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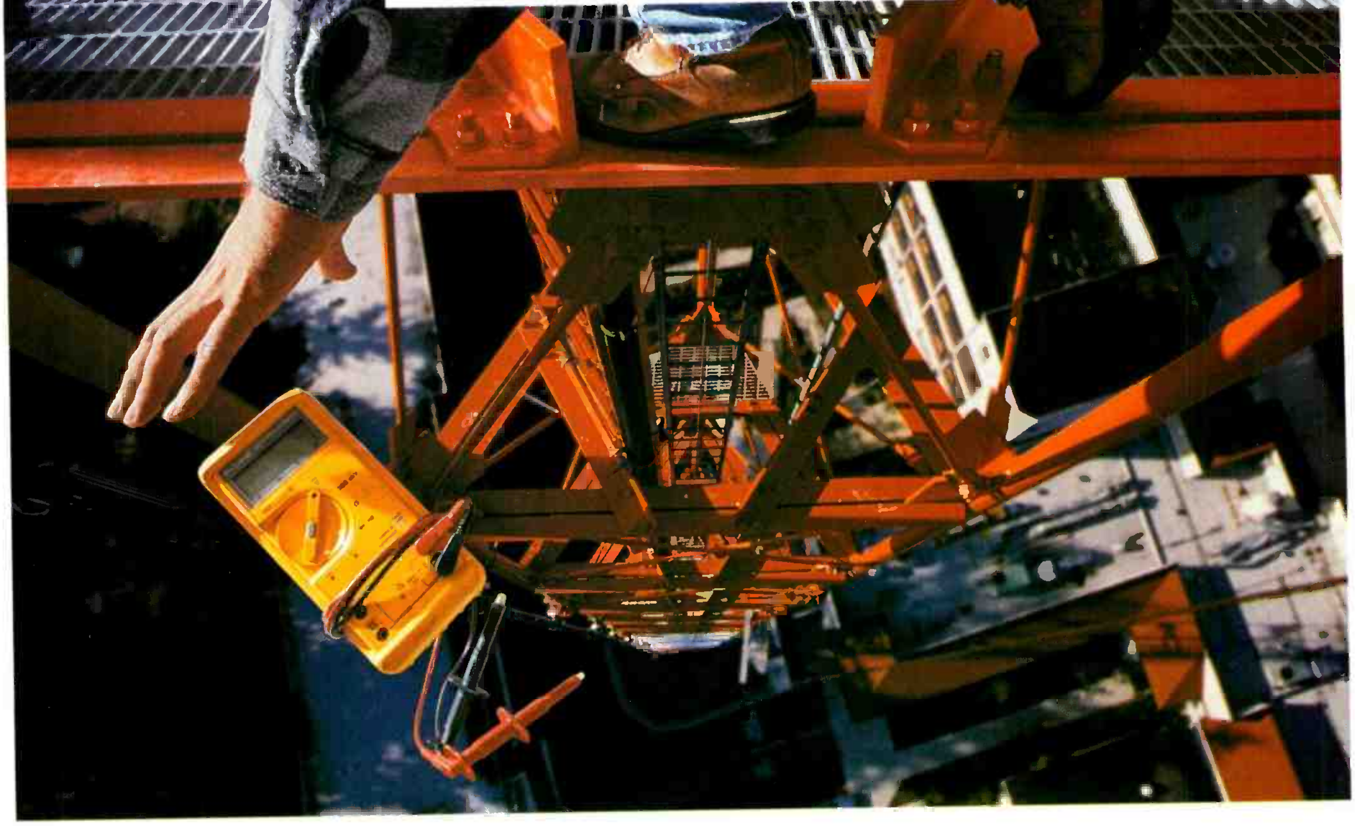

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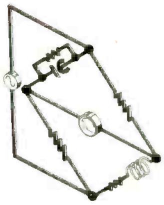

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WHAT'S NEWS

A REVIEW OF THE LATEST HAPPENINGS IN ELECTRONICS

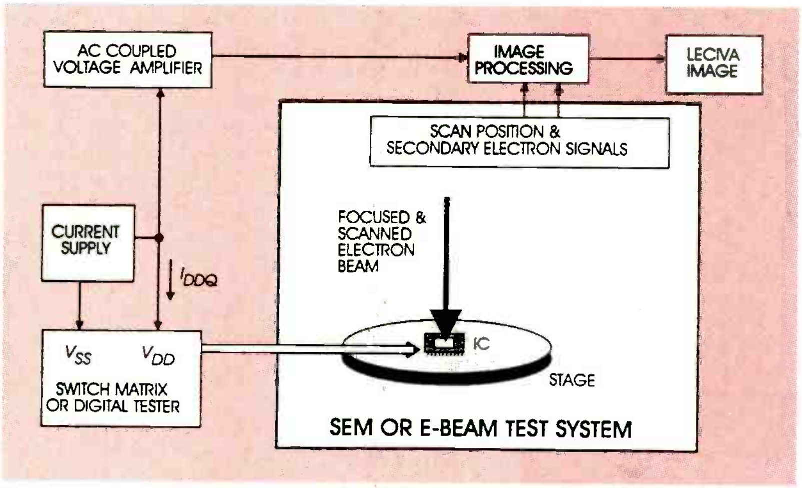
Safely spotting IC defects

A new, nondestructive technique for finding open conductors in integrated circuits with low-energy voltage has been developed by researchers at Sandia National Laboratories, Albuquerque, N.M.. The technique, called LECIVA (for low-energy charge-induced voltage alterations), locates microscopic cracks in IC substrates that break the electrical connections. LECIVA is seen as a method for improving the reliability of ICs, especially as linewidths have become smaller making it more difficult to detect and localize open conductors.

LECIVA is an improved imaging technique based on charge-induced voltage alterations. A scanning electron microscope (SEM) injects a small electric charge at a precise location on an interconnection. If there is an open conductor nearby, a voltage change will occur at the defect location.

As an electron beam is scanned over the device's surface, the voltage fluctuation of a constant-current power supply produces images that are detectable with the SEM. The brightness at a particular spot on the chip is proportional to the voltage required to keep the current constant.

LECIVA simplifies the process of checking for IC defects by removing the risk of damaging the chip with excess radiation. Another advantage to LECIVA is that the low energy level allows it to be performed with commercial electron-beam test systems as well as scanning electron microscopes.



A LOW-ENERGY CHARGE-INDUCED VOLTAGE ALTERATION imaging system from Sandia Laboratories locates defects on ICs without damaging them.

Rough road for electric cars

Hopes for the appearance of an electric cars that would appeal to consumers have yet to be realized despite mandates from three states and the setting of quotas for them. California, New York, and Massachusetts have decreed that by 1998, 2% of the cars sold in those states will be electric powered.

However, the inability of Detroit to build an attractive electric car has led Gov. William Weld of Massachussetts to relax the enforcement of its mandate. Weld said his state will not try to enforce its requirement until two years after someone, somewhere, introduces an acceptable vehicle.

Proponents of the electric car are now discussing the possibility of a "hybrid" vehicle with a small gasoline engine that would recharge the batteries because recharging is a significant problem that must be overcome. This raises the question of whether it is possible to build a small auxiliary gasoline-powered engine for charging purposes that will not, itself, pollute the air.

TV violence-control chip

In July President Clinton called the Nation's attention to the V-chip ("V" stands for violence) that would permit parents to block offensive television programs transmitted with a signal identifying them as containing violent scenes or other programming inappropriate for children.

Semiconductor manufacturers say the technology for making the device is readily available and similar to that for "closed-captioning." Television manufacturers add that the ICs could be installed in television sets for as little as $5. Consequently the possible stumbling block is neither technology nor price to produce such an integrated cir-

Continued on page 82

VIDEO NEWS

WHATS NEW IN THE FAST-CHANGING VIDEO INDUSTRY

BY DAVID LACHENBRUCH

And then there were none

U.S.-owned TV manufacturers, that is. The announcement that control of Zenith Electronics is being sold to Korea's LG Electronics (formerly Goldstar) brought forth an outpouring of nostalgia as the last of its breed became wedded to a global company—following the earlier sale of RCA and GE consumer electronics brands to Thomson of France and the sale of Magnavox to Philips of the Netherlands in earlier years.

From the technological standpoint, at least, the latest wedding is good news. After 10 consecutive years of losses, cash-short Zenith has lacked the funds to capitalize on the skill of its engineers. As a major contributor to the Grand Alliance digital HDTV system, Zenith stands to benefit in the future from the wealth and the technical acumen of its new Korean parent. In recent years, Zenith has had to shelve development work on the flat tension mask (FTM) picture tube because of costs. However, in 1991, when Zenith sold five percent of its stock to LGE, it made a deal to share knowhow on the FTM tube with the Korean company, which has since been working quietly to bring down the cost of this tube. FTM has a completely flat plate glass faceplate, virtually no reflections and the ability to reproduce a picture that resembles a 35-mm slide. Now LGE plans—along with Zenith—to accelerate work on FTM, which initially will be offered as a professional monitor, later as a TV tube if costs are sufficiently reduced.

Matsushita's 'PF' tube

The Zenith-Goldstar FTM tube has a competitor. Just one week before the two companies announced the takeover deal, Matsushita Electric of Japan, the parent of Panasonic, announced that it would begin pilot production of the "Pure Flat" or "PF" tube. Like Zenith's FTM, the PF tube uses a shadow mask mounted under tension and a completely flat faceplate, providing what Matsushita calls a "paper-like" image. The first PF tube applications will be 16- and 20-inch monitors, but Matsushita says it will offer a widescreen TV version in the future. The tube will be well suited for high definition TV, since the flat shadow mask has a very fine pitch—0.24 mm, which Matsushita claims is the finest ever achieved in a color CRT.

Zenith claims to hold the basic patent on the tension shadow mask and it is silent as to whether it has granted a license to Matsushita. However, it is known that the Japanese company consulted Zenith engineers during PF development.

Sony's Plasmatron

For a truly flat tube, Sony says it will offer its "Plasmatron" wall-hanging TV next year to mark its 50th anniversary. Developed by Tektronix with input from Sony, Plasmatron combines the principles of plasma and liquid crystal displays. Unlike conventional plasma displays which use gas discharge to provide the light source, Plasmatron uses gas discharge as an electrical on/off switch, with an external backlight for illumination. The plasma switching turns the LCD pixels on and off, passing or blocking the light. The display has a horizontal plasma channel for each scanning line—about 450 lines for an NTSC picture.

Sony says Plasmatron can be made in sizes from 20 to 50 inches, and the panels, which measure only 0.15 inch thick, can be made relatively cheaply. The company displayed a prototype widescreen 25-inch TV measuring three inches in overall depth, weighing about 3-3/4 pounds. The second model will have a 40-inch screen. Sony declines to estimate the price of the Plasmatron TV, but an official noted that it would be introduced as a home product, in the consumer price range. Sony said the tube can be produced inexpensively, with high yields and provides a picture with high brightness and contrast.

TV Via phone line

Terk Technologies has taken out a license under a package of six patents granted to Inline Connection Corp. of Arlington, VA. Inline's seemingly impossible feat of squeezing television and hi-fi audio signals into a standard phone line is based on the fact that the video output of a VCR or satellite receiver is relatively strong, compared with the signal needed for the antenna input of a TV set. While a high frequency signal introduced into a twisted-pair telephone line is quickly attenuated, enough of the strong signal remains over a relatively short line to fall within the tolerance range of a TV's antenna input. Field tests have shown that claer pictures and undistorted sound can be sent through about 300 feet of home telephone wiring. EN

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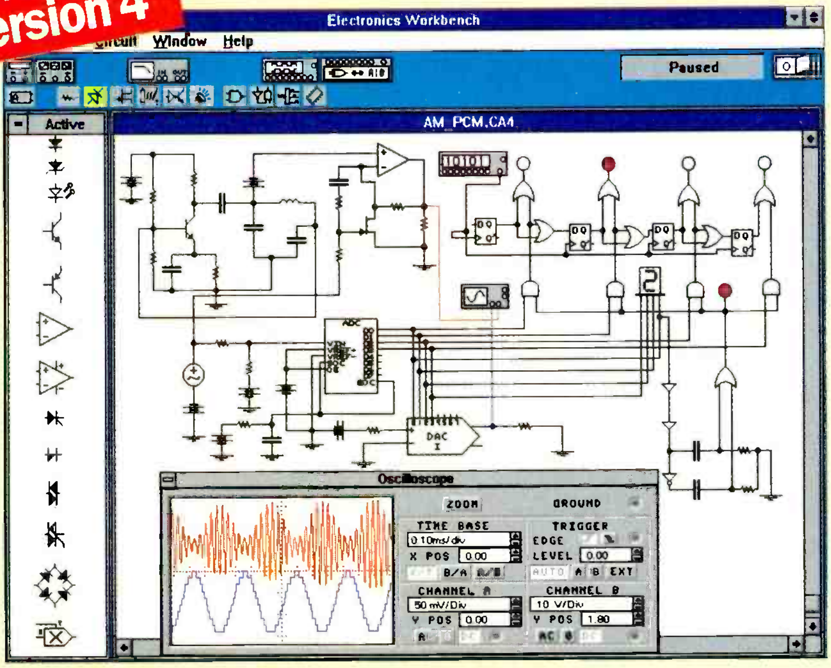

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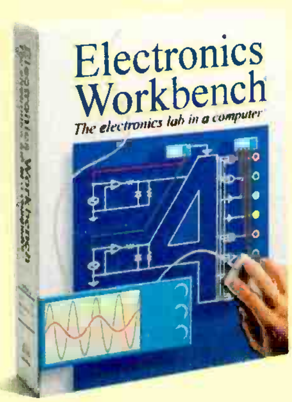

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Q & A

READERS QUESTIONS, EDITORS ANSWERS

Capacitor Dot Code

I repair TVs and radios and have occasionally come across capacitors that use a dot code to indicate their value. I've been unable to find a listing of these dot codes in any of the data books I have and I'm not even sure if this method of marking capacitor values is used any longer. How do you read the capacitor dot codes?—A. Brownstone, Philadelphia, PA

I haven't seen dot codes used in years but fortunately I never throw anything out. This information was sent by W. Saliba of Middleton, MA and you should save it because I don't know where else you'll be able to find it.

There were two dot codes used: a three-dot and a six-dot system. Since the former is only a subset of the latter, I'm listing only the six-dot system. The EIA introduced this system for mica capacitors and if you see only three dots, the capacitor is understood to be rated at 500 volts DC with a +/- 20% tolerance.

The complete dot code is shown in Fig. 1. You'll most likely see this kind of coding only in old radios and other vintage equipment. A similar marking system was also used for inductors but I haven't been able to find it anywhere.

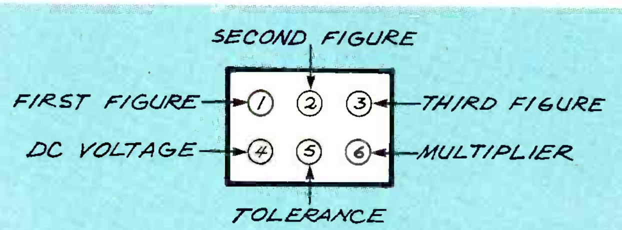
Password Swap

We have a problem with a small Novell network in our office. The network is working but someone inadvertently changed the supervisor's password, so we can't make any changes to the network. Is there any way to get the supervisor's password back without re-installing the entire network?—G. Fisch, Nehap, NY

It's inconceivable to me that someone could change the supervisor's password inadvertently—It's just not that easy to do. In any event, all is not lost because there are a few options. All rights and passwords are kept in the network's bindery which is made up of three files located in the SYSTEM directory on the file server. These are NET$VAL.SYS, NET$PROP.SYS, and NET$OBJ.SYS. Novell marks these files as transactional so there's no way you can do anything to them from a workstation.

A backup that was made before the supervisor's password was changed isn't enough. You won't be able to restore the bindery files because you need supervisory privileges to do so. The only way to get around this problem is to back up all the current data, then destroy all of the data on the server, reinstall the network starting with the backup that was made with the correct password, and then restore the newly saved data. Once this is done you can log in as a supervisor and restore the rights and passwords from your pre-problem backup.

If you don't have a backup containing the correct passwords, there are still two ways you can solve the problem. The first way is to back up the current data, rebuild the network, and then restore the data. You'll have to recreate the groups and users by hand but if your network is small enough, that isn't too difficult. The second method is a lot "sneakier", with access to the file server, it's a lot faster,too.



COLOR	FIGURE	MULTIPLIER	VOLTS	TOLERANCE
BLACK	0	1	—	—
BROWN	1	10	100	1%
RED	2	100	200	2%
ORANGE	3	1000	300	3%
YELLOW	4	10,000	400	4%
GREEN	5	100,000	500	—
BLUE	6	1,000,000	600	6%
VIOLET	7	10,000,000	700	7 %
GRAY	8	100,000,000	800	8%
WHITE	9	1,000,000,000	900	9%
GOLD	–	0.1	1,000	5%
SILVER	–	0.01	2,000	10 %
NO COLOR	–	—	500	20%

FIG. 1—CAPACITOR DOT-CODE SYSTEM. If you see only three dots, the capacitor is understood to be rated at 500 volts DC with a +/– 20% tolerance.

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Reboot the server from a DOS boot floppy and use a disk editor to search for the Novell directory on the server's hard drive. Tools that allow this come with the Norton Utilities, PC Tools, and other utility packages. Search for the string "NET$" to locate the directory entries for the bindery. Be sure that you get to the directory. A few hits will be found near the beginning of the disk because there are some text files on the small DOS partition that contain the same string.

Once you've located the directory entries, change the names of the bindery files from ".SYS" to ".OLD." The Novell Netware operating system maintains two copies of the server directory, so you'll have to change a total of six file names. If you don't change all of them you'll get an error when you try to reboot the server.

After you've changed the names of the bindery files, reboot the file server. When Netware sees that there's no bindery, it will create a new one with just a supervisor and guest as users. Log in as the supervisor (no password needed), and run BINDFIX.EXE. This will rename the .OLD files from the original bindery to .SYS making them the current bindery.

The supervisor's password will now be the unknown one again, but since you're logged in as the supervisor, you'll be able to run SYSCON.EXE and change the supervisor's password to whatever you want. You shouldn't attempt this procedure unless you're familiar with using a disk editor, have done a current backup, and have experience doing network maintenance. Although this procedure can fix the network if it's done properly. it can also totally mess it up. If you're not 100% sure you can do this, hire someone who can.

NPN Dilemma

I am having a problem in trying to use a transistor as a switch in a circuit. I'm using an NPN transistor and it always inverts the signal at the base. Is there a simple way for me to get it to the voltage I need?—E. Greenberg, Los Angeles, CA

Transistor switches are standard components in any designer's arsenal. As you can see in Fig. 2, the sense of the signal from an NPN transistor depends on where you take the output from. The standard way to do this, and the one you've obviously used, is to take the signal from the collector. This will invert the signal from the

Continued on page 51

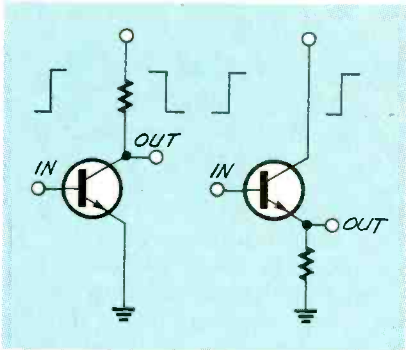

FIG. 2—THE SENSE OF THE SIGNAL from an NPN transistor depends on where you take the output from. If you take the signal from the collector, the signal at the base will be inverted. If you take the signal from the emitter, the output will have the

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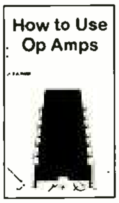

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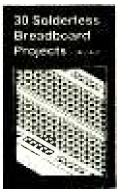

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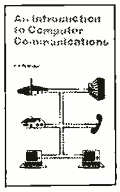

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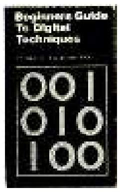

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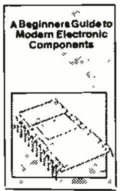
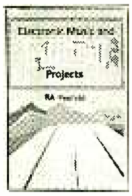


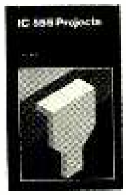
☐ **BP285—A Beginners Guide to Modern Electronics Components... $6.50.** It is easy for newcomers to electronics to become confused. There are a great many different types of components available often with numerous variations of each type. This book presents the reader with a vast amount of invaluable parts information to enable the right component to be selected every time for repairs and projects.

☐ **PCP103—Practical MIDI Handbook...$9.95.** The Musical Instrument Digital Interface (MIDI) is surrounded by a great deal of misunderstanding. This book is aimed at musicians and technicians who want to explore the vast capabilities of MIDI. It covers MIDI-based equipment you can use: keyboards, drum machines, sequencers, effects units, mixers, drum pads guitars. There's also a section on computer music.

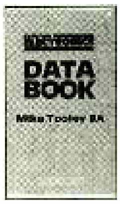


☐ **PCP119—Electronic Music and MIDI Projects...$14.95.** Save cash by building the MIDI gadgets you need. Want a MIDI Thru box, program change pedal, Metronome, analog echo unit? Over 16 practical and very useful music and MIDI projects.

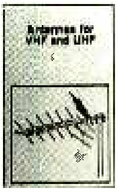
☐ **BP121—How to Design and Make Your Own PCBs...$5.75.** Simple methods for copying printed-circuit board designs from magazines and books on to copper. Covers all aspects of simple PCB construction as comprehensively as possible.



☐ **BP44—IC 555 Projects...$5.95.** Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer integrated-circuit chip is one such device. Included are basic and general circuits used by most hobbyists.



☐ **PCP109—Everyday Electronics Data Book ... $10.00.** An invaluable source of electronics information—the text contains sections that deal with the underlying theory of electronic circuits and a wide range of practical electronic uses for everyone.



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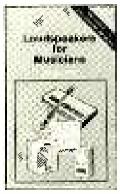
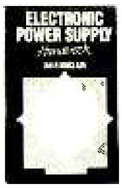
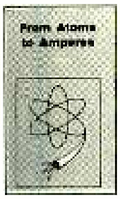


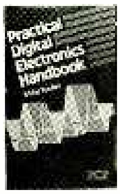
☐ **BP297—Loudspeakers for Musicians...$6.25.** Contains all the information that a working musician needs to know about loudspeakers; the different types, how they work, the most suitable for different instruments, for cabaret work, and for vocals. It gives tips on constructing cabinets, wiring up, available fittings, finishing and how to connect multi-speaker arrays, etc. Includes ten enclosure designs with plans.



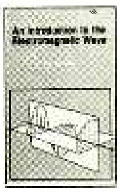
☐ **PCP110—Electronic Power Supply Handbook...$10.95.** All types of power supplies used for electronics purposes are covered in detail, starting with cells and batteries and extending by way of rectified supplies and linear stabilizers to modern switch-mode systems, IC switch-mode regulators, DC-converters and inverters. The devices, their operating principles and typical circuits, are dealt with in detail.



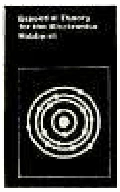
☐ **BP254—From Atoms to Amperes... $6.50.** Explains in crystal-clear terms the fundamentals behind the whole of electricity and electronics. Really helps you to understand the basis of the complex subject perhaps for the first time ever.



☐ **PCP101—Practical Digital Electronics Handbook...$9.95.** An introduction to digital circuits, logic gates, bi-stables, timers, microprocessors, memory and I/O devices. A special feature of the book is the section on digital test gear projects.



☐ **BP315—Introduction to the Electromagnetic Wave...$5.95.** A fundamental and easy-to-understand approach to a complicated theory topic. The beginner requires no more than elementary mathematics and basic knowledge of electronics.



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The ultimate guide to replacing foreign and domestic transistors.

