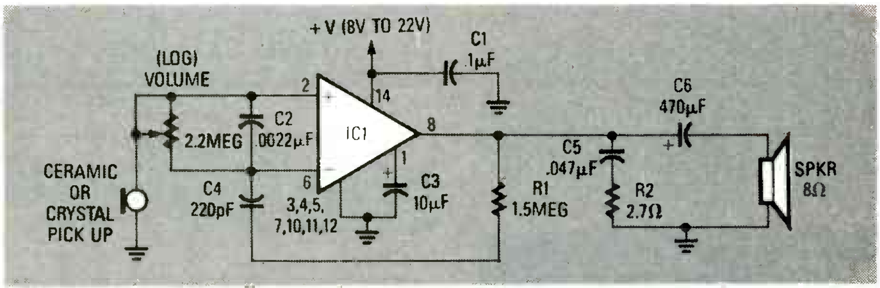

FIG. 22—2- OR 5-WATT PHONO AMPLIFIER with RIAA equalization.

bridge configuration, to provide 4 watts to an 8-ohm speaker when using a 12-volt power supply. The "balance" potentiometer is used to set the quiescent output of the two IC's at identical values, in order to minimize the quiescent current consumption of the circuit.

Note that the LM388 has fairly poor supply-line ripple rejection. If any such problems come about, they can usually be overcome by wiring a 10-μF (or larger) capacitor between pin 1 and ground.

LM380/LM384 circuits

The LM380 (Fig. 20) can work with any supply from 8 to 22 volts. It can deliver 2 watts into an 8-ohm load when operated with an 18-volt supply, but it needs a good external heat sink to operate at that power level. Its differential input terminals are both ground-referenced, and the output automatically sets at a quiescent value of half of the supply voltage. Its voltage gain is fixed at 50 (34 dB), the output is short-circuit proof, and the IC is provided with internal thermal limiting.

The LM384 is simply an "uprated" version of the LM380, capable of operating from up to 28 volts and of delivering 5 watts into an external load. Both IC's are housed in a 14-pin DIP, in which pins 3–5 and 10–12 are intended to be thermally coupled to an external heat sink.

Figures 21 and 22 show some practical applications of those two audio-power amplifier IC's. Fig. 21 shows how to use either IC as a simple ×50 amplifier with enhanced ripple rejection (via C2) and a very simple form of volume control (R2). Alternatively, Fig. 22 shows how to use either IC as a phono amplifier with RIAA equalization (via R1-C4). Also note that either IC can be used in the "bridge" mode to provide extra power when connected the same as Fig. 19. In that setup, a pair of LM380's would produce 4 watts when powered from 18 volts, and a pair of LM384's would produce 10 watts when powered from 22 volts. **R-E**

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AUDIO UPDATE

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records. I agreed, and we made a date for the following week.

When I arrived, and after Bill introduced by to several Japanese engineers, I was ushered into the company listening room. There I was confronted with three visually identical pairs of speakers labeled "A," "B," and "C"—obviously the same model that had been reviewed so well by our test lab. Bill handed me the control of a three-way switching system and asked me to switch among the three pairs of speakers and evaluate their sound quality. Since all the systems looked identical, I didn't know quite what to expect, but no more than about 15 minutes were needed to arrive at an opinion based on my A/B/C comparisons. I said that according to my ears system A sounded bad, system B was pretty good, and system C also sounded bad—but different from A. Bill seemed pleased with my response, but the Japanese seemed puzzled and upset.

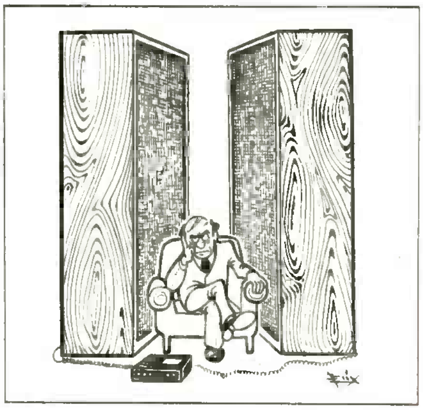
Here's where the inscrutable part comes in. Later, in private, I asked Bill to explain exactly what was happening. He said that the Japanese had been thrilled by our favorable test report and decided to heavily promote their speaker system in the U.S. In order to save the shipping costs from Japan, they intended to build the systems here, using an American-made cabinet and either local- or Japanese-manufactured drivers. To Bill's ears, the two pairs of locally assembled systems (A and C in my tests) sounded quite inferior to the original (B), but the Japanese insisted that they all sounded alike! That's why Bill had brought my ears into the act.