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LETTERS

SEND YOUR COMMENTS TO THE EDITORS OF ELECTRONICS NOW MAGAZINE

POWER CONTROL CIRCUIT CORRECTIONS

Some errors were introduced in the figures of "Power Control Circuits" (Electronics Now, June 1995). In Fig. 3, the collector of Q2 collector should be wired to the junction of diodes D1 and D2, and in Fig. 4, the polarity of diode D5 has been reversed.

In Fig. 5, transformer T1's secondary voltage value of 6.3 volts was omitted, and the emitter of transistor Q1 is incorrectly shown connected directly to the "hot" side of the AC power line. It should be connected to the isolated, low-voltage point at the top of resistor R1. —Ray Marston

LASER TURNTABLE

In the July 1995 "Q&A" column, reader John Leahy asked if a laser-based phonograph was available. Q&A correctly mentioned the publicity surrounding the Finial laser turntable and the fact that it failed to reach the market in the late 1980s. You might be interested in knowing that the story didn't end there.

When the U.S.-based manufacturer was unable to make the product economically so that it could be sold at an attractive price, the developers took the prototype to Japan. They found a small Japanese specialty manufacturer willing to make it. The laser turntable is now in limited production, and is available from a Japanese company called ELP.

The turntable is made in two versions: The LT-1L plays 33- and 45-rpm records, and the enhanced LT-1X can also play a broad range of 78-rpm records. The LT-1X also has an outboard equalization box for the many recording "standards" that were used in the early days of recording. The turntable will play only black records—not those that have colors or pictures.

The LT-1L is priced in Japan at 2.1-million yen (about $25,000 US), and the LT-1X is priced at 3-million yen, or $35,000. However, before Mr. Leahy becomes too discouraged, I suggest that he contact Andy Obst, 5 Timberline Ridge, Los Alamos, NM 87544. He is in contact with ELP and can assist in the importation of a laser turntable at a reasonable price.

STEVEN L. SETO
Chesterfield, MO

LEAD-ACID BATTERY SELF-DISCHARGE

I have read about several solutions to the problem of self discharge of a lead-acid battery when it is stored on a cold concrete surface in this column ("Q&A," *Electronics Now*, April 1995). All of them are wrong! The solution to the problem is a simple method for circulating the electrolyte.

My knowledge of battery self discharge under the conditions discussed in the article is based on several years of work with submarine storage batteries.

Self discharge of batteries is caused by temperature gradients in the battery electrolyte and is called *electrolyte stratification.* When a battery is stored on a cold surface, the lower parts of the cells are cooled to a temperature that is lower than the upper parts. That temperature differential causes a drop of the specific gravity of the cooler part of the cells at the rate of 0.004 points of gravity per 100° F of temperature change above or below 80° F.

The voltage produced by a cell is proportional to the specific gravity of the electrolyte. This difference of specific gravity between the top and bottom of a cell results in a potential difference that is proportional to the specific gravities of the two parts of the cell.

An electrical current will flow between any differences in electrical potentials, so a current will circulate through the cell plates from the top to the bottom of the cell. Those currents will persist as long as a temperature differential exists, and they can be enough to discharge the battery over time, as if it were connected to a constant load.

Devices called percolator tubes inside the cells controlled that condition in submarine storage batteries (where the steel hull immersed in ocean water provides a massive heatsink). A stream of air bubbles passed through the percolator tubes circulated electrolyte from the bottom to the top of the cells, maintaining constant specific gravity of the electrolyte.

FARNHAM M. CORNIA
Toledo, WA

Write To:
Letters,
Electronics Now Magazine,
500 Bi-County Blvd.,
Farmingdale, NY 11735

Due to the volume of mail we receive, not all letters can be answered personally. All letters are subject to editing for clarity and length.

RESISTOR RATINGS

Bill Stiles' letter (*Electronics Now*, June 1995) illustrates the practical benefits for readers of the circuits and projects published in *Electronics Now*. However, one item that caught my eye in that issue was the DPM design with a high range of 2000 volts DC.

Anyone building a high voltage voltmeter must be aware that resistors have maximum voltage ratings based on the flashover voltage limit of the resistance element. That value is not the same as the maximum voltage which relates to rated power dissipation (E^2/R), because it is limited by case size rather than by its value.

TABLE–1
STANDARD RESISTOR VALUES

Type	Code	Rating (Watts)	Volts Max.	Volts Derate
Metal Film	RN55	1/10	200	160
	RN60	1/8	250	200
	RN65	1/4	300	240
	RN70	1/2	350	280
Carbon Film	RC05	1/8	150	120
	RC07	1/4	250	200
	RC20	1/2	350	280
	RC32	1.0	500	400
	RC42	2.0	500	400

Thus, the voltage divider for the high-voltage ranges might require many series resistors to prevent the voltage rating of each individual resistor from being exceeded when making measurements.

The maximum voltage ratings of carbon and metal film resistors are listed in Table 1. For safety's sake, those numbers should be derated by a factor of 0.8 (i.e., limit a 200-volt resistor to 160 volts). Table 1 shows that to build a 2000-volt DC DPM with ¼-watt, 1% metal-film resistors, the high-voltage divider should be made up of 10 series resistors:

2000 volts DC/200 volts per resistor = 10 resistors.

Also for product safety, a low leakage current Zener diode should be placed across the input leads of the DPM. If the ground-side resistor of the high-voltage divider opened without the Zener diode there, full voltage would appear across the DPM's input.

CHARLES HANSEN
Tinton Falls, NJ

THE DEMISE OF SWEEP ALIGNMENT

I'd like to offer a more precise answer to the question, "Sweep Alignment A Lost Art?" in the June 1995 "Q&A."

Sweep alignment died because of the introduction and rapid acceptance of the *surface acoustic wave* (SAW) filter more than 20 years ago. Developed for the communications, SAW filters gained wide acceptance in television receivers because they offer precise bandwidth and can't be adjusted. If the device is out-of-limits, you simply replace it.

The SAW filter is based on piezoelectric principles. If a signal is applied to an input section on a piezoelectric crystal substrate (made from such materials as lithium niobate or quartz), a surface wave will propagate across the substrate and be picked up by an output section at the other end of the material.

A SAW substrate is typically about 0.15-inch square. By carefully controlling the length and spacing (weighting) of the input and output sections, a filter with the desired bandwidth is produced.

DOUGLAS L. MOORE
Oklahoma City, OK

LASER SHOW ENHANCEMENTS

In reference to the article "Laser Light Show" (*Electronics Now*, April 1995), Omega offers several enhancements for the project. The number of images available can be quadrupled by adding DPDT polarity-reversing switches for any two of the motors.

The addition of specialized laser-optical elements for the passage of the image before, between, or after the mirrors will add image multiplication, diffusion, blurring or amorphousness, and other effects. Effective elements include diffraction gratings, nebulizers, and lumia.

Since 1978, Omega has offered two kits containing these optical elements for laser light-show experimenters.

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EQUIPMENT REPORTS

FIELDPIECE HS24K15 STICK METER FIELDPACK.

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CIRCLE 15 ON FREE INFORMATION CARD

Field service technicians require test equipment that's specially designed for making measurements on the go. The equipment should be as light as possible, yet afford plenty of versatility. It should be designed to make troubleshooting as convenient out in the field as it would be at a test bench.

Fieldpiece Instruments, Inc. (231 E. Imperial Highway Suite 250, Fullerton, CA 92635, 714-992-1239) specializes in manufacturing multimeters and accessories that cater to field use. In particular, the *HS24* Stick Meter has a logic-probe design that is extremely versatile and makes it easier to do troubleshooting without the benefit of a test bench. Especially convenient is Fieldpiece's *HS24K15* Nylon Fieldpack, which contains the HS24 meter and four accessories in a convenient nylon carrying case.

The HS24 Stick Meter is housed in a rugged yellow plastic case with two input jacks on one end that are normally used for test leads or probe tips. Four head-like attachments included with the HS24K15 kit slide onto the end of the meter and adapt it for new functions.

The *ACH* current clamp head slides onto the meter and lets it inductively measure up to 300 amperes AC. The *ARH1* relative humidity head lets the meter directly measure relative humidity from 10% to 95% RH. The *ATH3* temperature head has switchable inputs for two K-type thermocouples and lets the meter display from −50 to 1800° F. The *AUA1* microamp head lets the meter measure current in microamperes. The stick meter and all mentioned attachments, plus all necessary test leads and accessories in a nylon carrying case costs $418. All items are also available separately.

The Fieldpack

Most readers can probably relate to the following situation: You have to measure a voltage with a standard multimeter and there's no convenient flat surface around to rest the meter on. Finally you locate a spot where the meter will rest only to find that the test leads don't reach where you want them to. After a bit more juggling you get the leads to reach only to realize that you can't see the display on the meter when you hold the probes in position. Clearly, something other than a regular DMM would be more ideal for troubleshooting in awkward locations.

Fieldpiece's HS24 Stick Meter is a more ideal instrument for field use than a common DMM. The HS24 is a $3^1/_2$-digit multimeter that can measure AC and DC volts, resistance, capacitance, check diodes, and perform audible continuity tests. There are four AC voltage ranges of 200 millivolts, 2000 millivolts, 200 volts, and 750 volts. There are three DC voltage ranges of 200 millivolts, 2000 millivolts, and 200 volts. There are two resistance ranges of 200 ohms and 200 kilohms, and one capacitance range of 200 microfarads. The meter is shaped more like a logic probe or a skinny remote control than a DMM. It fits comfortably in one hand, and the single rotary control and two pushbuttons—hold and reset—can be operated easily with the thumb. It is powered by a 9-volt battery.

The top end of the HS24 has two input jacks for either special probe-type tips or standard test leads. The most convenient setup for field use, however, is where a test lead with an alligator clip on the end connects to common and a probe-type tip is used for the hot input. That way the ground lead is attached to a convenient location and the meter is used like a logic probe to make measurements. With the meter in your hand right where a measurement is being made, the display is always easy to see.

The jaws of the ACH current clamp open to accommodate a single conductor of up to 23 millimeters in diameter. The head inductively measures AC amperes and converts them to millivolts AC. It slides onto the end of the stick meter, which must be set to one of its two millivolt AC ranges. The current clamp head lets the meter display up to 300 amperes AC at a frequency between 40 and 500 hertz.

The ARH1 relative humidity head converts relative humidity percent to millivolts DC. A black plastic tube with a semiconductor humidity sensor built in is mounted on the end of the

THE RELATIVE HUMIDITY HEAD is one of the more interesting stick meter attachments

humidity head. With the stick meter set to its 200-millivolt DC range, and the relative humidity head attached, the meter will directly display relative humidity from 10% to 95% RH. The relative humidity head contains its own 9-volt battery.

The ATH3 temperature head converts temperature to millivolts DC. The head has switchable inputs for two K-type thermocouples included with the HS24K15 set. A three-position switch makes the stick meter, set to a millivolt DC range, display either the T1 thermocouple input temperature, the T2 input, or a ΔT display that shows the difference between the two temperature inputs. The temperature head has a conversion range from −50 to 1800° F. Two externally accessible potentiometers allow the two temperature inputs to be calibrated simply by placing the thermocouple tips in ice water and setting the display to read 32. The temperature head also contains a 9-volt battery.

The AUA1 microamp head converts microamperes DC to millivolts DC. It works with the stick meter set to its 200-millivolt DC range. The microamp head has two input leads with spade lugs on the ends for connections to other circuitry.

The HS24K15 kit comes with all necessary test leads, two K-type thermocouples, and a rugged nylon carrying case.

With a price of $418 for the entire kit, the HS24K15 is a good value especially when compared with what it would cost if all items were purchased individually. And the $418 buys quite a bit of testing capabilities. Field service technicians, especially those who work in the heating ventilation and air conditioning (HVAC) industry, will find the set extremely useful. EN

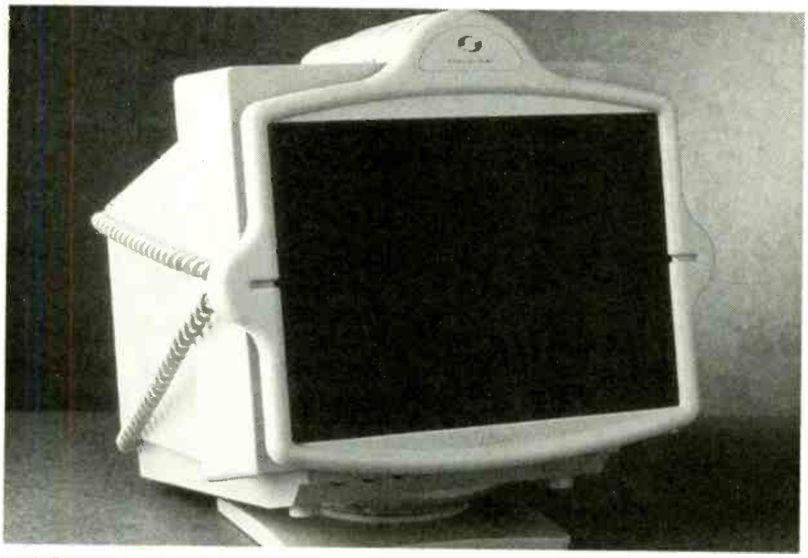
NEW PRODUCTS

USE THE FREE INFORMATION CARD FOR FAST RESPONSE

RADIATION-PROTECTION/ANTI-GLARE SCREEN

THE KEMMA RPS (RADIATion Protection System) monitor screen from Connectware, Inc. is intended to protect computer users from the possible health hazards of very low frequency (VLF) electrical and magnetic fields.

screen controls radiation emissions by sensing the monitor's magnetic signature and responding to it. The magnetic field from the monitor's deflection coils is canceled. After adjustment for specific monitor's topology, the radiation-protection



CIRCLE 20 ON FREE INFORMATION CARD

The Kemma screen is based on a proprietary, active magnetic canceling principle that is said to reduce the magnetic field around a computer monitor. The manufacturer claims that the product is an improvement over standard anti-glare screens that block electrical fields but do not screen out magnetic fields. Its claim is based on tests of the screen conducted in Sweden. VLF magnetic radiation was reduced by 85% at a distance of 24 inches from the screen and by up to 99% 40 inches away.

The screen can be installed easily over 14- and 15-inch monitors. Electronic circuitry at the top of the screen adapts automatically to video mode changes.

The Kemma RPS screen is priced at $199.00

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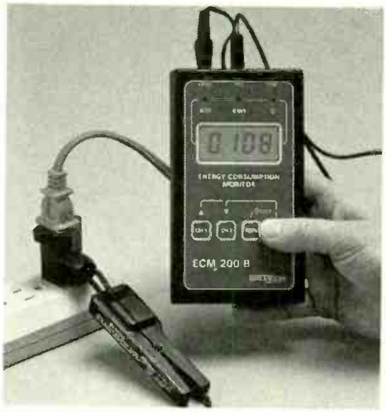
POWER CONSUMPTION MONITOR

THE ECM-200 POWER CONsumption monitor from Jensen Tools provides a safe, and reliable



CIRCLE 21 ON FREE INFORMATION CARD

way to determine AC electrical power consumption. It can locate abnormal energy-consuming products, detect overloaded circuits, and identify equipment that should be repaired.

The monitor has probes that clamp around the insulation of a cable to sense a fraction of the voltage being monitored. If local electricity unit cost per kilowatt-hour is entered, the ECM-200 displays incremental costs of power consumed, total time the load has been monitored, the kilowatt hours consumed, and instantaneous power in kilowatts.

The monitor is based on the same method employed by utilities to compute consumption values. It provides a readout of "true power" rather than "apparent power." An optional clamp-on probe allows 240-volt power or a second cable to be monitored.

The ECM-200 with a monitor, clamp-on probe, wall-outlet adapter, AC adapter, and manual, all in a case, is priced at $349.00.

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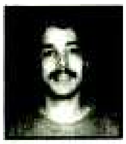

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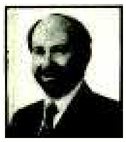

"CIE was recommended to me by my boss. It was appealing since I could study at my own pace at home and during business travel."
Dan Parks
Marketing Manager/Consumer Products
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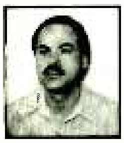

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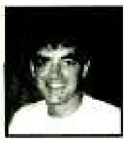

"I liked the way the school was set up with laboratory assignments to enforce conceptual learning. The thing which impressed me the most about CIE's curriculum is the way they show application for all the theory that is presented."
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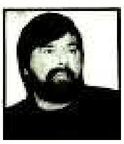
Missile Electro-Mechanical Technician
U.S. Air Force



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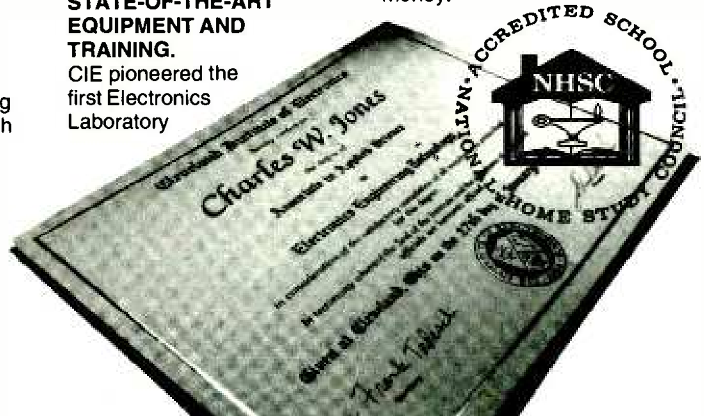

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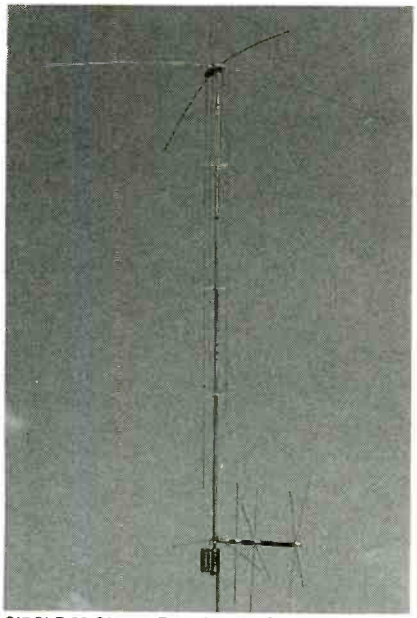
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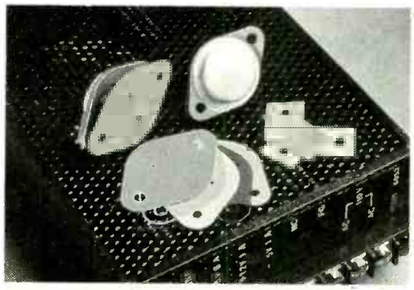
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The insulators are shipped loose or on rolls with thermally conductive, pressure-sensitive adhesive backing. They are thin enough so that they add little to component height.

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THE FLASHLITE SBC SINGLE-BOARD computer from JK Microsystems is a computer board that offers DOS pre-loaded in flash-memory. Intended as an embeded computer, the SBC board can be programmed in languages such as QuickBASIC or Tiny Basic, making it a suitable development platform. Any assembler or compiler that generates DOS-compatible EXE or COM files is suitable for firmware development.

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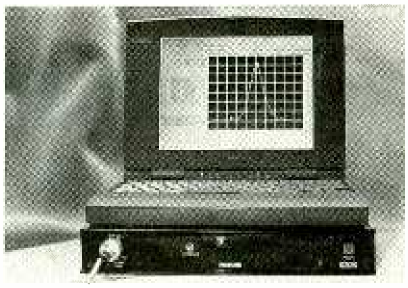

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The Flashlite SBC is $195.00.

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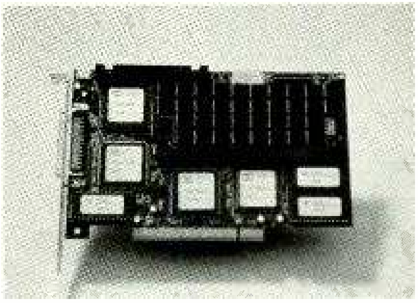

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The SCA-6520 caching adapter card with a user's manual, installation software, SCSI cable, full O/S drivers, and a copy of Corel SCSI is priced at $399.00

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Continued on page 83

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NEW LITERATURE

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The Quantum Dot: A Journey into the Future of Microelectronics

by Richard Turton.
Oxford University Press
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Turton's book provides a clear look at the science and engineering behind today's high-density microelectronics devices. The author explains the evolution of the integrated circuit by starting with a primer on atoms and electrons, and then going into a discussion of the properties of semiconductor materials. Finally he explains the role of the transistor as a discrete device and its place as the building block of most integrated circuits. You'll also learn how transistors and other circuitry are integrated into various semiconductor wafers.

Turton explains how more functions are being packed on a minuscule silicon chips that are smaller than a fingernail by ever finer photolithographic processes. He then takes the reader through an overview of the modern global microelectronics industry and its mutual interdependency, commenting on the latest semiconductor substrate materials and techniques. As an aside, he discusses the technology behind the latest superconducting materials whose resistance values disappear at temperatures that are getting closer to room temperature.

The book offers an intriguing glimpse into the future of microelectronics, explaining the relevance of quantum theory and how physical events at micrometer scale contradict intuitive perceptions. Turton explains some of the alternatives to the transistor and how they take advantage of quantum effects in incredibly small and fast devices. You will learn about "designer atoms" and the "quantum dot."

The author predicts the development of devices whose operation will depend on the electron's wave rather than particle characteristics and photonic computers that perform data manipulation, storage and transmission with light beams.

The Downloader's Companion for Windows

by Scott Meyers and Catherine Pinch.
Prentice Hall PTR
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This book and diskette package tells you all you need to know about downloading computer files and getting the most out of them. It includes all the software you will need to download files quickly with an easy-to-use Windows interface. Files that can be downloaded are usually in a form that are not compatible with your computer. They could be compressed, archived, encoded, or possibly all three. This book and diskette will help you translate both text and graphics files into usable formats.

The book includes valuable insider tips that will save the reader expensive on-line time that could be wasted by fiddling with trial and error methods for downloading files. The disk contains software such as WinZip, a compression/uncompression program that works with most common archive formats.

The package also provides quick-file viewers and instructions for accessing files in several formats. For pictures they include GIF, JPEG, BMP, and TGA, for sounds and music they include WAV, VOC, and AU, and for movies you get MPEG.

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This full-color catalog describes a wide assortment of CD-ROMs available from Walnut Creek for most computer operating systems. These include Windows, DOS, Unix, Mac, and OS/2. Many of the CD-ROMs are also BBS-ready. Among the titles offered are the QRZ! Ham Radio CD-ROM, with more than 643,000 names, addresses, and call signs, The Scientific and Technical Library, Hobbes OS/2 Archived, Ready to Run; animations and pictures, and the Space Shuttle Encyclopedia. The catalog includes a free offer of a CD-ROM that contains samples of Walnut Creek's CD-ROMs.

Electrical & Electronic Principles, Volume 2

by Christopher R. Robertson.
Chapman and Hall,
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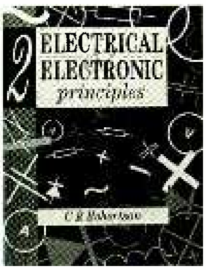
41st Floor, New York, NY 10119;
$22.50



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This textbook is the second volume of a two-volume course on the principles of electricity and electronics. Both volumes are intended to give students of science and engineering a firm foundation for further study and understanding of electrical and electronic devices and systems. Both volumes can serve as a valuable reference for review. The two volumes combine to form a complete set of course notes.

Among the many topics covered in Volume 2 are DC transients, single- and three-phase AC circuits, network theorems, attenuators, AC and DC machines, measurements and measuring instruments, control principles, data transmission, and modulation techniques. Most chapters contain examples that illustrate applications of the theory introduced, and they highlight specific principles. Questions at the ends of the chapters are intended to challenge the reader's understanding of the text in the chapter. Most of the questions call for mathematical solutions and, as an aid to the student, the answers appear at the end of each volume.