I've thought about that experience over the years, and have yet to figure out exactly what went wrong. I can understand that the Japanese engineers might prefer a different sonic quality (frequency balance) than I do, but the fact that they denied that there were *any* audible differences in the sound of three obviously differentsounding speakers puzzles me to this day. Perhaps something got lost in the translation.

Postscript

About a year later I had an unexpected visitor from Japan. The gentleman had been on assignment in California for the previous month or so setting up a slow-speed recording center for a major Japanese company. Things had gone well, until the question of monitor speakers for the studio came up. It seems that my visitor felt that the "West-Coast" speakers used by so many U.S. studios suffered from excessive colorations that in his view made it impossible to accurately monitor a recording with them. He was in trouble with the home office because he refused to use the "standard" monitors in the studio he had designed.

I was surprised and gratified to encounter a Japanese engineer who seem to hear things the same way I did, and we entered into a wide-ranging discussion about sound preference and sonic accuracy. I mentioned that in our test program we had encountered only one Japanese speaker that tested well and sounded right to our ears. "Yes," said my new friend, "I know of your test report since I designed that speaker, and, incidentally, it was a best seller in Japan!" I was flabbergasted! There should be a lesson in all this—other than that some people, whatever their nationality, can hear and others can't—but I'll be damned if I know what it is. **R-E**



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2716-1	2048x8	350ns (25V)	3.95
27C16	2048x8	450ns (25V) CMOS	4.25
2732	4096x8	450ns (25V)	3.95
2732A-20	4096x8	200ns (21V)	3.95
27C32	4096x8	450ns (25V) CMOS	4.25
2764-25	8192x8	250ns (21V)	3.95
2764A-20	8192x8	200ns (12.5V)	4.19
2764A-25	8192x8	250ns (12.5V)	3.49
27C64-15	8192x8	150ns (12.5V) CMOS	4.95
27128-20	16,384x8	200ns (21V)	5.95
27128-25	16,384x8	250ns (21V)	5.25
27128A-15	16,384x8	150ns (12.5V)	6.95
27128A-20	16,384x8	200ns (12.5V)	4.75
27C128-25	16,384x8	250ns (21V) CMOS	5.95
27256-15	32,768x8	150ns (12.5V)	8.49
27256-20	32,768x8	200ns (12.5V)	5.49
27256-25	32,768x8	250ns (12.5V)	4.95
27C256-15	32,768x8	150ns (12.5V) CMOS	7.25
27C256-25	32,768x8	250ns (12.5V) CMOS	5.49
27512-25	65,536x8	250ns (12.5V)	7.25
27C512-15	65,536x8	150ns (12.5V) CMOS	9.95
27C512-25	65,536x8	250ns (12.5V) CMOS	7.49
27C010-15	131,072x8	150ns (12.5V) CMOS (1 Meg)	19.95
68764	8192x8	64K 450ns (25V) (Chip Enable)	14.95
68766-35	8192x8	64K 350ns (25V) (Output Enable)	15.95

EEPROMS

2816A-25	2048x8	250ns (9V-15V) 5V Read/Write	5.49
2817A	2048x8	350ns 5V Read/Write	6.95
2864A	8192x8	250ns 5V Read/Write (Pin 1, No R/B)	10.95
2865A	8192x8	250ns 5V Read/Write	10.95