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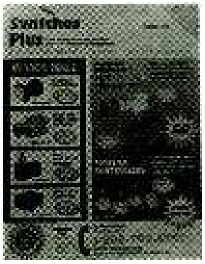

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This latest catalog from Switches Plus presents the company's complete line of snap-acting switches, joystick controllers, flush-mounted pushbuttons, pulse counters, and power supplies. Other products listed include heavy-duty oil-tight and waterproof industrial-grade switches, pilot lights, tools, and accessories.

Switches Plus products have Underwriters Laboratories and international approvals, including ISO 9001 certification. The catalog includes ordering information, product descriptions, illustrations, technical specifications, and pricing.

The Visual Guide to Visual C++

by Nancy Nicolaisen.
Ventana Press
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Chapel Hill, NC 27515
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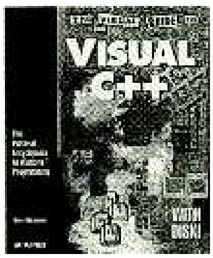

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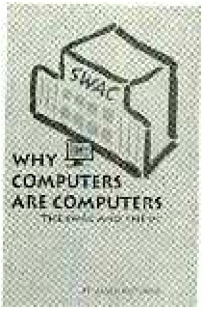
This book and its companion diskette is a guide to the development of applications for 32-bit computers. It includes an introduction to AppWizard, a tour of the resource editors, a cookbook of code examples, and a comprehensive reference to Microsoft Foundation Classes (MFCs). Photographs of computer screens and step-by-step examples will steer the reader through the complexities of Visual C++.

An in-depth examination of MFC 3.0, including useful examples, is included. A complete description of the member functions within each class will help the reader to gain functional literacy in this software. Nicolaisen has included tips on when to use the functions, traps to avoid, and code examples to demonstrate the use of code.

The book explains meaning, appropriate use, and possible value for all public data members. The companion disk contains all the programming examples from the book. This will save the users' time and help them to avoid errors.

Why Computers are Computers: The SWAC and the PC

by David Rutland.
Wren Publishers
P.O. Box 1084
Philomath, OR 97370
Phone: 502-929-4498
Fax: 503-757-0693
$24.95



CIRCLE 343 ON FREE INFORMATION CARD

David Rutland has written a basic book on computers that answers many questions that readers might have on the subject. He explains, among other things, how computers can perform so many different functions, the meaning of bits and bytes, and why computers are not patented, and the concept of the "stored program" computer. Other topics that are covered in the book include computer languages, the operating system and applications software.

The author was an engineer on the SWAC computer project at the University of California at Los Angeles in 1950. With 2700 vacuum tubes and weighing over a ton, SWAC was an evolutionary advancement over the University of Pennsylvania's ENIAC. From that perspective, Rutland looks backwards to explain how calculations were made before computers. With amusing anecdotes, he takes the reader on a tour through the early history of computers, describing the inventions, events, and personalities that made computers what they are today

You will gain insights into the rise and decline of the mainframe computer, and you'll learn how the personal computer evolved from little more than a sophisticated calculator to its present role as the backbone of the computer community because of its ability to do spreadsheets, an important tool for business.

You will also see the relationship between the early SWAC and the present generation of PCs, both complex instruction set computers (CISC). He goes on to discuss alternatives to the CISC computer such as the RISC (reduced instruction set) and parallel-processing computer. He also comments on networks and the rise of worldwide computer services.

1995/96 Power Products Catalog

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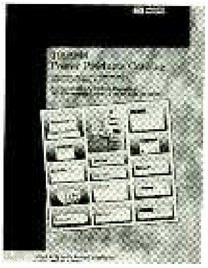
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This latest edition of the Hewlett-Packard's Power Products Catalog (Literature 5963-3906 EUS) contains technical information on HP's AC sources, DC power supplies, electronic loads, power test systems, and solar-array simulators for the laboratory and factory. The catalog is organized to give the reader easy access to extensive listings of application information, dimensioned product drawings, illustrations of equipment front-panels, and product specifications.

Magnum Terminal Blocks Electronic Catalog MTB1

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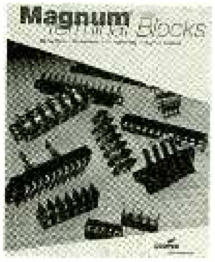

CIRCLE 345 ON FREE INFORMATION CARD

Magnum catalog describes the company's line of barrier-style terminal blocks and a wide selection of terminal, screw, and hardware options. The Magnum "Wire-Ready" option is now standard on all of its single-row terminal blocks, and molded mount ends are standard on Magnum's 2000 and 3000 series terminal blocks.

Other products covered in the catalog are double-row terminal blocks, edge board connectors, and Mag-Master electronic/field wiring interfaces. Complete specifications, illustrations, photographs, and ordering information are included.

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This edition of the Connex Connector's catalog describes the company's line of radio-frequency connector products. Pictures and specifications of standard and special application connectors for RF and data transmission are included. Also described are Connex Connector's in-house technical services that include testing, computer-aided design, and certification. EN

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HIGH-POWER HI-FI AUDIO AMPLIFIER

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THE AMPLIFIER DESCRIBED IN THIS article is a lightweight, high-performance stereo amplifier for the demanding audiophile. It can be built for less than $500 in parts, but it performs better than high-end amplifiers that cost up to ten times that amount. Its performance is comparable to top-of-the line professional products, and also is suitable for sound reinforcement because of its portability and rugged construction.

System description

Figure 1 is a block diagram for the amplifier. It consists of a pair of linear discrete amplifiers, both powered by a full-bridge, off-line, switching power supply. It is capable of providing well over 1 kilowatt of continuous power and 2 kilowatts peak with the most demanding audio loads. Both amplifier channels have MOSFET output stages rather than the more common bipolar power transistors.

The authors have found that MOSFET amplifier output stages deliver the best audio quality, but they recognize that they might not be as robust as their bipolar counterparts. That drawback was overcome in this stereo amplifier by powering it with a switching power supply. That supply contributes significantly to the amplifier's overall high performance because of its high instantaneous current capability.

The switching power supply permits the amplifier to be made smaller and lighter than if a comparable linear power supply were used. This high-performance amplifier weighs less than 20 pounds! The power supply's operation at 75 kHz permits the use of smaller and lighter magnetic components. As is true of all switching power supplies, this power supply has smaller filter capacitors than would be required for a linear power supply. The power supply can be switched between three different output voltages. This permits operation at lower voltage or power levels for speaker protection, or to drive lower than standard impedance loads.

A comparable conventional linear power supply would require a large and expensive transformer and large and expensive filter capacitors because they charge at the relatively low frequency of the 60-Hz power line.

Moreover, this higher charge poses a constant threat of damage or destruction to the output transistors if the amplifier is subjected to excessive loads or experiences short circuits. The smaller filter capacitors store much less energy to be dissipated if a short circuit occurs, reducing that threat.

This articles discusses two different amplifier configurations: One is intended for fixed installation in the home, and the other for portable applications so that it can be carried for use in large hall or auditoriums for sound reinforcement. The package for home use depends on natural thermal convection and conduction for cooling, while the portable package includes two 3½-inch, muffin-style fans for forced air cooling. Both cases have approximately the same volume and weigh about 18 pounds. The case for the home version is 5 inches high and the case for the portable version is 3½-inches high and is designed to fit a standard 19-inch instrument rack.

Both versions include two identical amplifier circuit boards and identical switching power supplies. Both include clipping indicators, DC output protection, optional bridging and differential input adapter stages on the amplifier boards. The optional bridging feature allows the amplifier to be reconfigured into a single channel capable of driving loads up to 700 watts and differential input adapter stages permit a 600-ohm balanced input.

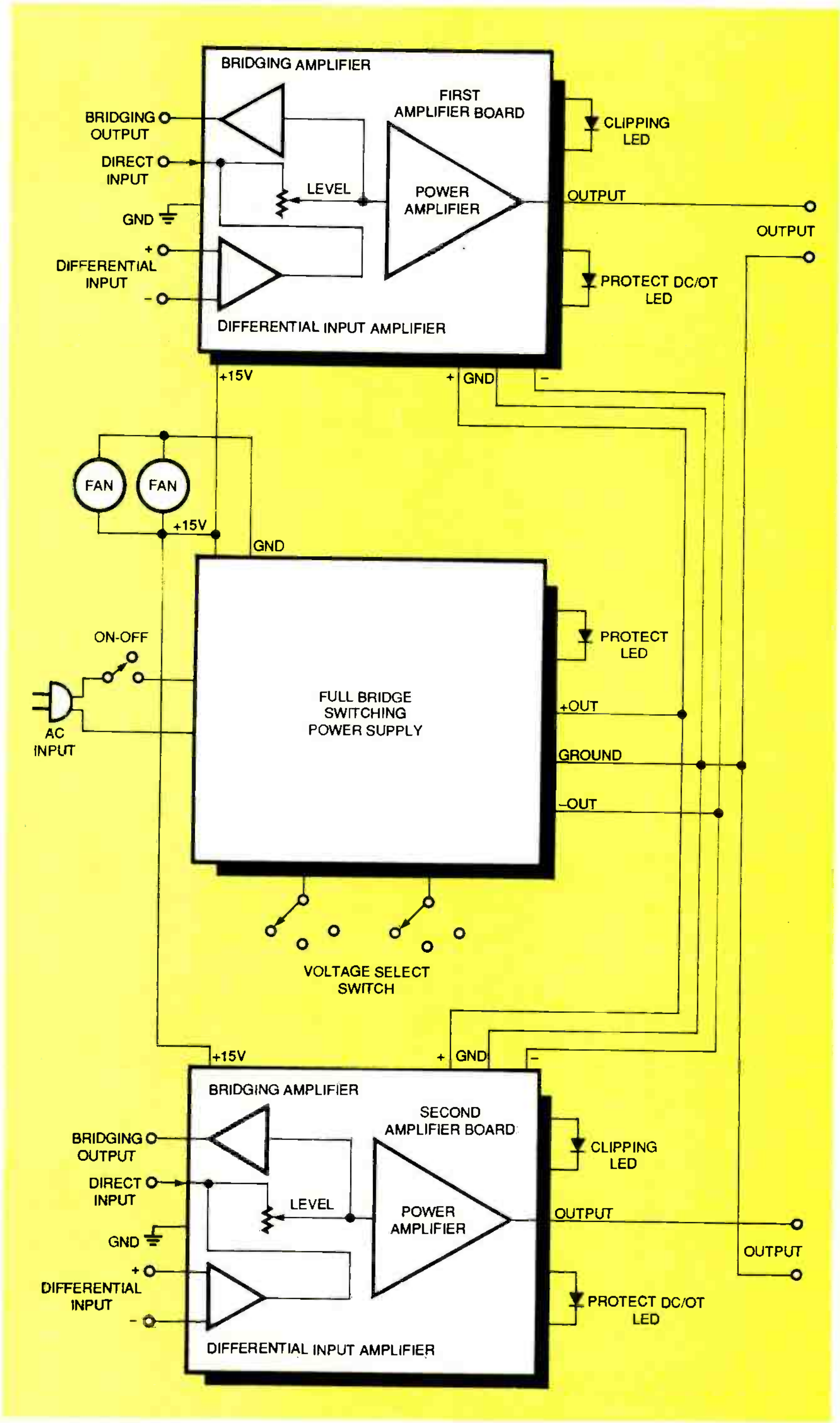

FIG. 1—BLOCK DIAGRAM OF STEREO AMPLIFIER. Designed for operation in homes or auditoriums, it contains two amplifier circuit boards and one switching power supply board.

Performance specifications

The specifications for both versions of the amplifier are given in Table 1. When compared with the most expensive commercial amplifiers, it can be seen that these performance characteristics are outstanding. Often low distortion and wide bandwidth are proclaimed as predictors of audio performance, yet many amplifiers whose measured performance is rated excellent will sound different. The audio purists will continue to argue about characteristics and what the specifications will or will not reveal.

The authors believe that there are discernible subjective differences between amplifiers even if the specifications do not identify them. In their view this just means that electrical measurements really don't test audio quality satisfactorily. Given otherwise favorable specifications, it has been the authors' experience that high output current capability is the most reliable predictor of subjective listening satisfaction, probably because it allows the amplifier to better handle the variations in a speaker's impedance. While the distortion and bandwidth specifications for this amplifier are commendable, the amplifier was specifically designed to optimize output current capability.

How the amplifier works

All of the components in both amplifier channels, with the exception of the bridging inverter and differential input adapter stage, are discrete, as shown in the schematic Fig. 2. Differential input capability is provided by IC2, an LM334 constant-current source and IC5, an LF357 JFET operational amplifier inverter that drives a second channel for bridging.

The normal single-ended input signal passes through the 10 µF input blocking capacitor C1 and the low-pass input filter network consisting of resistors R1, R2 and R3 and capacitor C2. Complementary differential input stage transistors Q1 to Q4 form the first gain stage and transistors Q5 and Q6 along with resistors R15 and R16 provide the second gain stage. Both stages drive the complementary cascode inversion stage.

Transistors Q10 to Q13 and Q24 develop the gate bias for the output power MOSFETs These MOSFETs, Q16 to Q23 (and optional Q26 and Q27) are mounted on aluminum angle stock that act as thermal adapters to the finned heat sink. In the home version the heatsinks form the back of the case; in the fan-cooled version they form two sides.

The inverter stage operates at

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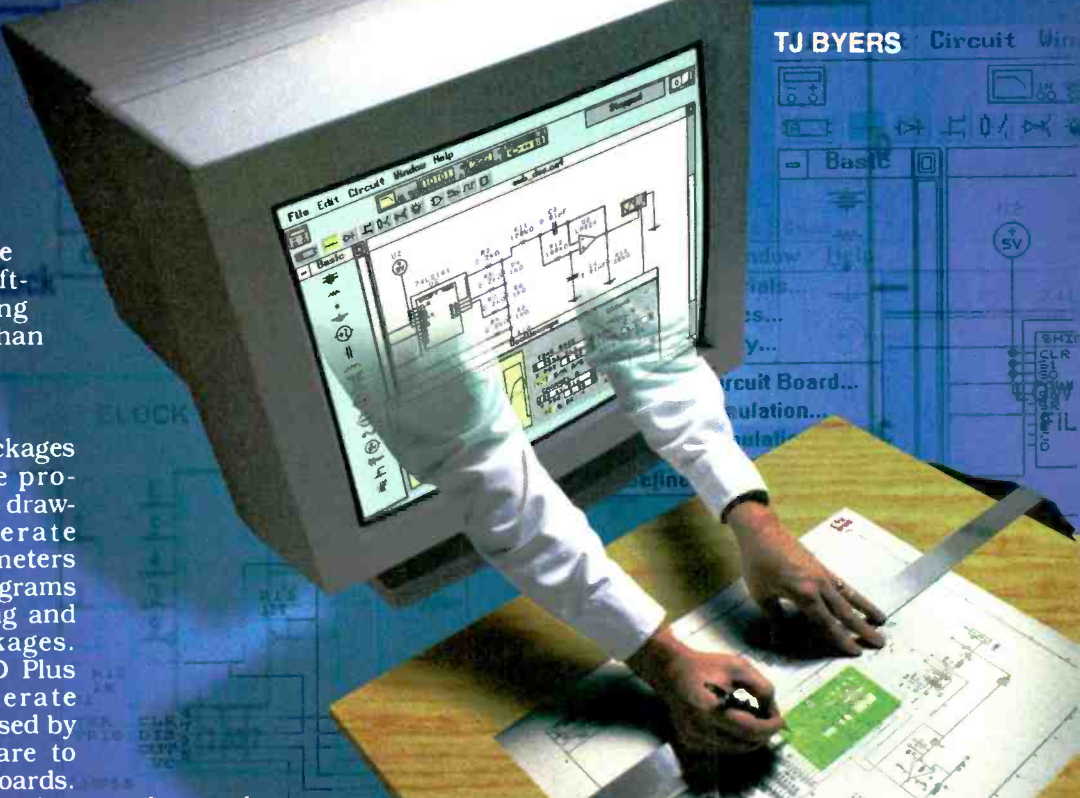
Low-Cost Software For Electronics

New low-cost software lets you draw schematics, lay out PC boards, and breadboard circuits on your desktop PC.



TJ BYERS

LAST MONTH WE looked at several schematic drawing software packages. Most of them could be used only for drawing purposes. This month we examine some more advanced software packages, including some that can do more than just draw schematics.

Schematic capture

The following four packages are schematic-capture programs that, in addition to drawing schematics, generate netlists of circuit parameters for exporting to other programs such as PC-board routing and circuit-simulation packages. The first two, SuperCAD Plus and WinScheme, generate netlist files that can be used by PC board layout software to create finished circuit boards. The second two, CircuitMaker and Electronics Workbench, are circuit simulators with integrated schematic capture. Prices start at $99 for the DOS version of SuperCAD, and increase to $299 for the integrated simulation packages.

Product:	SuperCAD
Version:	3.2 (DOS), 2.0 (Win.)
Price	$99 (DOS), $149 (Win.)
Platform:	DOS or Windows
Publisher:	Mental Automation, Inc.

SuperCAD is one of the best schematic capture programs on the market thanks to its capable editing features: True Type fonts, ease of use, and its very low $99 price. This program has not only survived over many years, but it has advanced without a price increase as new upgrades were released.

SuperCAD is built on a modular premise where you pay as you grow. The basic module costs only $99 for DOS and $149 for Windows, and you build from there, adding extra library modules ($59), utility software ($69), and analog/digital simulation ($99 each). Or you can do the smart thing, and buy the SuperCAD+ package with all the extras except circuit

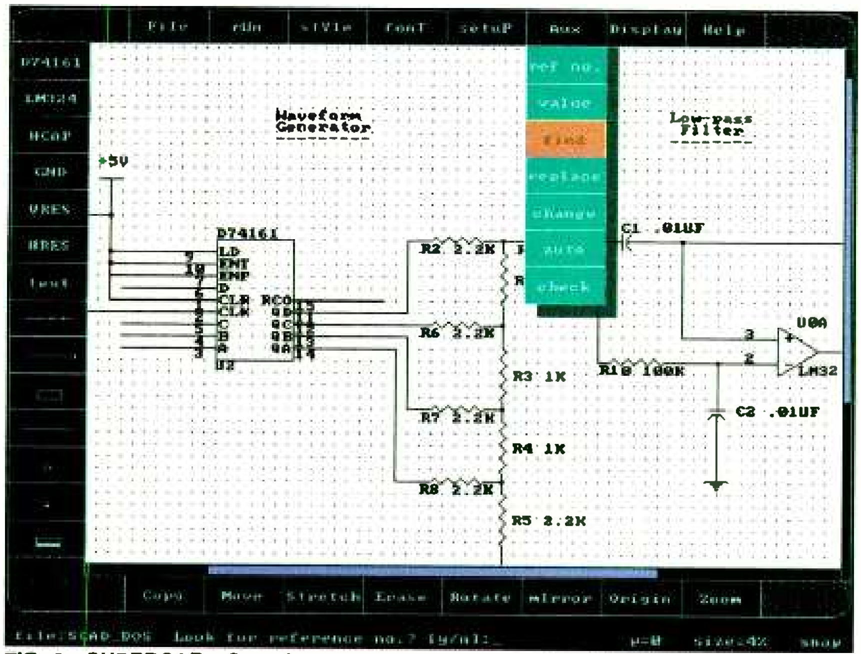


FIG. 9—SUPERCAD FOR DOS is an excellent schematic capture program with advanced features like auto wiring and find.

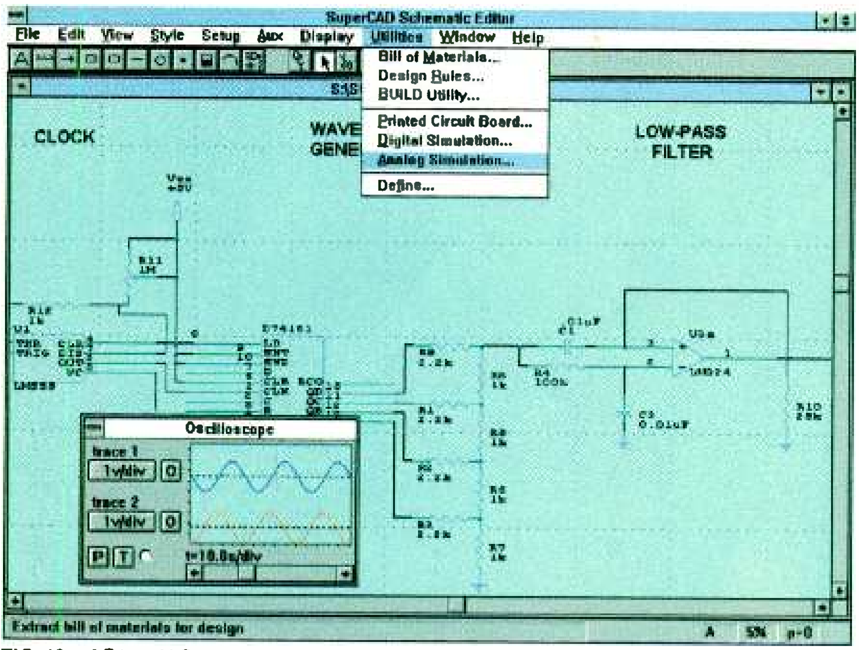


FIG. 10—AS WITH OTHER VERSIONS of the program, SuperCAD+ for Windows works with both digital and analog external simulators via compatible netlists and built-in waveform displays.

simulation for just $199 (DOS) or $249 (Windows). The following describes SuperCAD+ for Windows; if you're interested in the DOS version, see Fig. 9.

SuperCAD+ for Windows' symbols libraries are spread over several directories and subdirectories, and contain more than 2600 schematic symbols. The library menus have preview areas, where you can look at the symbol before placing it on the drawing. This is handy when the library doesn't contain the exact component needed, but it has something closely resembling it that can easily be modified by the library editor. Once a symbol is selected from a library, it can be placed repeatedly. Reference designators are assigned after placement either globally or one at a time. Assigning part values is done after placement, too, as is rotation and mirroring of parts. Attached nomenclature can be edited, but not moved.

Drawing wires is simple with the auto wiring feature, but you must be careful about how you make wiring connections. For the netlist to recognize a connection, it must be made at a legal (though invisible) termination point. Despite the fact that the program lets you tap into the component's rather lengthy pin wire, it's not a legal connection although it looks like one on the schematic.

The latest version of SuperCAD+ for Windows features a Multiple Document Interface (MDI) that allows up to 20 schematics to be loaded at once for easy access. Also up to 20 schematics can be included in a project group for easy handling—plus you can perform automated design checking and update reference designators.

Now the bad news. While the schematic capture program is among the best, and the related analog and digital simulation programs are dirt cheap (starting at $99), you're going to have to dredge up $149 for the companion PC board layout software ($299), if you opt for the autorouter and autoplacement options), and that gives you only two copper layers on a small 8 × 8-inch board. If you must create multilayer boards, it'll cost you $499 for the PC board layout software. Alternatively, you could use the netlist conversion software included in the utilities option to translate the netlist into formats that can be used with other PC board layout programs, such as OrCAD, but that's going to be expensive.

SuperCAD is a great program. It's inexpensive, extremely easy to learn and use, and generates a bill of material, has circuit simulation, and PC board layout netlists. Circuit simulation is a two-way street, where simulation is tightly coupled with SuperCAD for display on oscilloscope and logic analyzer screens (see Fig. 10). And it's backed by some of the best technical support available. What more can you ask from a schematic capture program?

Continued on page 63

POWERED SUBWOOFER

The "Little Earthquake" home-theater subwoofer delivers the deep bass you've been missing.