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Part No.	Price
6402	3.75
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6520	1.59
6522	2.95
65C22	4.25
6532	4.95
6551	2.69
65C802 (CMOS)	15.95
6800	1.75
6802	2.95
6808	2.49
6810	1.25
6820	2.75
6821	1.75
68B21	2.25
6840	3.49
6845	2.75
6850	1.75
6852	.75
MC68000L8	9.95
MC68000L10	11.95
MC68008P8	8.49
MC68010L10	19.95
MC68020RC12B	59.95
MC68450L10	29.95
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MC68705P3S	15.95
MC68705U3S	17.95
MC68881RC16A	129.95
MC68881RC20A	159.95

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SI3052P	.99
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6526	13.95
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8564	2.95
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8701	9.95
8722	8.95
*82S100PLA**	15.95
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325572-01	17.95
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901226-01	15.95
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901227-03	15.95
901229-05	15.95
901460-03	1.95
901486-06	2.95

*No specs available
**Note: 82S100PLA = U17 (C-64)

74C/CMOS

74C00	.25	74C174	.39
74C02	.25	74C175	.39
74C04	.25	74C192	.99
74C08	.25	74C194	.49
74C10	.19	74C221	1.79
74C14	.49	74C240	.99
74C32	.45	74C244	1.49
74C74	.49	74C373	1.49
74C85	1.29	74C374	1.49
74C86	.29	74C911	5.95
74C89	2.95	74C912	7.95
74C90	.99	74C915	1.19
74C151	1.75	74C917	3.95
74C154	2.95	74C920	3.95
74C157	1.49	74C921	3.95
74C160	.49	74C922	3.95
74C161	.49	74C923	3.95
74C162	.49	74C925	4.95
74C173	.49	74C926	5.95

MISC. COMPONENTS

TANTALUM CAPACITORS

TM.1	.1µf @ 35V	.19	TM4.7	4.7µf @ 35V	.45
TM1	1µf @ 35V	.19	TM6.8	6.8µf @ 35V	.59
TM2.2	2.2µf @ 35V	.25	TM10	10µf @ 35V	.69

POTENTIOMETERS

Values available (insert ohms into space marked "XX"): 500Ω, 1K, 2K, 5K, 10K, 20K, 50K, 100K, 200K, 1MEG

43PXX	3/4 Watt, 15Turn	.99	
63PXX	1/2 Watt, 1Turn	.89	

TRANSISTORS AND DIODES

PN2222	.13	PN2907	.13	1N4004	.10
2N2222A	.29	2N4401	.15	1N4148	.07
2N3055	.69	1N270	.25	1N4735	.25
2N3904	.12	1N751	.15	C106B1	.49

SWITCHES

JMT123	SPDT, On-On	1.25	206-8	SPST, 16-pin DIP	1.19
MPC121	SPDT, On-Off-On	1.25	MS102	SPST, Momentary	.39

D-SUB CONNECTORS

DB25P	Male, 25-pin	.69	DB25S	Female, 25-pin	.75

LEDS

XC209R	T1, Red	.15	XC556G	T1¾, Green	.17
XC556R	T1¾, Red	.13	XC556Y	T1¾, Yellow	.17

IC SOCKETS

Low Profile		Wire Wrap (Gold) Level #2	
8LP	.11	8WW	.49
14LP	.12	14WW	.65
16LP	.13	16WW	.69
24LP	.21	24WW	1.19
28LP	.23	28WW	1.39
40LP	.29	40WW	1.89

Soldertail Standard (Gold & Tin) & Header Plug Sockets Also Available

74HC HI-SPEED CMOS

Part No.	Price	Part No.	Price
74HC00	.19	74HC175	.59
74HC02	.19	74HC221	.89
74HC04	.19	74HC240	.69
74HC08	.19	74HC244	.79
74HC10	.19	74HC245	.79
74HC14	.29	74HC253	.49
74HC30	.25	74HC259	.49
74HC32	.25	74HC273	.49
74HC74	.29	74HC373	.69
74HC75	.35	74HC374	.69
74HC76	.35	74HC595	1.29
74HC85	.55	74HC688	1.49
74HC86	.29	74HC943	6.95
74HC123	.59	74HC4040	.79
74HC125	.49	74HC4049	.29
74HC132	.49	74HC4050	.29
74HC138	.45	74HC4060	.69
74HC139	.39	74HC4511	.99
74HC154	1.49	74HC4514	1.79
74HC163	.39	74HC4538	1.19
74HC174	.59	74HC4543	1.19

74HCT-CMOS TTL

74HCT00	.17	74HCT139	.39
74HCT02	.17	74HCT157	.29
74HCT04	.19	74HCT174	.29
74HCT08	.17	74HCT175	.29
74HCT14	.29	74HCT240	.69
74HCT32	.19	74HCT244	.49
74HCT74	.29	74HCT245	.49
74HCT86	.25	74HCT373	.49
74HCT138	.39	74HCT374	.39

LINEAR

Part No.	1-9	10+	Part No.	1-9	10+
TL071CP	.69	.59	DS14C88N	1.19	1.09
TL072CP	.79	.69	LM1489N	.49	.45
TL074CN	.99	.89	DS14C89N	1.19	1.09
TL081CP	.59	.49	LM1496N	.69	.59
TL082CP	.59	.49	LM1871N	1.95	1.75
TL084CN	.99	.89	LM1872N	1.95	1.75
LM307N	.45	.39	ULN2003A	.79	.69
LM308N	.65	.59	ULN2004A	.79	.69
LM309K	1.49	1.25	26LS29	2.95	2.75
LM310N	1.49	1.25	26LS31	1.19	.99
LM311N	.49	.39	26LS32	1.19	.99
LM317T	.69	.59	26LS33	1.75	1.49
LM318N	1.09	.99	ULN2803A	1.19	.99
LM319N	1.29	1.19	LM2901N	.39	.29
LM323K	3.49	3.25	LM2907N	1.29	1.19
LM324N	.39	.35	LM2917N (8 pin)	1.75	1.49
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LM336Z	1.09	.99	MC3479P	3.95	3.75
LM337T	1.29	1.09	MC3486P	1.29	1.19
LM338K	4.49	4.25	MC3487P	1.29	1.19
LM339N	.49	.39	LM3900N	.49	.45
LF347N	1.49	1.25	LM3905N	1.29	1.19
LM348N	.69	.59	LM3909N	.89	.79
LF351N	.49	.39	LM3914N	1.95	1.75
LF353N	.59	.49	NE5532	.89	.79
LF356N	.89	.79	NE5534	.89	.79
LF357N	.99	.89	7805K	1.29	1.19
LM358N	.59	.49	7812K	1.29	1.19
LM380N	.89	.79	7815K	1.29	1.19
LM385Z1.2	1.75	1.49	7805T	.49	.45
LM386N-3	.89	.79	7812T	.49	.45
LM393N	.45	.39	7815T	.49	.45
LF398N	1.95	1.75	78L08	.35	.29
LF411CN	.79	.69	7905K	1.49	1.25
LF412CN	1.29	1.19	7905T	.55	.49
NE555V	.35	.29	75113	1.39	1.19
XRL555	.75	.65	75150	1.29	1.19
LM556N	.49	.39	75154	1.29	1.19
LM565N	.99	.89	75174	2.95	2.75
LM566CN	1.29	1.19	75175	2.95	2.75
LM567V	.75	.65	75176	2.25	1.95
LM723CN	.49	.39	75451	.45	.39
LM741CN	.35	.29	75452	.45	.39
LM747CN	.59	.49	75492	.89	.79
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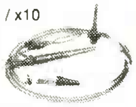

- Attenuation: x1 / x10
- Capacitance (LF180): 180pF / 22pF; (LF210): 40pF / 17pF

LF180 40MHz Oscilloscope Probe **$19.95**
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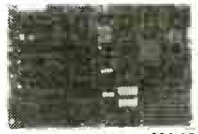
JE3520 Pictured



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TEST EQUIPMENT

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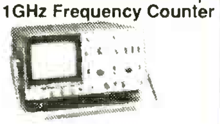

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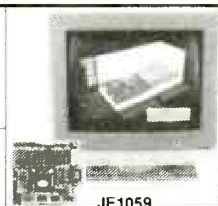