RODRICK SEELY

BY NOW, JUST ABOUT EVeryone has heard about home theater, and anyone who has had the pleasure of hearing a demonstration can appreciate the incredible sound that home-theater systems can deliver. Unfortunately, those great sounding systems usually have high price tags. In this article, you will see how to save big bucks by building your own subwoofer—usually one of the most expensive home-theater components.

Many people have already started to experiment with home theater by connecting a television set or VCR to the auxiliary inputs of a stereo system. In most cases, this simple configuration provides a terrific improvement over the TV set's built-in speakers. However, popular compact bookshelf-style stereo systems usually don't have speakers that are big enough to provide the deep bass that gives volume and power to theater sound. This important feature of home-theater sound comes from the subwoofer speaker.

Subwoofers provide a clean, deep bass that you can feel. The rumble of spaceships blasting through the galaxy in Star Wars, the musical tremors of Close Encounters, and the thundering stampede of dinosaurs trampling across Jurassic Park are just a few examples of the great movie moments that a subwoofer can bring to life.

Subwoofers can be divided into two main categories: passive and powered. Passive subwoofers generally consist of a passive crossover network and a speaker mounted in an enclosure. Although this kind of subwoofer is the least expensive, it must be powered by an external amplifier, and the amplifiers of most integrated stereo systems are too small to drive a passive subwoofer adequately.

The Little Earthquake is a powered subwoofer that features an active crossover network, 50-watt power amplifier, a 10-inch driver, and a fourth-order bandpass enclosure. The built-in power amplifier enables the Little Earthquake to work with virtually any stereo system. You can build the Little Earthquake for less than $200.

Circuit design

Figure 1 is the schematic diagram of the powered subwoofer. The power supply consists of a center-tapped 48-volt transformer, bridge rectifier, and filter capacitors C7 and C8. The rectified and filtered output is about ±35 volts. The power supply for op-amp IC1 is regulated to ±15 volts by Zener diodes D1 and D2 and resistors R19 and R20.

Most of the circuit is built around a TL074 quad op-amp (IC1), which functions as an input buffer, bandpass filter, and output driver. The input circuit consists of a mixer and voltage divider formed by resistors R1 and R2, potentiometer R3, and unity-gain buffer IC1-a. Potentiometer R3 is provided to adjust the output of the subwoofer to the desired level. Op-amp IC1-b provides a 12 dB per octave high-pass filter with capacitors C2 and C3, and resistors R5 and R6. The cutoff frequency for this filter is $1/2\pi RC$, or about 34 Hz with the values shown. Resistors R8 and R7 set the gain and Q of the filter. Capacitor C1 and resistor R4 form an additional 6 dB per octave high-pass filter at about 20 Hz. A 12 dB per octave low-pass filter is formed by IC1-c, C4 and C5, and R9 and R10. The values shown set the low-pass cutoff at 72 Hz. The gain and Q of this stage are set by R11 and R12. These two filters, connected back-to-back, form a bandpass filter with the transfer function shown in Fig. 2.

The output stage operates as class-B amplifier for higher efficiency. Because the TL074 has a high slew-rate, crossover distortion commonly associated with class B amplifiers is virtually eliminated. Any distortion caused by the amplifier is in a frequency band higher than the subwoofer speaker can reproduce. When operated with ±15-volt supplies, the output of op-amp IC1-d can swing about 10 volts peak to drive transistors Q1 and Q2. Resistors R17 and R18 provide negative feedback, and set the gain of the output stage at about three. Hence, the output can swing to about 30 volts peak. As long as the transistors are the high-

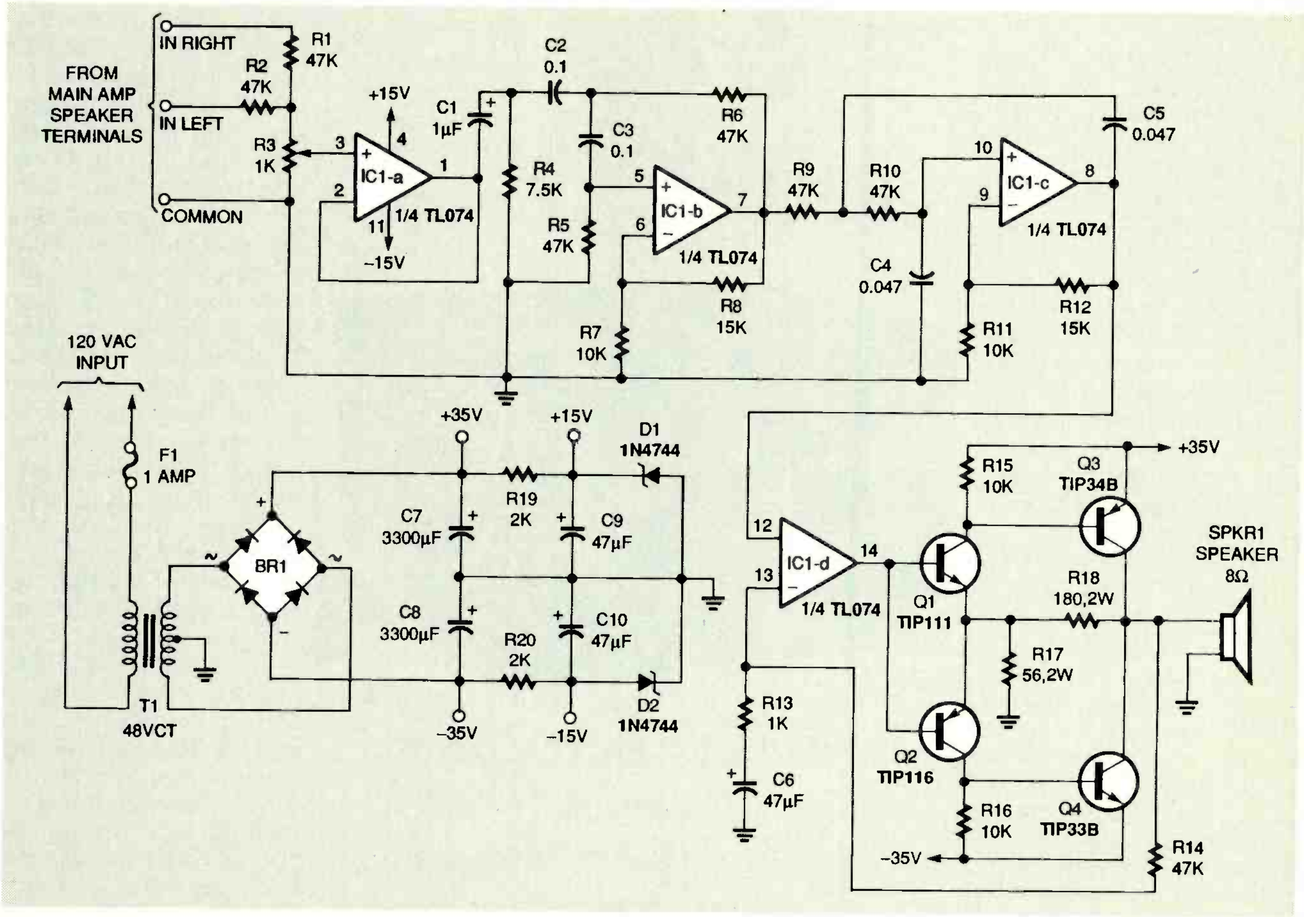


FIG. 1—SCHEMATIC DIAGRAM of the powered subwoofer. The power supply consists of a center-tapped 48-volt transformer, bridge rectifier, and filter capacitors C7 and C8.

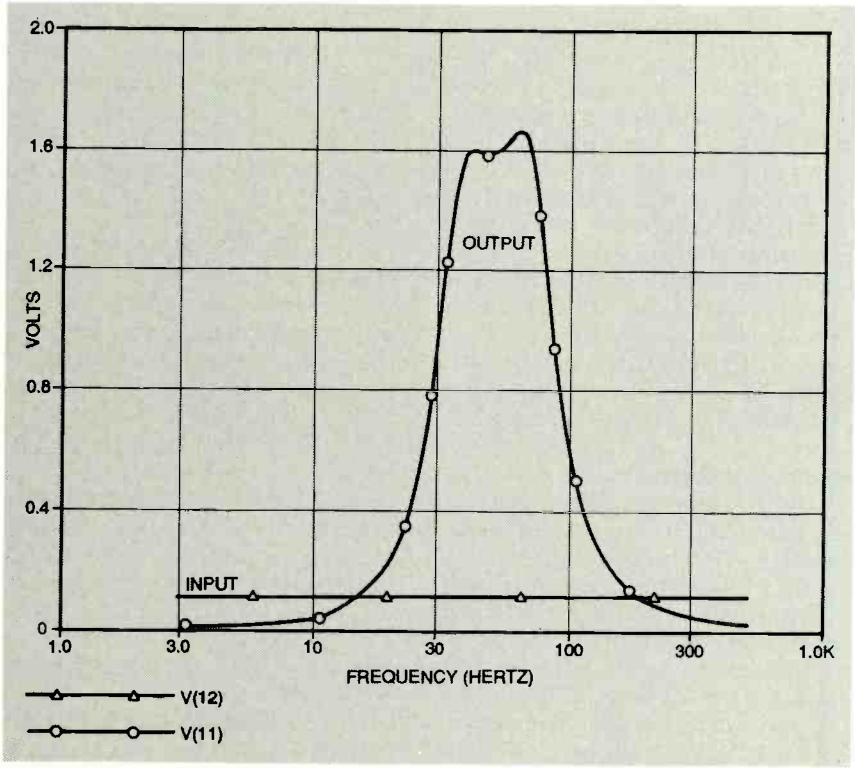


FIG. 2—TWO FILTERS connected back-to-back form a bandpass filter with this transfer function.

beta types specified, the peak power output into an 8-ohm load is (30×30/8)/2 = 56 watts RMS. The overall gain of the amplifier is set by resistor R13 and feedback resistor R14. Capacitor C6 provides DC blocking.

Cabinet design

The enclosure is a critical component of any subwoofer design. The Little Earthquake has a fourth-order bandpass enclosure which was designed with the aid of computer software.

The computer model is based on a 10-inch speaker with the parameters shown in Fig. 3. The maximum excursion of the speaker cone was selected to be ±¼-inch. For best results, a speaker with similar parameters should be selected. The amplifier and speaker are mounted in a sealed 17- × 14- × 8½-inch compartment, which has a volume of approximately

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Adding this subwoofer to your car audio system will dramatically improve its bass response and lower its distortion.

BUILD THIS SUBWOOFER FOR YOUR CAR

MARK RUMREICH

WHAT'S THE BEST WAY TO UPGRADE your car stereo? For many systems, replacing poor quality speakers with better ones is the best way to upgrade the sound without spending a lot of money. After that, adding a subwoofer tops the list. A high-quality automotive subwoofer system can be assembled for less than $150. This article explains how to assemble it.

A subwoofer provides two main advantages: First, it provides a dramatic improvement in bass, and second, it improves the higher frequencies by letting you turn down the bass frequencies that are fed to the other speakers. That lowers distortion and lets you play the other frequencies louder.

After a subwoofer is added, many people are astounded by the clarity of the resulting sound. This occurs because amplifier clipping and speaker excursion "bottoming" during loud passages are eliminated, and no longer distort the upper bass, midrange, and treble. The main amplifier no longer need supply high-power bass to the main speakers.

Subwoofer strategy

The subwoofer system is composed of three basic components: a subwoofer crossover, a power amplifier, and a subwoofer speaker and enclosure. Many subwoofer installations are based on quality subwoofers and power amplifiers, but include poorly designed (cheap) crossovers. The results are boomy bass, poor imaging, high distortion, and noise. The three most important things to look for in a subwoofer crossover are a steep cutoff slope (at least 18 dB per octave), a selectable cutoff frequency, and a subsonic filter.

A steep cutoff slope is important to prevent midrange and upper bass frequencies from reaching the subwoofer. Midrange and upper bass frequencies are *directional* for the human ear, which means that you can detect the direction where the sounds are coming from. Deep bass is *nondirectional*, which means that you can't determine the direction from which the sounds are coming. Keeping directional frequencies out of the subwoofer is necessary if you want to install the speaker anywhere in the vehicle without degrading the stereo image. It also lets you use a single mono subwoofer rather than separate left and right subwoofers.

Another reason to keep midrange and upper bass out of the subwoofer is to prevent boomy-sounding bass. Only a filter with a steep cutoff slope can effectively eliminate the boomy-sounding upper bass without reducing the desired deep bass frequencies.

Selectable cutoff frequency lets you match the subwoofer to the rest of the system. This prevents a "peak" or "hole" in the combined frequency response. The best way to obtain selectable cutoff frequency is to use a

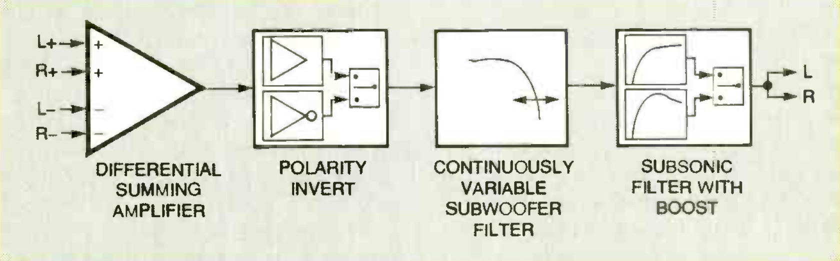

FIG. 1—BLOCK DIAGRAM of the subwoofer crossover. The crossover has a 24 dB per octave cutoff slope and a continuously variable cutoff frequency.

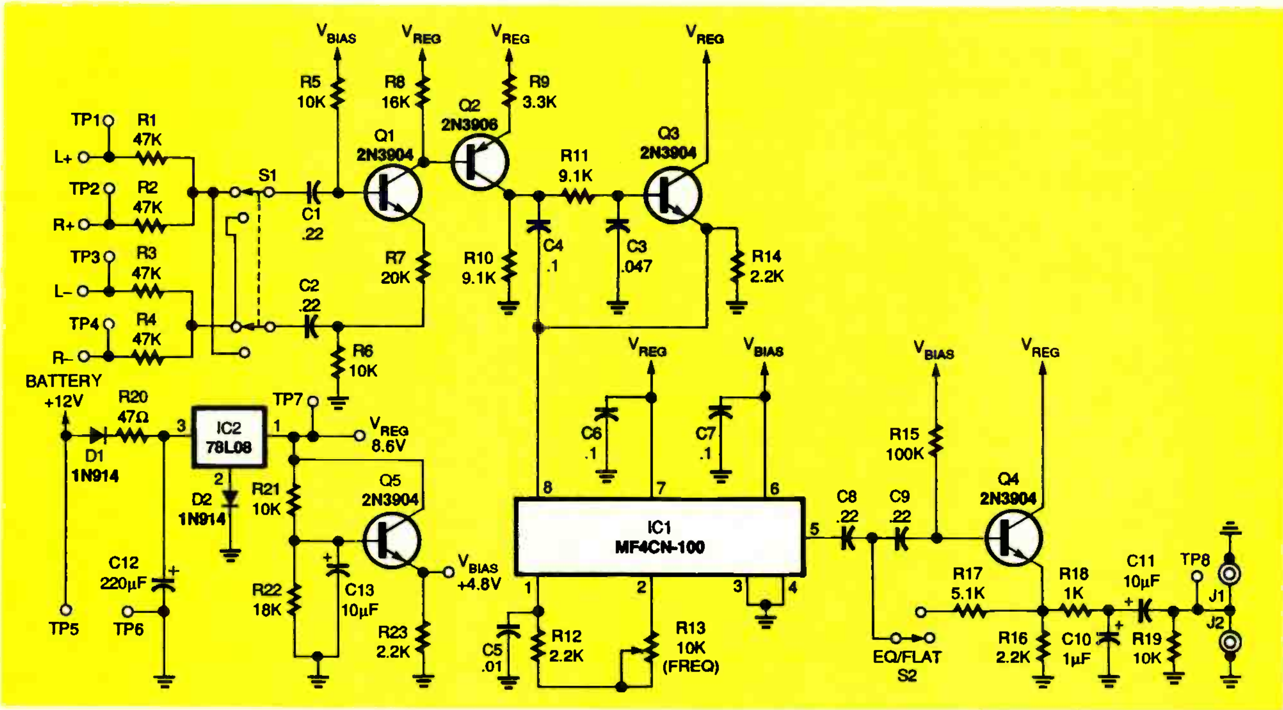

FIG. 2—SCHEMATIC OF THE SUBWOOFER CROSSOVER. Potentiometer R13 controls the cutoff frequency of IC1 by controlling its sampling frequency.

continuously variable filter that lets you fine tune the subwoofer response for the best sound. Then you can tailor it for the vehicle's interior acoustics and mask the low-frequency effects of road noise.

A subsonic filter prevents subaudible energy from reducing dynamic headroom and distorting the bass. It also eliminates annoying turn-on thumps. To be effective without sacrificing the deep-bass response, the subsonic filter should have a slope of at least 12 dB per octave.

Subwoofer crossover

Figure 1 is the block diagram of the subwoofer crossover. The crossover has the following features:

- 24 dB/octave cutoff slope
- Continuously variable cutoff frequency
- 18 dB/octave subsonic filter
- Polarity switch
- 40 Hz boost switch
- Speaker level inputs with active ground-loop isolation

The design incorporates a tunable 24 dB per octave Butterworth filter based on switched-capacitor technology. The cutoff frequency is continuously variable from 50 to 150 Hz. The subsonic filter is 18 dB per octave, and has a cutoff frequency of 20 Hz. In addition, the frequency response of the subsonic filter is switchable between a "flat" characteristic and a "boost" characteristic (which provides a 5 dB peak at 40 Hz). This boost can extend low-end response and provide deep bass punch without damaging the woofer.

The subwoofer crossover is engineered to prevent system noise problems. It has a differential amplifier at the front end to provide ground-loop isolation and a precision linear regulator to provide clean power for clean sound. This combination eliminates such problems as alternator whine, blower motor pickup, and ignition noise.

Figure 2 is the schematic for the subwoofer crossover. The inputs through Q1 form a differential summing amplifier with switch S1 functioning as a polarity inverter. A 24 dB per octave switched capacitor filter (IC1) is the heart of the continuously variable filter. Potentiometer R13 controls the cutoff frequency of IC1 by controlling its sampling frequency. Because of the inherent sampling action of switched capacitor filters, an anti-aliasing filter is required at the input of IC1. Transistors Q2 and Q3, along with the surrounding components, form this second-order, low-pass, anti-aliasing filter.

The subsonic filter with a boost stage follows the output of IC1 at pin 5. When switch S2 is closed, the boost is added. Additional subsonic filtering action is provided by C1 and C2 at the inputs of the crossover circuit. A "reconstruction filter" that eliminates sampling artifacts is formed by R18 and C10 at the output of IC1.

The power-supply circuit, based on the 78L08 voltage regulator IC2, provides both an 8.6-volt main supply and a 4.8-volt bias supply. Diode D1 protects against negative voltage spikes and incorrect hookup. Diode D2 biases the 78L08 regulator reference pin at 0.6 volt to provide an output of 8.6 volts rather than 8 volts.

Crossover construction

Figure 3 is the parts-placement diagram for the crossover PC board. You can make your own board from the foil pattern provided here, or you can purchase one from the source men-

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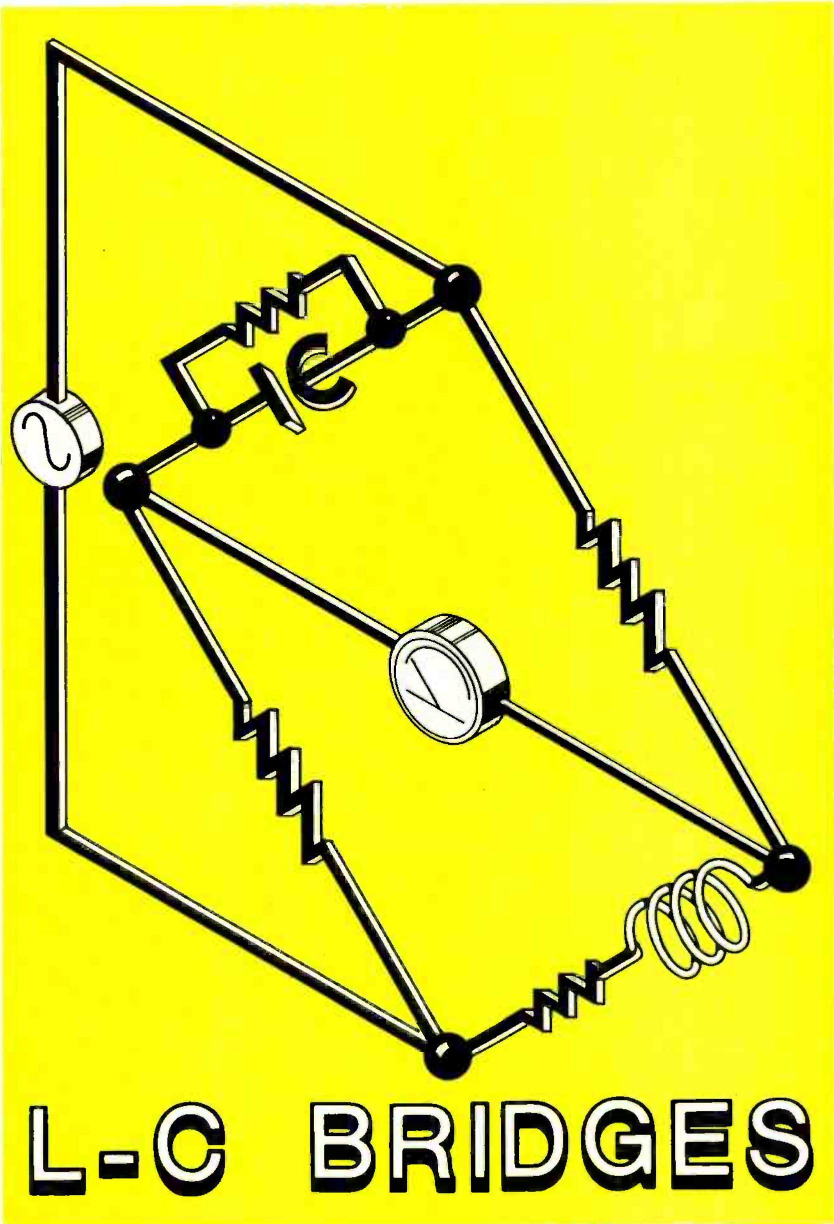
RAY MARSTON



Learn about popular capacitance and inductance bridges, and build your own Hay-Maxwell bridge and an 18-range LCR laboratory-grade bridge.

THIS ARTICLE IS ABOUT AC BRIDGES for measuring inductance and capacitance. It explains one popular capacitance bridge and two popular inductance bridges. Included are schematics for building your own AC bridges and modifying them for your requirements in experiments or making precise laboratory-grade measurements. The previous article in this series on bridges explained the basic Wheatstone DC resistance bridge and modifications to that bridge that made it possible to measure both inductance and capacitance.

Reactance, impedance, and Q

Inductors and capacitors offer resistance to alternating current. In a capacitor, resistance is known as capacitive reactance, and in an inductor it is known as inductive reactance. Reactance depends on frequency, and the capacitor's value farads and the inductor's value in henrys. The equation for capacitive reactance is:

$X_C = 1/(2\pi fC)$

The equation for inductive reactance is:

$X_L = 2\pi fL$

The term $2\pi f$ is called *angular frequency* and is represented by the lower-case Greek letter omega (ω).

It is important to remember that neither practical capacitors nor inductors are pure reactances because of the presence of mechanical elements that introduce parasitic inductance and resistance into capacitors and parasitic capacitance and resistance into inductors.

However, the true equivalent circuits for inductors and capacitors can be simplified for accurate measurements of most components used in general applications, but all of these residual effects must be taken into account in measuring some components such as high-value aluminum electrolytic capacitors.

Because of phase relationships in AC circuits, current is seldom in phase with voltage. In a pure capacitor, current leads voltage by a phase angle of 90°, and in a pure inductive circuit voltage leads current by a phase angle of 90°. Phase angle is designated by the lower case Greek leter theta (θ). These angle relationships change with the introduction of other reactive components.

Impedance is the result of resistance and reactance in an AC circuit. The phase angle θ between the voltage and current can be any angle between −90° and +90°.

Impedance in a series circuit is:

$$Z = \sqrt{R^2+X^2}$$
$$\Theta = \tan^{-1} X/R$$

Impedance in a parallel circuit is:

$$Z = RX/\sqrt{R^2+X^2}$$
$$\Theta = \tan^{-1} X/R$$

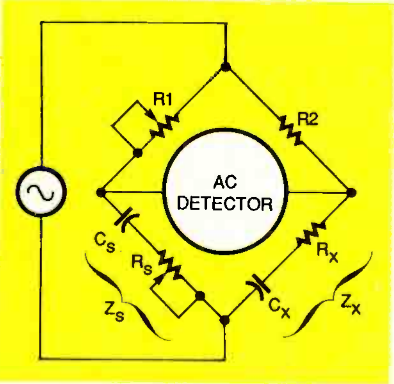


FIG. 1—A SERIES RESISTANCE capacitance bridge

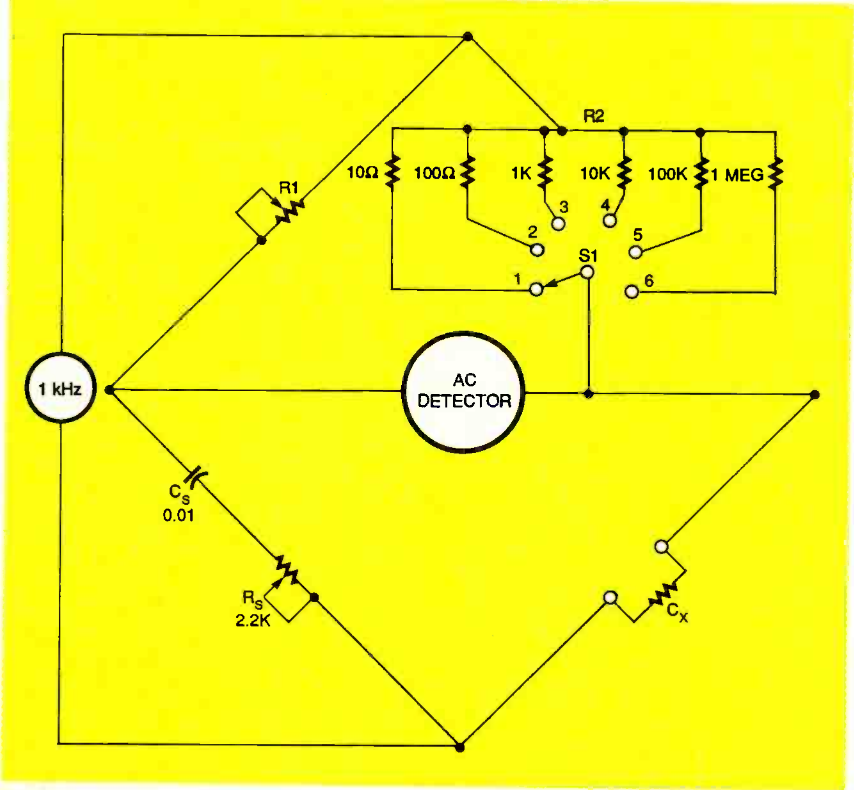


FIG. 2—SIX RANGE SERIES resistance-capacitance bridge.

TABLE 1
RESISTANCE VS. CAPACITANCE RANGE VALUES
RESISTANCE-CAPACITANCE BRIDGE

Switch S1 Range	Bridge Range	Resistor R2 Value	Z_X Full Scale R_S=0
1	0 - 10 μF	10 Ω	15.9 Ω
2	0 - 1.0 μF	100 Ω	159 Ω
3	0 - 0.1 μF	1.0 K	1.59 K
4	0 - 0.01 μF	10 K	15.9 K
5	0 - 1.0 μF	100 K	159 K
6	0 - 100 pF	1 MEG	1.59 MEG

The Q of a capacitor, coil or device is a figure of merit for its energy-storing capability. The higher the Q, the longer it takes for energy to be released. The Q of an inductance equals X_L/R, where R is the series resistance of the inductance. The Q of a capacitor equals $-X_C/R$ (a negative value).

L and C bridges

Capacitance bridges can make precise measurements of capacitors and their associated loss resistances in terms of a known capacitance and resistance value. There are different bridge circuits capable of making these measurements.

There are also many different bridge circuits that can measure inductance because the impedance of each arm can be a combination of resistances, inductances, and capacitances. One popular capacitance bridge and two popular inductance bridges are discussed later in this article.

Series RC bridge

The schematic for the series RC bridge is shown as Fig. 1. It is a resistance-ratio bridge that compares a known capacitance with an unknown capacitance. The bridge is balanced when $R1/Z_S = R1/Z_X$. Under this condition:

$C_X = C_S(R1/R2)$
$R_X = R_S(R2/R1)$
$Q = 1/2\pi f C_X \times R_S$

The values of R1 and R_S balance the AC voltages and phase shifts on the detector's left legs with those on its right legs.

Figure 2 is the schematic for a six-range series RC bridge that spans the range of 1 picofarad to 10 microfarads in six decade ranges. About half of the source 1kHz voltage appears at each end of the detector at balance. The AC detector can be either a simple meter or headphones. Table 1 relates the six capacitance ranges switched by S1 with the resistance value in each channel and full-scale impedance value.

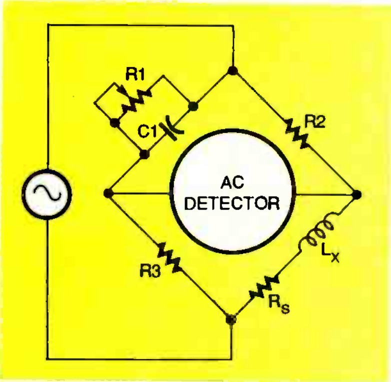


FIG. 3—THE MAXWELL BRIDGE can measure the values of low-Q coils.

Variable resistor R_S permits a null to be obtained when capacitor C_X has Q values as high as 7.2. (Any capacitor with a Q value that high should be discarded.) The value of potentiometer R_S can be calibrated directly in 1/Q values because in this circuit with a 1-kHz source, $1/Q = 0.001$ per 15.9 ohms of

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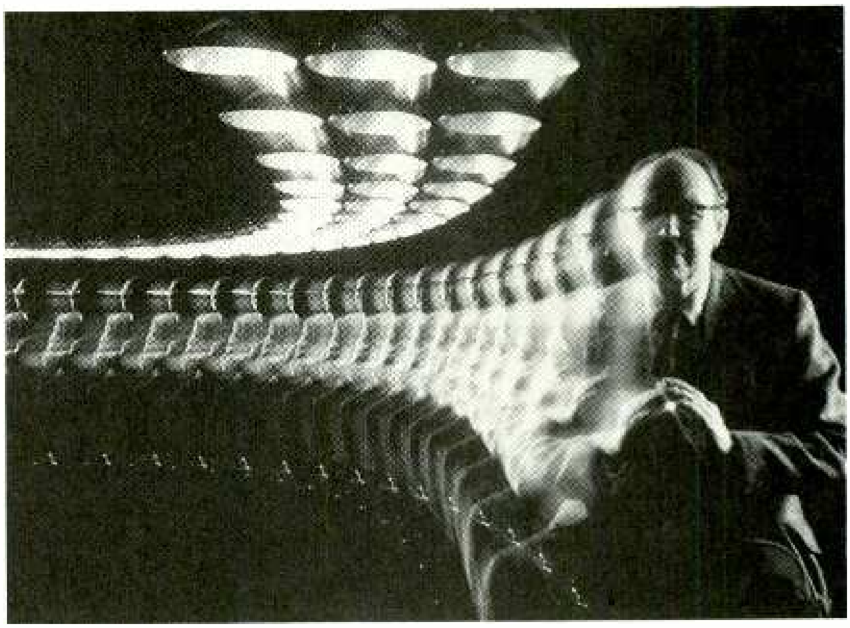
Harold Edgerton was a prolific inventor of stroboscopes, high-intensity lamps, underwater cameras, and specialized sonar. But he is best remembered for his ultra-high-speed photographs that are recognized as works of art.



SEEING the UNSEEN

PHILIP CONDAX

AN EXHIBITION AT THE GEORGE Eastman House in Rochester, N.Y. entitled *Seeing the Unseen: Dr. Harold E. Edgerton and the Wonders of Strobe Alley*, offers the public an opportunity to appreciate some of the outstanding contributions to science, engineering and art made by Dr. Edgerton. The exhibit is scheduled to leave Rochester on October 31 to tour five other museums before it ends in San Diego in 1997.

Photography was only one of the many consuming interests of this American engineer, scientist, inventor, and educator whose curiosity and energy led him to improve large synchronous motors and invent high-intensity flashlamps, stroboscopes, special undersea cameras, and exploratory sonar. This Massachusetts Institute of Technology professor, who died in 1990, actually became an artist by accident.

Dr. Edgerton's perfection of the stroboscope made it possible for engineers to stop the action of moving machines so they could see their faults and correct them, and his methods for "freezing" actions on film that are too fast to be seen by the human eye gave us our first clear pictures of events in the microsecond domain.

While Harold Edgerton might not be a household name, there can scarcely be a person on this planet who has not seen his photographs of a crown formed by a milk drop as it splashes into a saucer or speeding bullets passing through apples and playing cards. Perhaps less memorable, but of great importance to athletes, trainers, and physiologists are Edgerton's multiple-image pictures of a diver's trajectory as he springs off a platform or the fan-like images made by a golf club as the golfer swings to drive a ball.

Edgerton's methods for making those landmark pictures have long since been adopted by others for photographing eggs dropping, birds in flight, and glass bulbs exploding— to mention but a few of his subjects. His techniques advanced man's knowledge of ultra-high speed motions that occur in nature, science, and engineering. But you have probably also seen those television commercials extolling the benefits of stain-free carpet on floors that have received a cascade of slow-motion food spills. All of those special effects owe a debt to Dr. Edgerton's techniques.

Edgerton's early stop-action photographs were taken, almost reluctantly, from his laboratory to art museums where they are now declared to be images of esthetic beauty. His pioneering work on stroboscopes turned a laboratory curiosity into a practical engineering tool for diagnosing faults in moving machines from electric motors to jet engines, and his flashtubes have become standard equipment in the camera bags of photographers.

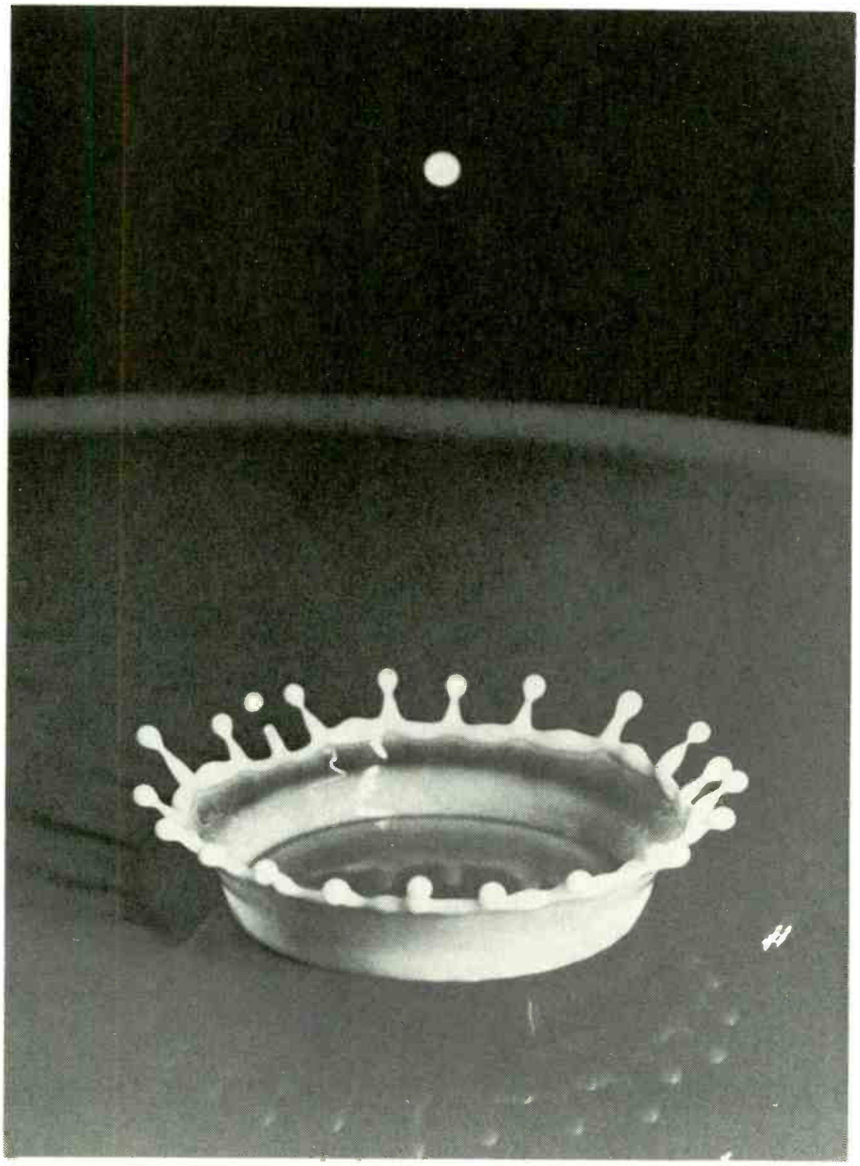
Home on the plains

Harold Edgerton was born in one small town in Nebraska in 1903, but his family soon moved to another small Nebraska town, Aurora. This move was to have a lasting influence on his philosophy of life and career direction. He credited his successes, in part, to being raised on the Midwestern plains where he learned, early in life, the virtues of hard work and perseverance.

But, of more importance was the power station in this town of less than 4000 people. Aurora was one of the few small towns in Nebraska to be electrified before World War I because wealthy farmers living nearby could finance and support a power station. As many as 20 years would pass before many of the neighboring rural towns would be electrified.

Edgerton was so fascinated by the power station's generators and transmission equipment that he sought and obtained work there as a janitor and general laborer while attending high school and during college vacations. As luck would have it, a labor shortage during World War I gave him the opportunity to become a lineman, a prestigious occupation, at an early age.

Not surprisingly, that satisfying work experience determined his major at the University of Nebraska—electrical engineering. While still an undergraduate at Nebraska, Edgerton earned an internship at General Electric's research laboratory in Schenectady, New York. After graduation from Nebraska in 1925, he continued to work at the GE lab before deciding to start graduate work at MIT in the fall of 1926.



THE MILK DROP CORONET, the famous photo of a drop of milk falling into a shallow dish.

Subjects that had intrigued him while working at the power company influenced his choice of research projects as an MIT graduate student. He sought to improve the efficiency of large industrial and utility synchronous motors. Both his master of science and doctor of science theses were on the mechanical and electrical shortcomings of those large motors and his recommendations for improving them. He received his master's degree in 1927 and his doctoral degree in 1931 from MIT, both in the field of electrical engineering.

While testing a motor in what was then called the Dynamo Lab at MIT, Edgerton noticed that the motor's armature appeared to be standing still when viewed in the flashing light from a firing thyratron tube. That observation was the start of his association with the stroboscope, a scientific instrument that could "stop" the actions of moving machines.

The armature of the motor was turning at hundreds of revolutions per minute, but in the flashing light from the thyratron it appeared to be stopped. He was able to see what was occurring in the motor under load conditions because of the *stroboscopic effect* made possible by human *persistence of vision*. Far more economical and efficient than taking motion pictures of the moving motor, the strobe effect made it possible for him to analyze motor faults as they occurred and correct them while standing there.

The human eye-brain response is too slow to react individually to two separate images that reach the eye within less than one-tenth of a second.

Continued on page 90

BY DON LANCASTER

Understanding Pitot tubes.

Plus a GPS navigation update, picking a new microcontroller, new Internet directories, and more on the mystery band.

MAYBE IT'S BECAUSE I AM SITTING HERE ON A SAND DUNE WATCHING GILA MONSTERS IN THE MIDDLE OF THE UPPER SONORAN DESERT, BUT NOBODY HAS EVER ACCUSED ME OF BEING much of a boat person—at least not lately. I do know that the binnacle goes on the top and the barnacle goes on the bottom. Interchange those two and you end up with a serious breach of maritime etiquette. At any rate, one recent help-line caller wanted to find out if I knew anything about how boat speedometers operate.

Boat speedometers

Not having the faintest idea at the time, I muttered several things about gyros, strain gauges, differential thermistor temperature sensing, GPS, and sonic Doppler radar shifts. Most of which were wrong.

Let me review the normal ways of finding an answer to something I do not have the foggiest clue about: Ask some expert or visit a suitable place where I can find an answer. In this case, that would be a marina or a boating supply store. Read relevant magazines and trade journals, such as those on boating or on marine retailing, and even boating-supply catalogs. Then contact the manufacturers for useful literature. Most important, seek out relevant reference papers.

Another option is to search the Internet or a commercial online service. You can also try a surefire solution that lets you instantly find *any* answer to *any* technical question: Use the *Dialog Information Service* found at your local library or conveniently online at *GEnie*. If there's no real rush, try my ultimate ploy: let your subconscious work on the project for a few weeks until you stumble over an answer.

Sure enough, *Motorola* sent me a new *IC Sensor Device Data* manual. And right there on page 4-166 is application note AN1536 on, of all things, boat speedometers, including the full construction plans. There's also one magic word that tells us all about how boat speedometers work: *Pitot.*

That tells us that boat speedometers work exactly the same way that airplane speedometers operate. Only one uses a liquid, and the other a gas.

Pitot tubes were first developed by Henri Pitot, an eighteenth century French physicist. Figure 1 shows details. Create a smooth flowing and non-turbulent liquid or gas channel of constant diameter, such as a pipe. Measure the *differential* pressure between a radial and an axial port. The pressure difference should be nearly proportional to the *square* of the velocity, usually within five or ten percent.

The exact results depend on the density of the liquid or gas and the temperature. Figure 2 shows the curves for freshwater and saltwater boat speedometer pressures. The

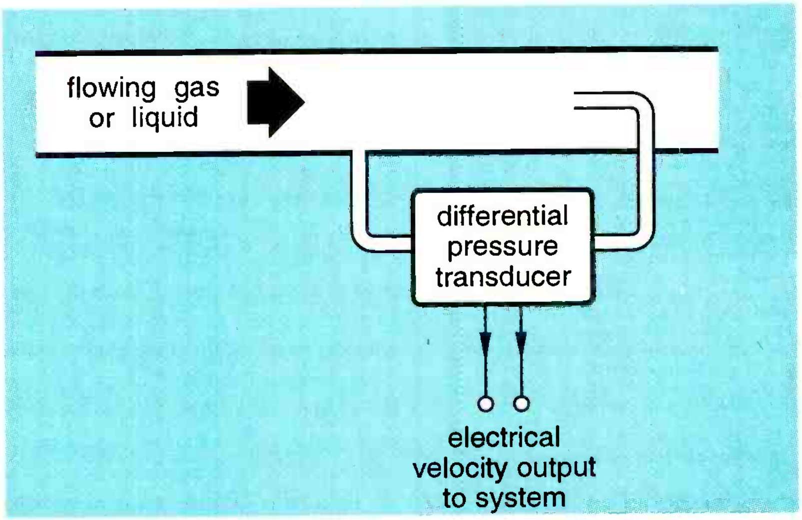


FIG. 1—A PITOT TUBE can be used to measure the velocity of a flowing liquid or gas. Uses include boat speedometers and fire hydrant testers.

speed will, of course, be that of the boat *relative* to the water current.

Motorola has a unique offset-canceling scheme which swaps the op-amps around and then cancels out the difference so that the speedometer can show absolute speed instead of realative speed. Other low cost pressure transducer sources are available from *Sensym*, *IC Sensors*, and *NovaSensor*.

Pitot tubes are not suitable for sailboats or other low-speed applications. Other techniques are required for ultra low velocities. Differential GPS is an obvious choice.

Ah, hindsight. After thinking about it for a while, it seems I do use a boat speedometer quite a bit after all. Except that its box is plainly labeled "Fire Hydrant Flow Tester." All fire hydrants must be tested twice each year. First to make certain they work at all, and second to verify a peak fire flow gallonage rate that can meet a given insurance rating class.

You hold this beast in the middle of an open hydrant stream and grab a reading. Then you look up the flow in a graph remarkably similar to the curves of Fig. 2.

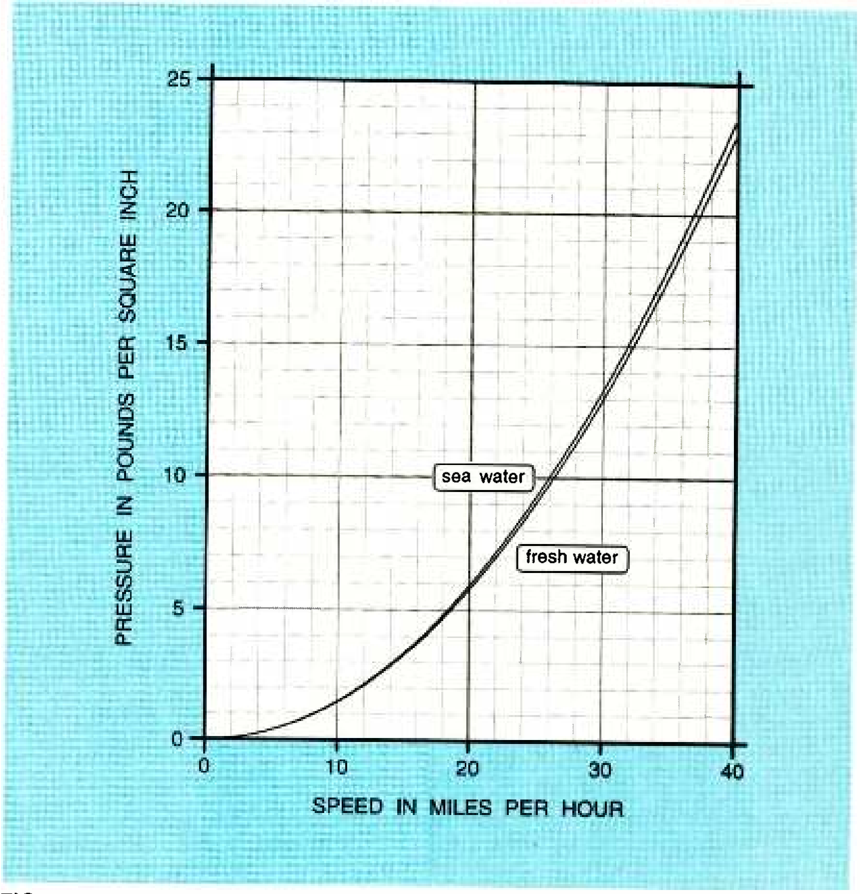


FIG. 2—PRESSURE VERSUS SPEED for flowing water at 60 degrees F.

I still don't have any information on commercial versions of boat speedometers. So, how about sending me some data sheets on them. There's a free *Incredible Secret Money Machine II* for your trouble.

Controllers

What is the difference between a microprocessor, a microcontroller, and a digital signal processing chip? Why would you select one of those devices over either of the others?

Before you can find the answers to those questions, you should first look into a concept called *address space*. Figure 3 shows some details. The address space is the sum total "reach" of a programmable IC. As in a city directory, an address space has *locations*. Into each location, you can put one "unit" of information.

This unit of information is often called a *byte*. Any given byte can be a computer command, one piece of data, one character in a document, a musical note, or an I/O "window" to the outside world. Bytes are eight bits in length. One byte is capable of representing as many as 256 different values. Multiple bytes can be combined for additional values.