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XY1683

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MPF11 Pictured

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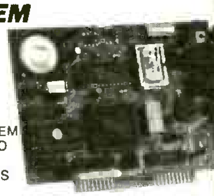

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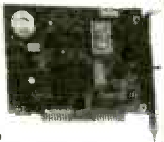

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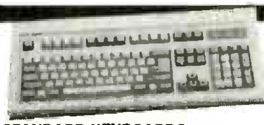
QUALITY KEYBOARDS



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MAX-5060	WITH TACTILE FEEDBACK	$64.95

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MCT-FH	FLOPPY/HARD CONTROLLER	$139.95
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DISPLAY ADAPTOR CARDS:

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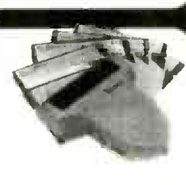

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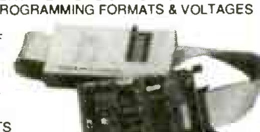

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42.8MB	ST-251-1	28 MS	5-1/4"	$339	$389	$449
65.5MB RLL	ST-277-1	28 MS	5-1/4"	$389	$449	$549
80.2MB	ST-4096	28 MS	5-1/4"	$569	—	$679
122.7MBRLL	ST-4144R	28 MS	5-1/4"	$699	$759	$859
21.4MB	ST-125	40 MS	3-1/2"	$259	$299	$373
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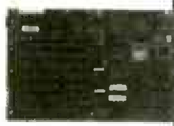

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- AMI BIOS • XT-SIZE BOARD

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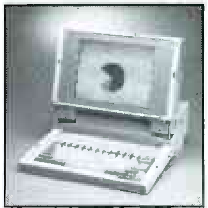

- 80386 32-bit processor, 12/6 MHz (switchable).
- 40 MB (28ms) hard drive.
- One 3.5" 1.4 MB floppy disk drive. • 2 MB RAM.
- 100% IBM compatible.
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- Supports: MS OS/2 version 1.0, Xenix, and Microsoft Windows/386 environments.
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- Socket for 80387 numeric coprocessor.
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- Serial and parallel printer ports.
- Resolution: 640 x 400 pixels.
- 79-key full function detachable keyboard.
- Real time clock and calendar.
- "Fast" charge NiCad battery pack included.
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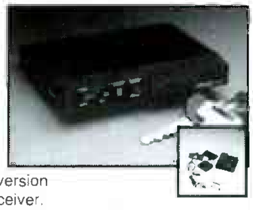

- Instant-on radar gun "pulse" signals and alerts you in 1/10 of a second!
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- Micro-size...only 4-1/2"W x 3-1/4"D x 11/16"H.
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- Intelligent home security system.
- Detects intruder during entry.
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- Difficult to defeat because of new, advanced technology.
- Lamp command flashes lamp upon intrusion.
- Signal relay—relays entry sensor intrusion signal from a remote area of your home to controller.
- Tamper resistant. • 85 decibel alarm on inside siren.
- Piercing 120 decibel outside siren.
- Fail-safe battery back-up. • Low battery warning.
- **2 Year Warranty!**
- **Factory New & Perfect!**

Includes:
- 8 entry sensors, 1 system controller (includes inside siren) 1 signal relay, 1 lamp command, 1 outside siren, 2 window stickers, 1 yard sign, and complete hardware and batteries.

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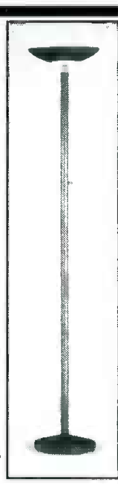
Fill your room with light from this sleek-looking Halogen Torchiere Floor Lamp. It's truly a lamp of the '90s with its stylish modern design and upward position shade.



- Halogen torchiere floor lamp.
- Shines light upward, yet fills entire room.
- Variable light control switch.
- 500 Watt halogen bulb included.
- Sleek, black finish.
- U.L. approved.
- Contemporary design.
- Glass insert below shade allows light to shine downward also—for a complete lighting effect.
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