The hardware located in any particular address space location is often RAM, ROM, I/O, or nothing. RAM is any memory that is fast and easy to change. ROM is any memory that stays more or less permanent, even on power-down. These days, of course, RAM is becoming very ROM-like, and vice-versa. There is a continuum of intelligently chosen options here.

I/O is short for *input* or *output*, and is the way your computer circuitry can reach the outside world. And finally, not all of the address space must actually be used. Some of it could be empty; other portions can be available but not in use.

The size of the address space can be as little as 256 bytes in certain controllers. A classic 8-bit microcomputer has an address space of 64K, or 65536 locations. Newer chips have

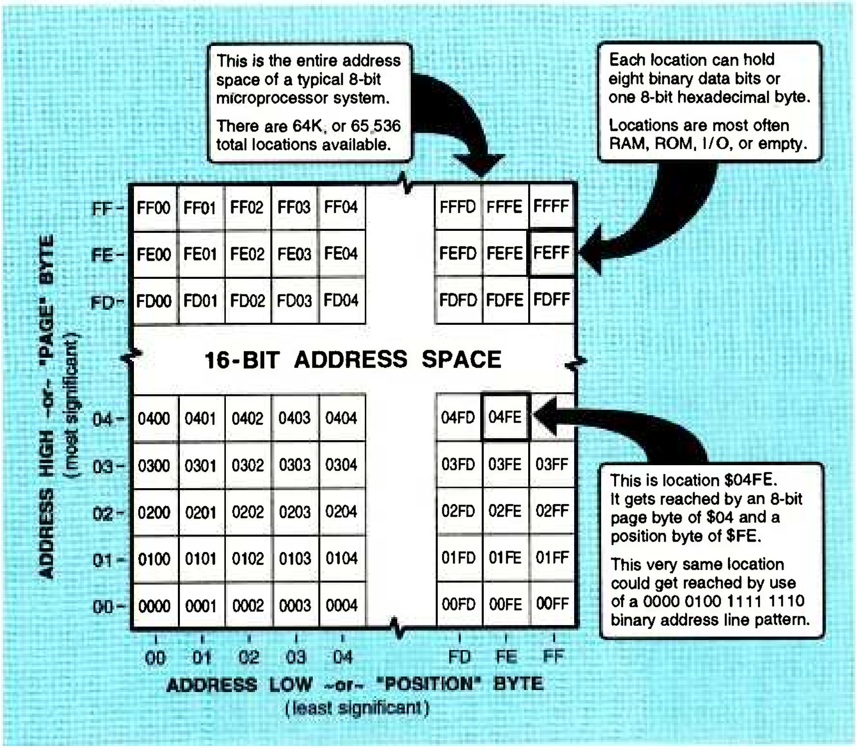


FIG. 3—THE ADDRESS SPACE of a classic microprocessor.

address spaces of 24 bits (for a grand total of 16,777,216 locations), or 32 bits (for a vast 4,294,967,296 possible locations).

The big tradeoff between microprocessors and microcontrollers is chip count. A microcontroller with internal-only address space often allows your design to get by with a single integrated circuit. But the RAM and ROM provided is both fixed and restricted. An external address space lets you add nearly anything you want. Almost any way you like, for much greater flexibility and performance at higher system cost.

Some single-chip solutions let you have the best of both worlds. While their address space stays fixed and internal, they easily let you add low-cost *serial* memory chips for extra data storage and whatever. Although serial memory is much slower than memory inside the "real" address space, it is more than fast enough for many real-world applications. Figure 4 summarizes the key differences between these main three computing options.

A *microprocessor* normally has a large address space, a generalized instruction set, and requires additional chips for a complete system. A *microcontroller* normally has a small internal address space, and its instruction set is optimized for control and other bit manipulations. Microcontrollers usually provide a single-chip solution. A *digital signal processor* (or DSP) is just a different name for a microprocessor, except that it uses fewer, more specialized commands.

The instructions for a DSP chip are carefully optimized for digital filter uses and related tasks, and thus aren't all that great for anything else. The specialized DSP instructions might include an ultra fast multiplier, a multiplier/accumulator that adds a small value to a large total, or some *barrel shifter* that instantly multiplies or divides by powers of two.

NEED HELP?

Phone or write all your Tech Musings questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ, 85552
(520) 428-4073

For fast PSRT access, modem (800) 638-8369. On prompt, type JOINGENIE. When asked for the offer code, enter DMD524.

US Internet email access link:
SYNERGETICS@GENIE.GEIS.COM.

There are certain things that DSP chips do very well. But their highly specialized nature and their military heritage has kept them expensive and out of the mainstream. Sadly, DSP program development and emulation remain as costly hassles. But DSP popularity is very much on the upswing, especially for applications in sound generation, fancy filters, and video compressors.

By far the finest choice in any microcontroller today is the PIC from *Microchip Technology*. The best way to get started using microcontrollers is with the *Basic Stamp* from *Parallax* and the *Scott Edwards Tools* for full machine code access and speed.

By special arrangement, I've made the complete Basic Stamp manuals available on my *GEnie* PSRT. See BASTAMP1.PDF for the intro, BASTAMP2.PDF for the instruction set, and BASTAMP4.PDF for updated and expanded applications.

Microcontroller resources

The usual places to start learning about microcontrollers are the hobby press publications and in the mainstream electronic trade journals. But there are a bunch of virtually unknown "second tier" trade journals that focus on topics of interest to microcontroller designers. I thought I'd gather a few of these together for this month's resource sidebar.

GPS update

Prices are coming down fast and furious on the GPS navigation front. I'd expect a $190 device from *Radio Shack* about the time you're reading this. Probably somewhat comparable to a *Garmin 45* receiver.

What everybody is waiting for, of course, is a full set of topographical maps built into a $99 handheld GPS device with an instant and high resolution "you are here" full-color 3-D display.

Some surprising giant steps have been taken toward that goal. One Israeli machine lets you slide a topographical map inside it, and then it can X-Y plot your current position and track for you. It is, however, way overpriced and clearly the device needs improvement.

The brand new *ScoutMaster* from *Trimble* knows an even handier trick: Besides telling you how fast you are hiking, it will tell you where you are on which topographical map!

Inside the machine is a database of 53,689 USGS (United States Geological Survey) topographical maps in their 7-1/2 minute or "seven by nine mile" size. Not the entire map, of course, but the map name and the latitude-longitude for enough key points to give you the nearest 2-1/2-minute reference point. That is *one-ninth* of the map, or well inside a three-mile square.

The readout then displays your *scaled map distance* away from one of these reference points. Say an inch and a half west and three quarters of an inch north. That sure beats messing around with latitude and longitude. The usual "on the run" accuracy of a single GPS measurement on most single low-end receivers is only 300 feet or so. By changing to *differential* GPS techniques, you can drop this down into the twenty-foot range. By going to multiple stations and longer term measurements that need premium multi-frequency receivers, you can actually achieve a "surveyor" accuracy of one centimeter—anywhere in the world.

Here is how the differential GPS works: You start with *two* receivers, and place one at a fixed and known location. Let it record where it thinks it is, and you can determine the error because you know where it really is. Then make your real measurement with the moving receiver, and then subtract out the error difference. Since these errors are pretty much the same over some thirty miles or so, there are now pager services and commercial FM broadcast subcarriers that will transmit these GPS corrections for you in real time.

A *differential ready* handheld GPS receiver simply has a jack on the side that accepts the correction data in a standard format. Plug in a suitable service and your location accuracy can improve dramatically.

One GPS trick that newcomers do not pick up on: You can easily fake the differential results. Simply use a second and fixed position receiver and then manually or automatically record the time and the error. Then take the error out during the final plotting. The closer you can get the two readings in time, the better your final overall accuracy.

I am using GPS on a historical archeology project I have going on the utterly astounding aerial lumber tram that's literally in my front yard. See my *Blatant Opportunist* reprints or GRAMTRAM.PDF on *GEnie* PSRT for more details. Yeah, I could use some help on some of the more gruesome portions of the terrain on this project.

One good source of GPS receivers, books, and tutorials is *Navtech*. They resell the Garmin and ScoutMaster receivers, and many others. The "horse's mouth" tutorial documents are provided by the *Institute of Navigation*.

The main source for FM services is *Differential Corrections*. The leading trade journal is *GPS World*, which publishes a *GPS Showcase* shopper.

OBSCURE MICROCONTROLLER PUBLICATIONS

AI Expert
600 Harrison Street
San Francisco CA 94107
(415) 905-2200

C++ Report
71 West 23rd Street 3rd Floor
New York NY 10010
(212) 785-5996

CADence
600 Harrison Street
San Francisco CA 94107
(415) 905-2200

Compliance Engineering
One Tech Drive Ste 215
Andover MA 01810
(508) 264-4208

Computer-Aided Engineering
1100 Superior Avenue
Cleveland OH 44114
(216) 696-7000

Dr Dobb's Journal
411 Borel Ave #100
San Mateo CA 94402
(415) 358-9500

DSP & Multimedia Technology
PO Box 1603
Los Altos CA 94023
(415) 969-6920

Embedded Sys Programming
600 Harrison Street
San Francisco, CA 94107
(415) 905-2200

Forth Dimensions
PO Box 2154
Oakland CA 94621
(510) 525-1295

IC Card Systems & Design
6300 S Syracuse Way, #650
Englewood CO 80111
(303) 220-0600

Integrated System Design
5150 El Camino Real Ste D31
Los Altos CA 94022
(415) 903-0140

Microsoft Systems Journal
411 Borel Avenue Ste 100
San Mateo CA 94402
(415) 358-9500

Personal Engineering
Box 430
Rye NH 03870
(603) 427-1377

Surface Mount Technology
17730 W Peterson Road
Libertyville IL 60048
(708) 362-8711

A New Internet directory

While not well known, the three leading suppliers of library reference directories are: *Bowker*, *Oxbridge*, and *Gale Research*. That's where such resources as *Books in Print*, *Ulrich's Periodicals Dictionary*, the *Encyclopedia of Associations*, and related goodies come from.

Sadly, these valuable directories are too pricey for most individuals, besides being unloanable references at most libraries. Many are, however, newly available both online and as CD-ROM based products.

There is one brand new $95 *Gale Guide to Internet Data Bases* which should turn into a major and highly useful printed Internet directory. The Internet has been defined by some as a humongous library without shelves, librarians, reference numbers, or card catalogs—in front of which numerous truckloads of new books get dumped daily, and from which lots of other texts vanish without a trace.

Two random selections here: #710

NAMES AND NUMBERS

Boardwatch
8500 W Bowles Avenue #210
Littleton CO 80123
(303) 973-6038

RR Bowker
121 Chanlon Rd
New Providence NJ 07974
(908) 464-6800

Dialog Information Services
3460 Hillview Ave
Palo Alto CA 94304
(415) 858-2700

Die Casting Engineer
9701 W Higgins Road #880
Rosemont IL 60018
(708) 292-3600

Differential Corrections
10121 Miller Ave #201
Cupertino CA 95014
(800) 446-0015

Scott Edwards Electronics
964 Cactus Wren Lane
Sierra Vista AZ 85635
(602) 459-4802

Fastener Technology
3869 Darrow Road Ste 101
Stow OH 44224
(216) 686-9544

Gale Research
835 Penobscot Blvd
Detroit MI 48226
(313) 961-2242

Garmin
9875 Widmer Road
Oenexa KS 66215
(800) 800-1020

GEnie
401 North Washington St
Rockville MD 20850
(800) 638-9636

GPS World
859 Willamette St
Eugene OR 97440
(503) 343-1200

Institute of Navigation
1800 Diagonal Rd #480
Alexandria VA 22314
(703) 683-7101

Internet World
11 Ferry Lane West
Westport CT 06880
(203) 226-6967

Lattice Semiconductor
5555 NE Moore Ct
Hillsboro OR 97124
(503) 681-0118

Microchip Technology
2355 W Chandler Blvd
Chandler AZ 85224
(602) 963-7373

Motorola
5005 E McDowell Rd
Phoenix AZ 85008
(800) 521-6274

Navtech Info Services
2775 S Quincy St #610
Arlington VA 22206
(800) NAV-0885

Oxbridge
150 5th Ave #202
New York NY 10011
(212) 741-0231

Parallax
3805 Atherton Rd, #102
Rocklin CA 95765
(916) 624-8333

Sony Semiconductor
10833 Valley View St
Cypress CA 90630
(714) 220-9100

Texas Instruments
PO Box 809066
Dallas TX 75380
(800) 336-5236

Trimble Navigation
585 N Mary Ave
Sunnyvale CA 94086
(800) TRI-MBLE

Gargoyles Then and Now and #629 *Fact and Fiction About Armadillos*. The current directory contains around 2000 data bases and 8000 individual files. I would expect future editions to expand this greatly.

Two other useful Internet guides include *Boardwatch* and *Internet World* magazines. The quickest and easiest way to gain Internet access these days is by way of some commercial online service such as *America Online*, *GEnie*, or *CompuServe*.

New tech lit

Lots of exciting things are happening in that *mystery band* we looked at a while back. Start off with *Tuning up an Electromagnetic Accordian* in *Science* for March 24, 1995. Terahertz waves

Q & A

continued from page 12

base because when the base is made high, the collector-emitter junction essentially becomes a short circuit and the output at the collector goes low.

If you want the output to follow the sense of the input, put the resistor between the emitter and ground as shown in the figure. When you trigger the base, the output from the transistor will be high.

Notice that by using appropriate resistors between both the collector and the positive supply rail and between the emitter and ground, you can pick off any voltage you need when the transistor is triggered. The exact values of the resistors depend on the voltage you want at the output.

Degaussing Coil

Q *I would like to build a demagnetizer for TV sets. What type of wire should I use and what specifications should I follow?—C. P., El Monte, CA*

A A degaussing coil (demagnetizing coil) is what you use to fix a color picture tube that shows patches of poor color in fixed locations on the screen. The discolored patches are caused by magnetization of the shadow mask, a metal grid just inside the CRT.

Many TVs and computer monitors have a degaussing coil built in which is activated for a few seconds every time you turn the equipment on. To degauss a TV of this type, just turn it on, wait 30 seconds, turn it off, wait 30 seconds, turn it on again, and so on, four or five times.

If that's not sufficient, you'll need a source of an alternating magnetic field. To make a degaussing coil, wind 200 turns (4 pounds) of No. 20 magnet wire into a ring 1 foot in diameter, then wrap the whole thing in electrical tape and add a power cord to plug into the 120-volt AC line.

Turn on the TV or monitor so you can judge the strength of the magnetic field. Hold the degausser several feet away from the screen and turn it

Continued on page 52

Most MICROPROCESSOR chips have a large and external address space. Into which you place your choice of additional RAM, ROM, I/O or nothing. The instruction set is a general one, often optimized for file manipulation and complex computing tasks.

Instead, a MICROCONTOLLER offers a single chip solution with a smaller and fixed internal address space. All resources are defined on chip, with the possible exception of some slower and serial EEPROM memory. The usual instruction set has additional commands in it that favor simple I/O tasks. Such as bit sets, clears, or tests.

Finally, a DIGITAL SIGNAL PROCESSOR also usually has a large and an externally accessible address space. But its instruction set is often strictly limited to specialized tasks. Such as a very rapid multiplier, one or more adder/accumulators, or a barrel shifter.

FIG. 4—WHICH COMPUTER CHIP TO USE?

are generated by generating much lower frequency microwaves in a plasma and then by blasting that plasma with a laser, squashing the wave!

The sudden compression magically upconverts the output frequency. It's sort of a mega *Doppler* effect resulting in coherent, tunable, and high power terahertz waves.

It looks as if mystery-band transmissions are going to be called *T-Rays*. See *Science* for June 23,1995 for the second brand new method of T-ray generation. In this scheme, ultrashort laser pulses are blasted at a suitably blackened array of tiny dipoles. The light becomes an energy impulse that "rings" the dipoles at the correct frequency, opening a whole new world of imaging tools.

You can expect lots of exciting new developments where these came from. The T-band is an incredibly large chunk of spectrum up for grabs.

Sony has a new *CCD Area Sensor* data book. There's a *Lattice Data Book* covering programmable logic chips and development tools. Two unusual trade journals include *Die Casting Engineer* and *Fastener Technology*. *Texas Instruments* has free samples of its TPS2013 high side power control switches.

The old *HP-GL/2 Reference Guide* from *Addison-Wesley* gives you full details on the innards of the *Hewlett Packard* plotter language. The HPGL is an older and simpler ASCII character based format. It includes such commands as PD for *pen down*, and so on. It has no intelligence, and woefully limited font capabilities.

There's lots of interest these days in converting HPGL from or to that infinitely more versatile, powerful, and flexible PostScript language. See PS2VECT.PS and FLUTOOLS.PS for lots more details.

For those fundamentals of creating your very own technical venture, try my *Incredible Secret Money Machine II*. And we just got a great heaping new shipment of *Active Filter Cookbooks*. These are now self published by my *Synergetics Press*, and are often *not* available locally.

Yes, all new resellers are certainly welcome. Distribution is one of the major hassles of self publishing. See my *Book-on-demand Resource Kit* for more insider information.

Instant help answers, preprints and reprints of most of my stories, and all referenced files are available in my *GEnie* PSRT. I've managed to wrangle a special ten free hour signup for Electronics Now readers. See the *Need Help?* box for additional details.

A reminder here that most of the mentioned resources appear either in the *Microcontroller Resources* or the *Names & Numbers* sidebars. Be sure to check here first before calling our no-charge technical helpline. EN

Q & A

continued from page 51

on. Bring it slowly up to the screen, just close enough to scramble part of the image. If it's too close and too strong, it can bend the shadow mask, ruining it permanently.

Move the degausser around so that the whole screen gets demagnetized. Then take it far away from the screen before you turn it off. At the moment you cut power to it, there will be a strong burst of magnetism which can magnetize nearby objects.

PC Thermometer

Q *I would like to interface a thermometer to my PC. Should I use an A/D circuit reading an amplified thermocouple, or a temperature chip of some type? I'd like to be able to do this for $20 or less if possible.—J. McCormick, Salem, OR*

A Just connect a thermistor across pins 1 and 3 of your joystick port (game port), and read it with the BASIC statement:

R = STICK(0)

which will give an approximate resistance in kilohms. Radio Shack's 10K thermistor will do, but for best results, use a 100K thermistor in series with a 68K resistor. Then you can compute the temperature by doing something like this:

```
R = STICK(0)
P = 4000
Q = 45
TEMP = P/R + Q
```

Here P and Q are numbers you'll have to adjust by trial and error. You can use two cups of water, one hot and one cold, with thermometers in them, for calibration. For more information, including software, see PC Techniques, April-May 1994, pp. 34 to 38.

The high-tech solution is to use a Dallas Semiconductor DS1620 digital thermometer connected to your parallel printer port. We published an equipment report on Dallas Semiconductor's development kit for the DS1620 back in the March 1994 issue of *Electronics Now.* EN

BY LARRY KLEIN

High-Definition Compatible Digital Processing.

I BECAME AWARE OF THE LATEST AUDIOPHILE LOVE OBJECT IN, OF ALL PLACES, THE BUSINESS PAGES OF *THE NEW YORK TIMES*. IT APPEARED UNDER THE CATCHY HEADLINE "HOT NEW Audio Technology Chases Dolby's Soundprints." Once into the article you realized that the only relationship that the "hot new technology" (High Definition Compatible Digital Processing) has with Dolby is the intention of its producers (Pacific Microsonics) to emulate their notion of Dolby's original marketing approach. However, Microsonics has it wrong; Ray Dolby did not start out by selling small numbers of professional encoders and large numbers of consumer decoding chips—but that's another story.

Here's what I learned from the *Times* article: HDCD, which has audiophile hearts all aflutter, is (like Dolby A, B. C, etc.) a two-step process. An HDCD encoder/converter replaces the conventional analog-to-digital converter in the recording studio, and an HDCD decoder chip is installed right before the D/A output circuitry in the home player. An essential difference between the two-step HDCD processing and schemes such as Dolby and dbx is that HDCD-encoded CDs are said to not only be compatible, but to have improved sound even when played back undecoded on conventional players. HDCD players are also claimed to make conventional CDs sound better through the superior quality of their circuitry.

The virtually universal endorsement given to HDCD by the audiophile press and high-end manufacturers and engineers includes the typical audiophile blather about broader sound stages, greater depth, improved detail, air, ambiance, and so forth. The *Times* article claims that the encoder being shipped to recording studios in June "captures aural information ordinarily missed by digital recordings and reduces noise and distortion. The process also squeezes additional sonic data into little-used bits in the code." All this achieves "recordings that are at least equal in resolution and freedom from distortion to the finest analog master tapes." In other words, digital is now finally as good as analog! The audio millennium is upon us!

I consulted with some audiophile friends who stay on top of such matters (but who are nevertheless quite rational) and I was, I must admit, somewhat surprised to learn that HDCD was neither harebrained nor a scam. I was told that one of the designers, Keith Johnson, was a brilliant recording engineer in addition to being a

PACIFIC MICROSONICS' HDCD ENCODER converts an analog audio signal into a digital signal having a word length longer than 16 bits and a sampling frequency higher than 44.1 kHz.

top-notch audio equipment designer, and his partner, Michael Pflaumer, is well-known and respected in the computer networking systems field.

Technical description

Pacific Microsonics' technical description of the process goes something like this: In the recording studio the analog audio signal is fed to the HDCD encoder, which converts it into a digital signal having a word length longer than 16 bits and a sampling frequency higher than 44.1 kHz. Since this digital signal has more data than a standard compact disc can handle, "a continuous real-time analysis of the high-resolution signal is made using DSP techniques to determine what elements beyond the range of a conventional compact disc are perceptually important." In other words, which aspects of the improved signal are audible.

The extracted high-resolution data is snuck into the 16-bit, 44.1-kHz CD standard using two methods. Part is added directly to the standard signal by "optimizing utilization of its linear bits" (a.k.a. data compression?) and part is encoded into a control channel also within the standard signal. When a CD embodying the modified digital signal with the added high-resolution signal components is played on a standard CD player, the additional information is said to somehow provide a clear improvement in fidelity over a conventional CD.

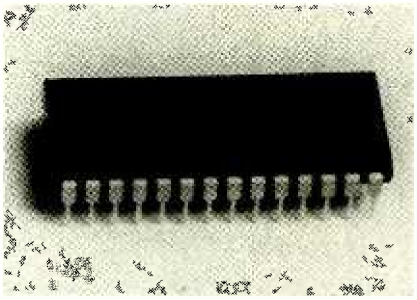
But to take full advantage of the HDCD process an HDCD player is required. The encoded signal then gets the full treatment with the information in the hidden control signal directing the decoding function to precisely reconstruct the complete high-resolution signal for the HDCD player's 20-bit, 8×oversampling DAC.

In other words, the recording studio uses an HDCD encoder to extract and save those elements of the signal that are lost in the normal digital recording process. (There's a strong implication that it is those lost parts that make CDs sound inferior to LPs.) Some of the saved signal components benefit an HDCD disc in conventional play; full recovery of the normally lost signals occurs during playback through an HDCD-equipped recorder.

Cavils and carps

My problem with all of the above comes down to two questions: (1) Does the CD format really have something inherently and substantially wrong with it?, and (2) Can HDCD fix it? If the first question gets a "no," then the second question is pointless. Microsonics claims that "there is a growing consensus among both recording industry professionals and audiophiles that the existing compact disc format doesn't contain enough amplitude or frequency information to be musically accurate." It seems to me that here we have a claim that is testable both by instrument and subjective double-blind evaluation.

Pacific Microsonics does tell of playing an analog master tape through a highly regarded, industry standard 44.1 kHz, 16-bit record/play chain. The result, as related in their press release, was dramatic: "compared to the original analog source, the digital sound was dull, closed in, and harsh." I find it strange that such an apparently convincing and easily duplicated experiment has not been repeatedly demonstrated to objective listeners and/or presented as an AES technical paper.



AN HDCD DECODER CHIP in a home player will decode the "hidden" music.

The bottom line

So what's my tentative final word on HDCD? It should be clear that I approach the format with a somewhat negative bias, if only because of its high-end audiophile perspectives and language. I suspect that the process has technical merit, but its real-world audible virtues may be acoustically minuscule. A friend who has listened to the same excellent Keith Johnson recordings with and without HDCD processing tells me that everything sounds superb, but that he hears no consistent difference in favor of HDCD. Perhaps HDCD processing is like audiophile cables—you need to believe in the product before you hear the improvement.

At the time of writing, there are perhaps 40 quite pricey audiophile models of HDCD players and about 20 HDCD discs available to feed them. Will the band wagon take off? Historically, major record companies have been loath to spend money on processes that (1) they didn't invent themselves, and (2) won't have a worthwhile financial payoff. To put it bluntly, they are not in it for the fidelity!

Will the record companies see HDCD as a cash cow, or even a calf? I doubt it, since their focus is on the mass music market, which has never demonstrated its concern for nuances of fidelity. The success of CDs over cassettes and LPs does not rebut my point. CDs made it because of their superior convenience and noise-free properties, not because they were sonically superior to cassettes. (LPs sound better than cassettes, but the cassettes' convenience won the dollars of the music buyers.)

Will some recording studios install HDCD encoding equipment? Of course, especially if some recording artists demand it, or the studios feel they can create a demand among the artists. And don't forget there's a small but hard core of audiophile recording engineers who cheerfully buy into Microsonics' sonically-flawed-CD story. These are the same guys who wire their studios with multi-dollar-a-foot esoteric cables. Will the HDCD processors ever be as ubiquitous in recording studios as Dolby encoders? I doubt it.

Am I an aging cynic who wouldn't know an genuine audio advance if it hit him between his no-longer golden ears—or have I, by a combination of technical good sense and market savvy, correctly predicted the course of a newly promoted product? Time, perhaps a year or so, will tell. EN

BY ROBERT GROSSBLATT

This month we start the design of a general-purpose controller circuit.

WHENEVER I HAVE TO START ON A NEW PROJECT HERE, THE FIRST PLACE I SEARCH FOR IDEAS IS IN THE MAIL. HISTORICALLY SPEAKING, MY MAIL HAS CHANGED OVER THE YEARS.

Once upon a time, the majority of the requests I received were for coverage of very general subjects—a tutorial on op-amps, for example, or how to design with FETs. In the last few years, though, the requests have changed.

Most of the mail now concerns specific applications rather than general ones. This is okay with me because I've always believed that you learn more by working with real-world circuits. The only problem with doing this is that the projects often get so complex that the general theory behind them tends to get lost. Without a thorough understanding of the underlying theory, all you're really doing is building a kit. This becomes evident if you try to change to the design because you suddenly realize that while you might have built a circuit, you don't understand how it works—or why it doesn't work!

The best way for me to answer all the application-specific requests I've received is to design a circuit that can do many things with minimum changes to the design. The best way to design such a chameleon-like circuit is to base it on a microprocessor. Once you have a basic microprocessor circuit working with a good amount of controllable input/output (I/O), you can alter its function just by writing new software.

Designing a general-purpose controller circuit isn't all that difficult, but it is definitely more complicated than using discreet logic. The price you pay for a microprocessor's versatility is that you must know how the microprocessor works and how it can be programmed.

Different microprocessors require different support hardware and software. However, they differ only in the details—the principles are the same. If you can design around Intel microprocessors, you won't have any trouble adjusting to the Motorola family. I'll be using an Intel microprocessor here because they're inexpensive and easy to find. Perhaps the most important reason to use Intel processors is that you'll need to write software, and every version of DOS comes with utilities that make the job of converting source code to Intel-compatible binary files easy to do. Finally, I've designed many circuits around Intel processors, seen most of the problems, and have worked out most of the answers.

Over the next several cloumns, I'm going to design a general-purpose, microprocessor-based controller circuit, with software configurable I/O. Although I'll go through each step in detail, it will be impossible for you to follow unless you have the following:

1. Data sheets on the ICs we'll be using
2. A basic understanding of microprocessors
3. A general understanding of programming
4. Access to an oscilloscope
5. A familiarity with hex code
6. Access to an EPROM programmer

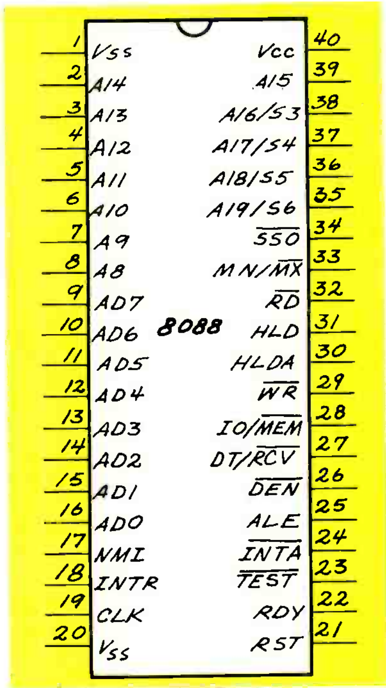
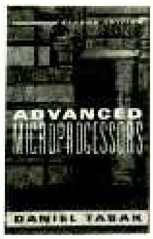


FIG. 1—THE 8088 MICROPROCESSOR is really a 16-bit chip squeezed into an 8-bit package.



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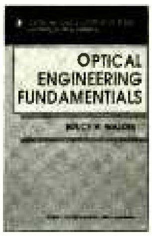

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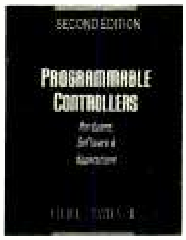

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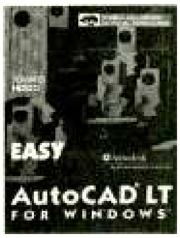

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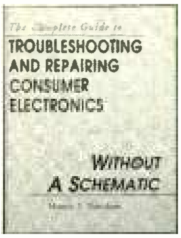

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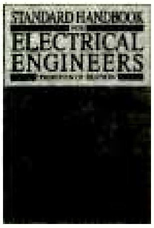

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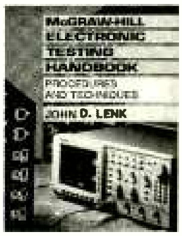

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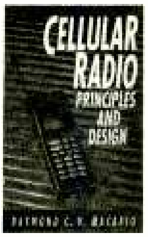

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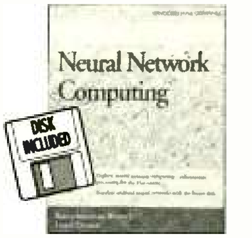

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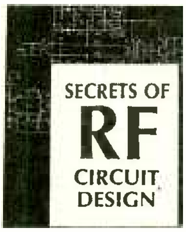

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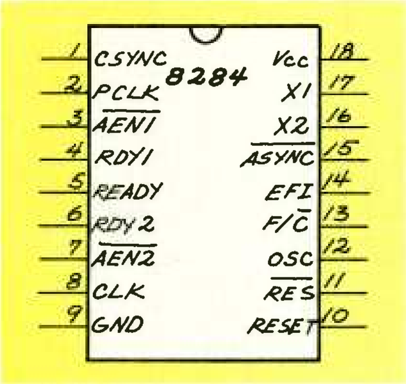


FIG. 2—THE 8284 CLOCK CONTROLLER will produce clock signals that are exactly tailored to driving the 8088.

It's sometimes hard to find books on this subject and that's why I wrote one myself. It's called "The 8088 Project Book," Book #3171 from TAB Books (800) 822-8158. You won't find data sheets (or an oscilloscope) in the book, but it will probably answer any questions you have concerning microprocessors.

The 8088 CPU

The 8088 microprocessor, whose pinout is shown in Fig. 1, is a field-tested CPU that you can buy for about a buck. If you look at the pin names, you'll notice that some of the pins perform double duty. This is because the 8088 is really a 16-bit chip squeezed into an 8-bit package. The standard 40-pin DIP just doesn't have enough pins for every line to be brought out separately.

A microprocessor needs a clock signal, memory, and software to tell it what to do. The 8088's pin-multiplexing scheme requires some additional, minimal hardware.

CPU satisfaction

The first of the 8088's circuit requirements is a clock signal, and this is pretty easy to satisfy. The clock must have sharp shoulders (rise and fall times of less than 10 microseconds) and a 33% duty cycle. The maximum speed depends on the CPU. A standard 8088 tops out at 4.77 MHz, the 8088-2 can run at 8 MHz, and the 8088-1 goes up to 10 MHz. Minimum speeds for all flavors of the CPU is about 2 MHz because the internal registers are made from single storage capacitors that must be refreshed in the same way as dynamic RAM. This saves space on the substrate, but it made it a bit more difficult to really slow things down to debug a circuit. Since you can't slow the clock to a crawl, you must use software to put in lots and lots of wait states to get the same effect.

When Intel first started to design the 80XX series of microprocessors, one goal was to offer a set of chips specifically designed to support the CPUs. These included clock generators, bus controllers, coprocessors, DMA controllers, and so on. Some of them became popular and others didn't. One of the most popular was the 8284 clock controller shown in Fig. 2. This chip, plus a handful of components, will produce clock signals that are exactly tailored to driving the 8088.

Getting the 8284 to generate the clock signals for the CPU is a piece of cake. As you can see in the circuit of Fig. 3, most of the control and data pins on the 8284 aren't needed for the simple job that we want the chip to do. They come into play when the clock generator must drive more than one CPU or generate more than one clock frequency. My circuit will use the 8284 in its simplest configuration—as a clock source for the 8088.

You have to get the clock circuit working before you can go any further since it's going to drive the rest of the circuitry you'll be assembling over the next few months. It's simple to find out whether or not you have the clock circuit working correctly. There are three clock outputs available on the chip: +scclk+xsc at pin 8 is the main output for the 8088. It's one third the crystal output and has a duty cycle of 33% that's required by the 8088. OSC at pin 12 is a TTL-level buffered version of the crystal frequency. PCLK at pin 2 is a TTL-level frequency that's equal to half the CLK output and has a 50% duty cycle.

If you put an oscilloscope or frequency counter on any of those outputs, you'll know immediately if the clock is working correctly. Next time I'll be adding the CPU, creating the address and data buses, adding memory, and putting some basic I/O on the board. A lot of information is going to be thrown at you and you'll stand a lot better chance of catching it if you have the basic data on paper in front of you. EN

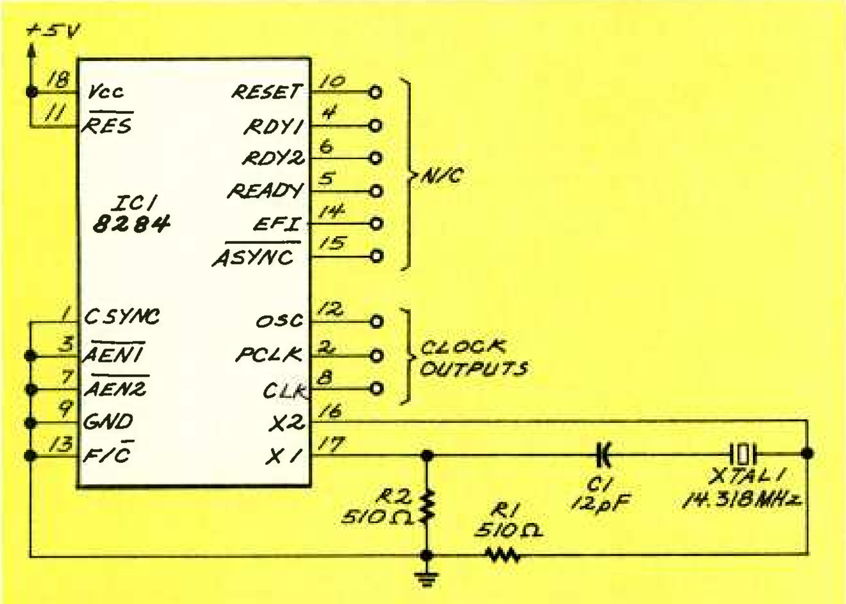


FIG. 3—WE'RE USING THE 8284 in its simplest configuration as a clock source for the 8088. Most of the control and data pins on the 8284 aren't needed for this project.

Would this be classified as a minor malfunction... a small design flaw... or just stupidity?

BY JEFF HOLTZMAN

Windows 95 update

Has Windows 95 achieved its intended design goals?

WINDOWS 95 SHOULD BE COMMERCIALLY AVAILABLE BY THE TIME YOU READ THIS, SO AT LONG LAST YOU'LL GET A CHANCE TO CHECK IT OUT FOR YOURSELF. FOR MORE THAN A year now, I've been playing with various pre-release versions of it, studying its architecture, comparing and contrasting it with its predecessors as well as other OS's. Barring any unforeseen last-minute catastrophes, what you will see should be very, very close to what I'm using now. This column describes what you can expect. It also provides my evaluation of how well Microsoft achieved its explicit design goals for Windows 95.

Installation hassles

Installation on older hardware can be difficult, but once you get the kinks straightened out, using Windows 95 can really grow on you. I now have Windows 95 running on two nodes of my network. One node, an old IBM PS/2 Model 70 (with 8 megabytes of memory and a 25 MHz 80386 CPU), functions as a print server, and will (by the time you read this) function as a remote-access server, allowing me to dial in by modem and access my network as if I were local. (Note: This is a good use for an old 386.) The remote-access feature is part of the current Windows 95 beta, but may be sold as a separate product by the time Windows 95 is released commercially. Note that Windows 95 (not to mention Windows for WorkGroups and Windows 3.11) will not run on a computer with anything less than an 80386 microprocessor.

The other Windows 95 node is a custom-built 486-based PC with 8 megabytes of memory. At the beginning of this experiment, that machine had an Always Technology SCSI adapter, and an old Paradise VGA card. The bad news was that I had to upgrade the disk controller, and chose to upgrade the video card. The SCSI problem was that the Always adapter card simply couldn't run both a hard disk and a CD-ROM. Lock-ups were frequent—and fatal.

I wanted to buy an Adaptec brand adapter, but the cost exceeded my budget for that old machine. Instead I gambled on a low-cost card made by a company called QLogic. I had no trouble installing it and running both hard disk and CD-ROM. Currently the setup uses "real-mode" drivers loaded via CONFIG.SYS and AUTOEXEC.BAT. QLogic had a beta protected-mode driver for the card available on its BBS, but it didn't work for me. I'm hopeful

TABLE 1—WINDOWS 95 EVALUATION

Criteria	Grade	Description
Ease of use	A	Definite improvement over Windows 3.x
Performance	B	No worse than WFWG; adequate on 386-25/8MB
Compatibility	B	Adequate; ran all software I threw at it; some hardware problems.
Networking and connectivity	B	Easier HW setup than WFWG, but configuration stilllacking.
Manageability and administration	A	Definite improvement over Windows 3.x. Easy switching among user and hard-ware profiles.
Communications and messaging	?	Retail configuration still TBD.
Mobile services and remote access	?	Not evaluated.

that the company will produce a usable protected-mode driver soon, but at least the real-mode drivers are stable.

The reason I want the protected-mode drivers for the QLogic adapter is that they will run in the 32-bit mode of the CPU, rather than the V86 mode, where the real-mode drivers run. The 32-bit mode will eliminate the need for mode switching, and will allow use of more-efficient 32-bit code.

The video situation was somewhat different. One application that had to run on that machine required a 256-color video driver, but the 1989-era Paradise card could only do so at standard VGA resolution (640 × 480), which was intolerable for me. So I bought another low-cost clone card: this time a Trident, with 1 megabyte of memory. The machine booted right up in standard VGA mode, but after allowing Windows 95 to auto-detect the new card and install a new driver, the machine repeatedly froze at a specific point in the boot sequence. I tried reinstalling Windows several times, always with the same result.

Then I received a Windows 95 update (build 490) from Microsoft, and it solved the problem. One useful tool in resolving the problem was Windows 95's ability to boot in a "safe" mode, in which only bare-minimum device drivers are loaded. I used safe boot many times in resolving problems with that machine and others.

The total cost for getting the old up to Windows 95 speed was about $250, plus another $300 to replace an eight-year old NEC monitor, which opportunely chose that time to die. In terms of effort, I had to reinstall Windows 95 several times, and reconfigure numerous system parameters. Based on this experience, I believe that there is no way that nontechnical users with older machines can count on getting a smooth Windows 95 upgrade. Even technical users had better be prepared for some frustration, and possibly some expense.

On the other hand, once you surmount the installation hurdles, Windows 95 is actually kind of nice. There is a consistency to the user interface that has been sorely lacking in prior versions of Windows. Although it is only a surface consistency (unlike OS/2), I still predict that it will become widely successful. By the time Memphis is released—the point where the Windows 95 and NT product lines converge in a distributed, object-oriented operating system—that consistency should extend well beneath the surface (as in OS/2).

One thing I don't like about Windows 95 is that it's slower to boot than prior versions of Windows. On the other hand, if you press F8 while the message "Starting Windows 95" is displayed, you get a menu that allows half a dozen or more ways to boot (command-line, GUI, safe-mode command line, safe-mode GUI, safe-mode GUI with networking, and more).

Windows 95 networking

Although I probably could, I still don't use Windows 95 on my main production machine, which continues to run Windows for WorkGroups 3.11. The Windows for WorkGroups machine does, however, provide clean access to the Windows 95 print server; likewise, I can also share the Windows for WorkGroups machine's resources with the Windows 95 nodes. Using Microsoft's little-known WorkGroup Add-On for MS-DOS, I can also access network resources from DOS-only machines.

Getting the network up and running was a piece of cake. Windows 95 correctly auto-sensed a variety of Ethernet cards installed in the various machines, and installed the correct drivers. Windows 95 automatically installs the IPX protocol stack for communicating with a NetWare network, but if you're only running Windows 95 and Windows for WorkGroups, IPX is unnecessary; Microsoft's NetBEUI is all that is required. Deleting the IPX drivers was simple enough, but installing them by default seems silly. By contrast, sharing the resources of a machine with others on the network is disabled by default—which also seems silly to me.

All in all, getting Windows 95 networking going was easy enough for me, but people without network-installation experience would in all likelihood require technical support to complete the installation. Microsoft could have done more to ease installation, but perhaps the company chose explicitly not to. Microsoft's current plan is to provide 90 days of free technical support (by telephone) for non-network related questions, and to charge $35 per network "incident."

Evaluation

My evaluation appears in Table 1; criteria in the table are those suggested by Microsoft on page five of the *Microsoft Windows 95 Reviewer's Guide.* In sum, Windows 95 has not met Microsoft's architectural goals; nonetheless, it is a major step forward in PC operating systems. If it turns out to be a short-lived step on the way to a more robust architecture based on Windows NT, so much the better. But the user-interface improvements provided by Windows 95 will be with us for a long time.

IBM buys Lotus

I don't want to say I told you so, but just remember you read it here first—in the July 1994 issue to be exact.

If you had $3.5 billion in spare change lying around, and wanted to do something to help ensure the longevity of your company, how would you spend it? Would you invest in exciting new technology R&D? How about some heavy-duty industrial espionage?

Let's put it another way. Suppose you were a broken-down old has-been playing an exciting but deadly game of craps with a powerful young chieftain. What's the best way of increasing power at the expense of your rival? Join forces with a complementary operation—albeit one suffering from an indifferent outlook and premature aging?

Some early commentators think that (if the deal goes through) IBM will focus on Lotus Notes, making it the centerpiece of a communications and integration infrastructure for

Continued on page 89

SCHEMATIC CAPTURE

continued from page 36

Product:	WinScheme
Version:	1.2
Price	$179
Platform:	Windows
Publisher:	The Great SoftWestern Co., Inc.

WinScheme is a Windows schematic capture program that's very easy to learn and use. The program was originally written as an update for Schema to change the raster display to a vector display for more detailed images with faster response. However, Omation sold Schema to Accel Technologies (the makers of Tango, a high-end schematic capture/PC board layout package) before the project was finished. The result is a modified version of the original program with a different look and feel—and a low $179 price.

Just because the project was cut short, the software certainly wasn't. WinScheme is every bit as powerful as schematic capture programs costing much more. For example, it has a long list of file output formats for linking WinScheme schematics with many popular PC board layout programs, including OrCAD and Tango. It provides forward-annotation capability, where changes in the schematic are automatically reflected in the PC board layout for those formats that support it. And if those features aren't enough, you can also import WinScheme drawings into PSpice or Susie for analog and digital simulation, respectively.

Like SuperCAD+ for Windows, WinScheme supports MDI which lets you group and simultaneously load multiple schematics under a project umbrella for easy management. However, the drawings are not related, so they don't interrelate when it comes to preparing bill of material lists or doing design rule checking. SuperCAD+ for Windows schematics can be linked.

Frequently used schematic symbols, such as resistors and capacitors, can be quickly placed on the drawing from a pull-down menu or by using keyboard shortcuts (see Fig. 11). However, the majority of symbols are placed by highlighting the part from one of the component libraries. The library menu has a symbol previewer that shows you what the component looks like as you browse through the libraries. Unfortunately, repeat placement isn't supported. WinScheme comes with nearly 1000 predefined symbols, and creating new devices is simple enough.

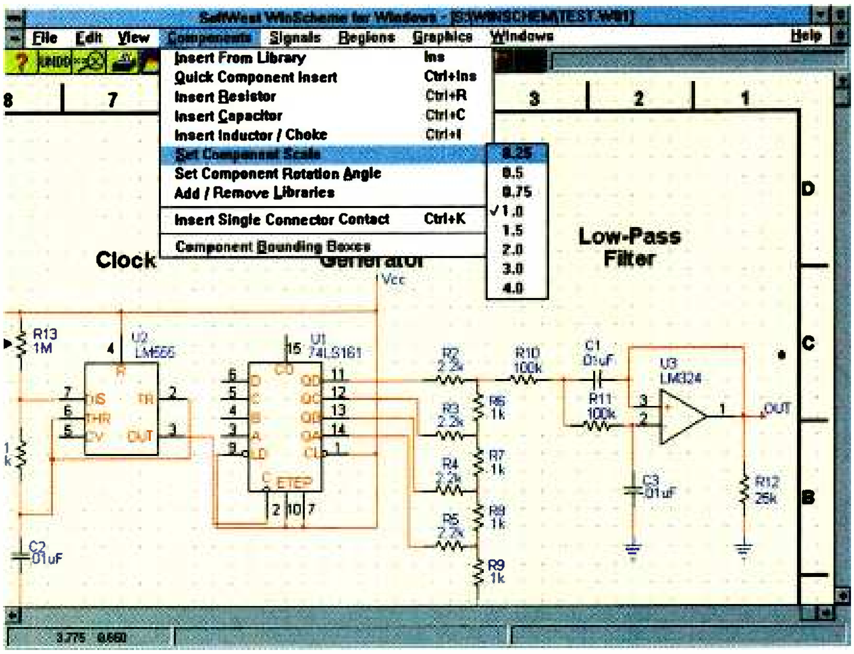


FIG. 11—WINSCHEME IS A WINDOWS SCHEMATIC CAPTURE PROGRAM with an abundance of built-in netlist formats, including PSpice and Susie simulation formats.

Unlike most schematic programs, you must enter the edit command before selecting the part to be edited. Clicking on a part without selecting an edit command brings up an information menu that lets you edit the component reference designator and value parameters. Attached nomenclature—including pin numbers—can be moved, copied, and rotated. The zoom is among the best in the business, with a 10,000-to-1 zoom ratio. You can set the zoom scale manually with a dialog box, or by drawing a box around the area you want to be magnified.

Wires are drawn with an auto router. All you do is click on the end points, and the router draws the wire for you, avoiding components and adding junctions as needed. For large designs, you can connect two components by entering the device references and pin numbers into a dialog box. All wires must have valid beginning and ending points; floating wires and dangling ends aren't permitted. This is done to preserve the integrity of the netlist, which otherwise would flag such occurrences as errors. While WinScheme supports rubberbanding, it works only with block moves. Wires will not stretch to follow a moved discrete device unless it's inside a block. A nifty feature, called a wire optimizer, minimizes wire lengths after making block moves.

WinScheme is a good schematic capture program with a lot of nice features. The number of netlist formats is second to none, the editing tools are powerful and easy to use, and the library is big enough to handle all but the most challenging designs. The only real complaint is the lack of linking between schematics, a drawback that essentially limits your design to whatever you can squeeze onto a single page. But this is an early release version, and the author promises a substantial upgrade in version 2.0, which should be available later this year. If you like the program, don't wait for the upgrade. The new release will be backward-compatible, and will be offered at a substantial discount to version 1.2 owners.

Product:	CircuitMaker
Version:	2.6
Price	$299
Platform:	Windows
Publisher:	MicroCode Engineering

CircuitMaker is an integrated Windows schematic capture and circuit simulation program with a $299 price tag. Like Interactive Image's Electronics Workshop, CircuitMaker is targeted at the user who wants to turn the PC into an electronic breadboard, complete with software-emulated power supplies, signal generators, voltage/current meters, and an oscilloscope. Here, we'll concentrate on the schematic drawing portion of the package. Besides CircuitMaker's ease of use, it also has excellent editing features. More precisely, it's edit-after-placement features are outstanding—but this turns out to be a double-edged sword, because you must use them frequently.

For example, you can't define a part's value during placement; it must be done afterwards. No, it's not like some of the schematic draw programs reviewed here where the values are unattached pieces of text. All device references are a part of the component, and they move as the part moves. It's just that in the beginning they're all the same. For example, the default value for fixed resistors is 1 kilohm, while capacitors—both fixed and variable—are given a value of 1 µF; inductors default to 1 µH. That means you will be forced to use the editor to change the values to those that your design requires—and that's why you'll be glad the editor is so easy to use.

Double clicking on any part of the circuit brings up a menu that lets you change any of the circuit's attributes, including its part value. Moreover, should any of the part's nomenclature conflict with another device or text, it can be moved and rotated by a simple drag and drop operation. The parts, too, are easily moved and oriented with simple mouse clicks and/or keystrokes. An excellent menu bar lets you place wires, junctions, and components without having to access a menu. And there's rubberbanding for both devices and blocks. However, the rubber wires snap to orthogonal routing, which can be annoying when moving a multipin device because the wires often overlap into what looks like a bus on the drawing, without labels.

The component library comes with all the devices needed to draw the rather-demanding example schematic, plus a surprising number of objects you wouldn't expect to find in a library this small, like a programmable 1 kilohm RAM chip with SPICE parameters. But finding the parts can be a test of patience. That's because the 217 library symbols are simply tossed into 10 pull-down menus, with no rhyme or reason to their order—and there's no dialog box shortcut. That means you often have to search through several menus before finding the part you are seeking for (see Fig. 12). What's worse, as new devices are added, they are tacked on to the end of this queue in the order in which they are created. When a pull-down menu is full (each menu holds just 24 parts), CircuitMaker automatically creates a new pull-down menu and proceeds to fill it. This is clearly a clumsy way to catalog components. Thankfully, once a part is accessed from the library, it can be repeatedly placed on the drawing. Auto annotation and on-the-fly rotation/mirroring is provided, as is global re-annotation after placement. A nice touch is CirciutMaker's ability to turn off repeat placement and auto annotation individually, which speeds up the drawing of simple schematics.

There are two ways to create new devices. If you need a complex design, such as a phase-locked loop, the fastest method is to use CircuitMaker's macro editor, which assembles the device from other library components. For simpler devices, such as a neon lamp, the best method is to create the device from primitives (lines and circles) with a drawing program, like Paintbrush. The knack to using a drawing program, though, is adjusting the new part's size to match those already in the library, which takes practice.

It is very easy to draw a profes-

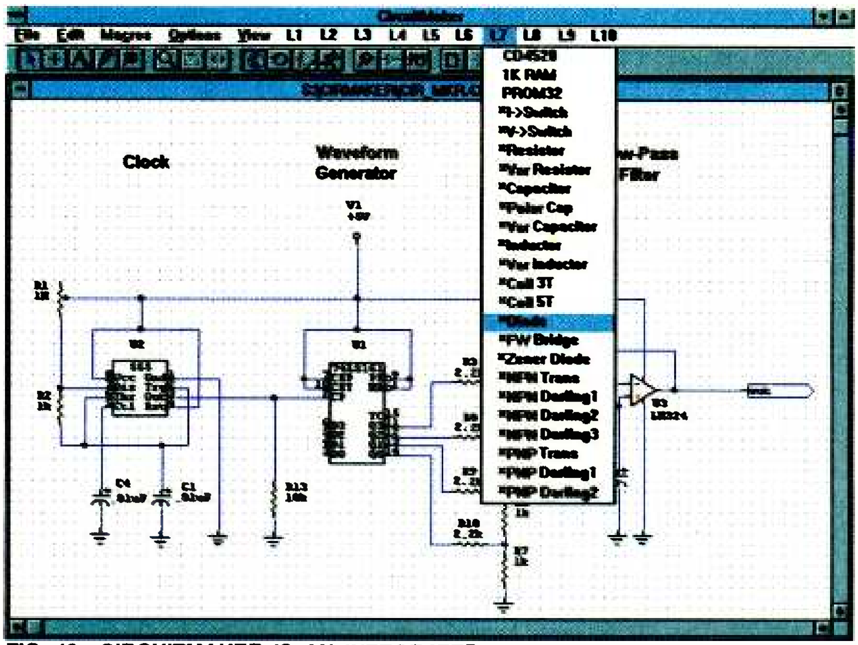


FIG. 12—CIRCUITMAKER IS AN INTEGRATED SCHEMATIC CAPTURE and circuit simulation program with excellent editing features.

sional-quality schematic with CircuitMaker, and its powerful analog/digital circuit simulator is even better. For the circuit designer who doesn't need PC board layout, this is an excellent choice. You can find a demonstration version of it on the Gernsback BBS. The demo's also available, along with online technical support and upgrades, on CompuServe.

Product:	Electronics Workbench
Version:	4.0
Price	$299
Platform:	DOS or Windows
Publisher:	Interactive Image Technologies

Touted as "The electronics lab in a computer," Electronics Workbench is an integrated schematic capture and circuit simulation program whose primary purpose is the design and verification of circuits using your PC as a test bed. While that's true, it does a decent job of drawing schematics, too, and can generate OrCAD netlists for PC board layout (the latter is a $75 extra cost option). Electronics Workbench sells for $299, the same as CircuitMaker, its closest competitor.

Electronic Workbench comes in both a DOS and Windows version which are practically identical. The screen is conveniently laid out, with the library parts located in a column to the left, and the libraries expressed as icons in the toolbar just above the worksheet (see Fig. 13). Parts are placed on the drawing by clicking on the library symbol, dragging it to its destination, and dropping it into place. Part rotation is done after placement. While there's no mirror function per se, the rotation command eventually gives you mirrored versions of many of the devices if initiated often enough. (For example, after three rotations, the inverting and noninverting inputs of an op-amp trade places; another rotation flips the op-amp left to right for true mirroring.) Unfortunately, most logic devices, which constitute up nearly three-fourths of the library's

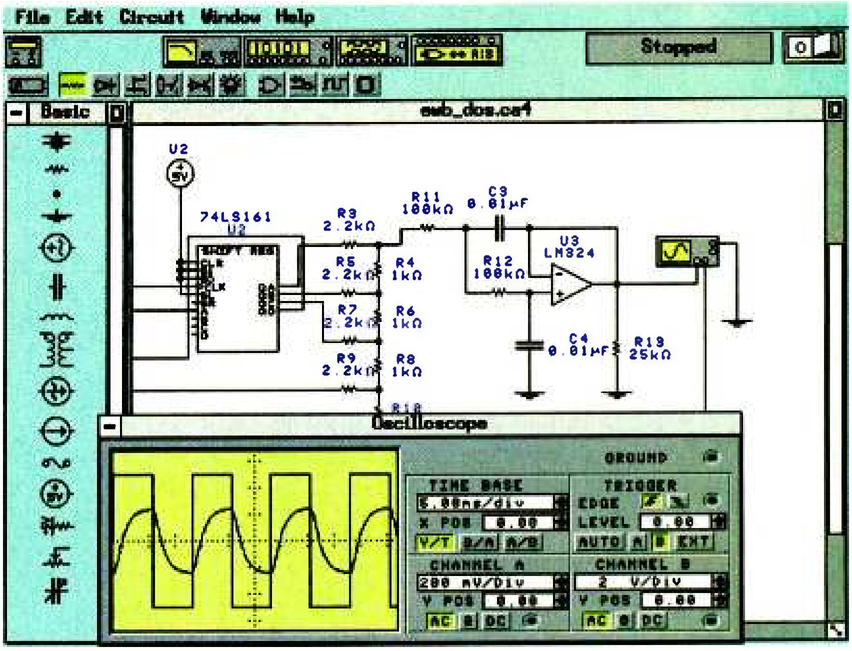


FIG. 13—PLACING PARTS on an Electronics Workbench schematic is as easy as clicking on the symbol icon and dragging it into place.

350 devices, can't be rotated. You can let the auto router place wires on the diagram by clicking on the destination and dragging the wire to a valid termination; the auto router maps the route, avoiding components and other wires.

Components can be moved with a simple click and drag procedure; rubberbanding is always engaged, so components never lose connection. However, the results are often less than pleasing, with wires that crisscross so often that they're hard to trace. A complex series of moves took nearly 20 minutes to sort the jumble of wires—a process that was complicated by Electronics Workbench's lack of block moves and zoom.

Double clicking on a part brings up a menu that lets you modify various parameters, depending on the kind of part it is. For example, double clicking a resistor lets you set its value (default is 1 ohm). Double clicking on an 74xx brings up a menu of logic devices, from which you can choose CMOS or TTL logic, and the device type (e.g., 74LS08). It has a library of "ideal" gates that can be converted to real-world devices as the design matures. To change other parameters, such as part reference, you have to highlight the part and choose the appropriate edit command from the circuit pull-down menu. All nomenclature is fixed in place, and can't be moved or edited.

Unlike CircuitMaker, Electronics Workbench won't let you create new devices; only Interactive can do that. However, designs can be saved as subcircuits in a library, which appear as boxes on a new schematic. That means you can create compound components, like an LM555, from gates and transistors. Selecting the semiconductors that equal the performance of the real part, however, is a challenge. Additional library modules are available for $75 each ($200 if you buy all four).

The DOS version has an adjustable percentage formula that lets you fit the drawing to the page—if you take the time to figure out what percentage it takes to fill the page. Plotters are supported only in the Windows version, which basically supports any output device you have loaded into your Windows print manager. The DOS version also has a screen capture feature that saves the schematic to a PCX file (which was used for Fig. 13).

Schematic capture with PC board layout

The programs described pre-

TABLE 1

	AutoSkem	BoardMaker I	CADPAK II ISIS Supersketch	CircuitMaker	Easy-PC	Easy-PC Pro	Electronics Workbench	EZ-Route Std EZ-Logic	Schematic Plus	SuperCAD	SuperCAD for Windows	TurboCAD for Windows	WinScheme
Price	$29	$95	$159	$299	$195	$349	$299	$249	$20	$99	$149	$99	$179
Format	DOS	DOS	DOS	Windows	DOS	DOS	Win/DOS	Windows	Windows	DOS	Windows	Windows	Windows
RAM required	384K	512K	640K	2MB	512K	640K	4MB	512K	2MB	640K	1MB	2MB	2MB
Hard disk required	N	N	2MB	7MB	N	5MB	4MB	3MB	N	N	2MB		10MB
Schematic	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Capture	N	N	N	Y	N	Y	Y	Y	N	Y	Y	N	Y
PCB netlist	N	N	N	N	N	Y	Y(1)	Y	N	Y	Y	N	N
Simulation netlist	N	N	N	Y	N	Y	Y(1)	Y	N	Y	Y	N	Y
Design rule check	N	N	N	N	N	Y	Y	Y	N	Y	Y	N	Y
PCB Layout	N	Y	Y	N	Y	Y	N	Y	N	N	N	N	N
Circuit Simulation	N	N	N	Y	N	Y	Y	N	N	Y	Y	N	N
Analog	N	N	N	Y	N	Y(1)	Y	N	N	Y(1)	Y(1)	N	N
Digital	N	N	N	Y	N	Y(1)	Y	N	N	Y(1)	Y(1)	N	N
Drawing Features													
Ortho disable	n/a	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	N
Diagonal wires	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	N
Auto annotate	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	N	Y
Supports buses	N	N	Y	Y	N	N	N	Y	N	Y	Y	N	Y
Repeat object placement	N	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N
Rotate part prior to place	Y	Y	Y	Y	Y	Y	N	N	Y	M	M	Y	Y
Zoom range/on-the-fly	n/a	Y	Y	20:01	Y	Y	N	Y	n/a	draw to fit	24:1	n/a	10,000:1
Auto pan	N	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	N
Find/search	N	N	Y	N	N	N	N	N	N	Y	Y	N	N
Editing Features—Placement													
Rotate	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mirror	N	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y
Find	N	N	Y	N	N	N	N	N	N	Y	Y	N	N
Undo	N	N	Y	Y(2)	N	N	N	Y	N	Y	Y	Y	Y
Rubberband	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y
Block													
Move	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Hide	N	N	N	N	N	N	N	N	N	N	N	Y	N
Delete	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Save	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y
Part reference													
Move	Y	n/a	Y	Y	N	Y	N	N	N	N	N	n/a	Y
Hide	N	n/a	Y	N	N	N	N	N	N	Y	Y	n/a	Y
Delete	Y	n/a	Y	Y	N	N	N	N	N	N	N	n/a	Y
Adjustable font size	Y	n/a	N	N	N	N	N	N	N	N	N	n/a	N
Global reannotate	N	n/a	Y	Y	N	N	N	N	N	Y	Y	n /a	N
Library													
Screen directory	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y
DeMorgan	N	N	Y	N	N	N	N	N	N	Y	Y	N	Y
Printer Output													
Fit to page	Y	Y(3)	N	N	N	N	Y	n/a	n/a	N	n/a	n/a	n/a
Border off	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Y	n/a	Y	Y	n/a	n/a
Title box off	n/a	n/a	n/a	Y	n/a	n/a	n/a	Y	n/a	Y	Y	n/a	n/a
Software control	Y	Y	Y	Y	Y	Y	Y	Y	n/a	Y	Y	n/a	n/a
Plotter Output													
Fit to page	Y	Y	Y	N	N	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maximum page size (inches)	8 × 20	17 × 17	34 × 34	34 × 34	17 × 17	17 × 17	n/a	34 × 34	n/a	n/a	34 × 34	n/a	n/a
Software control	Y	Y	Y	N	Y	Y	n/a	Y	n/a	n/a	Y	n/a	n/a

1) Extra cost **2) Limited to move and change only** **3) Except dot-matrix printers**

viously have been pretty much mix-and-match, allowing you to assemble a circuit design package a la carte. The really serious user, however, will want an integrated package—in other words, schematic capture with linked PC board layout and forward and backward annotation. However, pricing on these programs generally starts at $500, and quickly escalates from there. Fortunately, there are two packages that won't break your piggy bank. Here are their stories.

Product:	EZ-Route
Version:	2.2
Price	$249
Platform:	Windows
Publisher:	Advanced Microcomputer Systems

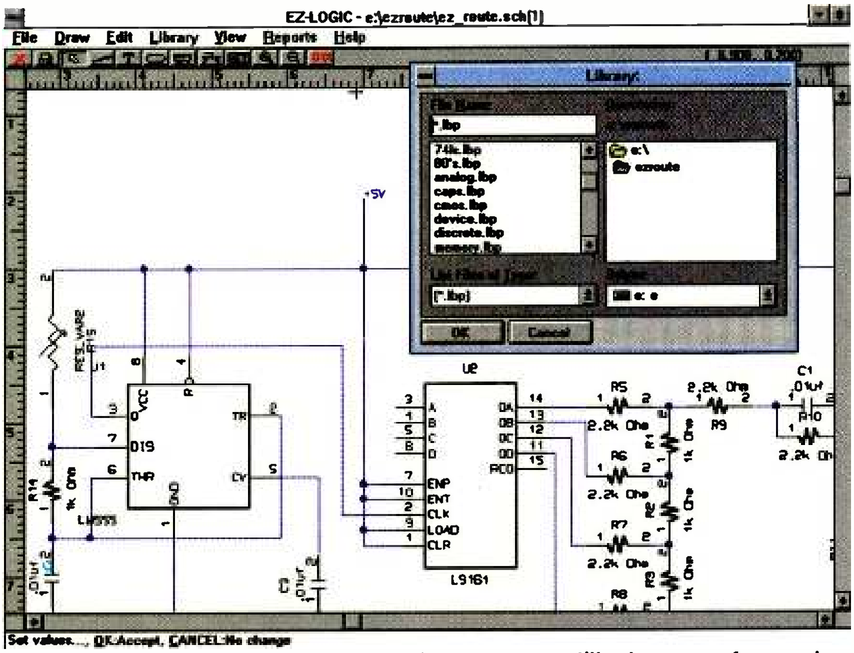


FIG. 14—WHILE THE SCHEMATIC itself is rustic and utilitarian, not of magazine quality, the link between EZ-Route's schematic capture (EZ-Logic) and PC board layout (EZ-Route) programs is fantastic.

It usually costs a fair chunk of change to buy netlist-linked schematic capture and PC board layout software. That's why it was delightful to find EZ-Route Std selling for just $249. In addition to linked schematic capture and PC board layout, EZ-Route Std includes design verification and interactive error checking—plus SMD (surface-mount device) support.

Each program is separate and differs in both looks and operation. For instance, the schematic capture drawing menu lists the drawing options as wires, buses and lines, whereas the PC board layout draw menu offers tracks, pads, and lines. Each program is run as an individual application and, yes, you can run both at the same time and switch between them with Windows' task manager. Moreover, changes made in the schematic are readily recognized by the PC board layout program. This means you can essentially make modifications to the schematic on the fly as you lay out the circuit board. Best of all, each schematic can have as many as 32 pages—all of which are linked to each other and to the PC board layout program.

Unfortunately, EZ-Route Std schematics have a very busy look because the netlist references are always visible and can't be hidden. In other words, it's not something you'd want to publish (see Fig. 14). That's a shame because the program includes thousands of symbols, including DeMorgan equivalents, in a dozen libraries. While components are easily placed from an on-screen menu, you can only guess at what they will look like because nowhere—not on the screen or in the user's manual—are they pictured. You must sort through several parts before you find the ones you need. Worse yet, you can't rotate or mirror the symbol prior to placement. All editing is done afterward, and even then you can't edit a part's value. That's why a 27 kilohm load resistor was placed on the output of the op-amp instead of the 25 kilohm resistor called for. A 25 kilohm resistor could have been created and added it to the library, but that probably would be too much trouble for what should be a simple value change. Library symbols are created and modified with a separate program under a third icon.

Fortunately, the PC board layout side of EZ-Route Std is a lot stronger than the schematic capture program. Basically, AMS has put its effort into what really counts—linking schematic capture with a hot PC board layout program. Moreover, the schematic netlist can be read by a number of major CAE applications and simula-

Product:	Easy-PC Pro
Version:	N0444
Price	$349
Platform:	DOS
Distributor:	BSOFT Software

A problem with reviews that split integrated programs into separate functions is that you sometimes get a bad image of the software because of something that was said at the beginning of the series. Such is the case of Easy-PC Pro, a second-generation PC software package from the makers of Easy-PC. Essentially, Easy-PC Pro is a classy PC board layout program hooked up with squirrely front-end schematic capture software that is unappealing and hard to use. However, the program also links the schematic capture to optional analog and digital simulation programs (Analyzer III and Pulsar, respectively). In addition, will accept and convert Easy-PC schematics into netlist format for PC board layout. What you get for $349 is the nucleus of a fairly powerful design/

test/production software package. For $298 more ($647 total), you get the whole package.

As expected, Easy-PC Pro has the look and feel of BoardMaker I and Easy-PC. But, like EZ-Route Std, the schematic is too busy with netlist details to provide magazine quality. And the schematic is unclear because wire connections are made accompanied by a beeping sound as you wire the diagram, rather than by the placement of the dot normally used to represent connected wires. So without a netlist, you haven't a clue as to which wires connect and which just pass in crossing.

Schematic parts are easily accessed and placed from a pull-down menu. Parts can be rotated and mirrored before and after placement, and the zoom and pan features are excellent, letting you roam as you please while placing wires or parts. Moreover, there's auto annotation and repeat parts placement. Part references and values can be moved anywhere on the drawing with a simple edit-text command. All capacitors come with a default value of 100 nanofarads, and resistors start life as 1 kilohm clones. The values can be edited before or after placement. However, it would be nice to know what the

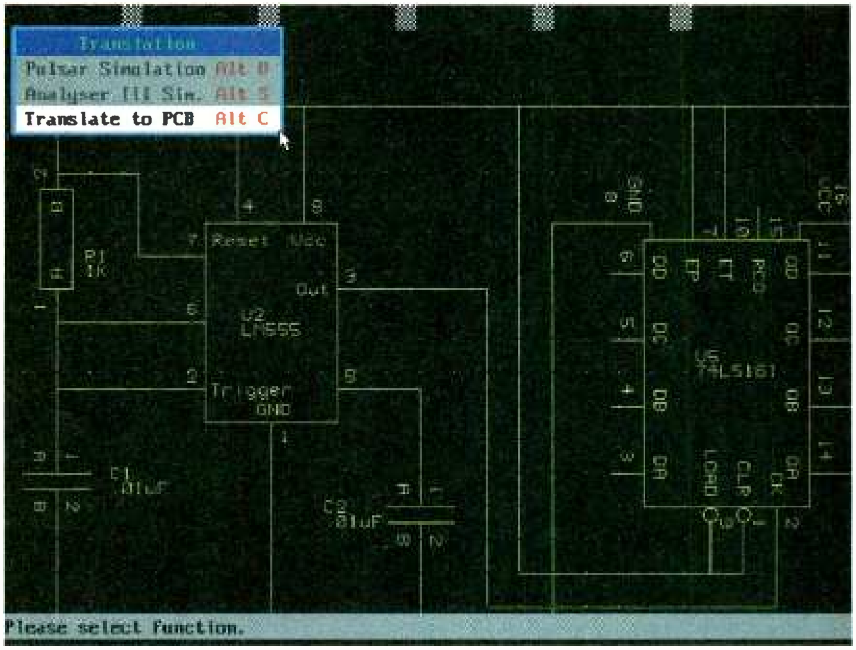


FIG. 15—WE'D BE EMBARRASSED to publish an Easy-PC Pro schematic. There are no junction dots, so you must guess which wires pass and which connect, and the netlist references are distracting.

symbol looks like before you place it (there's no chart like Easy-PC provides), because some are really poor (look at the 74LS161 chip in Fig. 15).

None of the libraries have a 555 timer, which had to be created for this project, or a variable resistor. That's because the variable resistor made for Easy-PC isn't in the same format, and making new parts for Easy-PC Pro is not an easy chore. Briefly, you start with a library symbol editor, which provides the seed file for the generation of the schematic component and PC board components. Altogether, you wade through four editors and two files—quite an ordeal. But in the end, you have a symbol that works with all of the Easy-PC products, including the circuit simulators. Printer and file output functions are identical to those of Easy-PC.

The way Easy-PC Pro displays schematics isn't the best way, and creating new parts leaves a lot to be desired. But Easy-PC Pro does a lot more than draw schematics, and the price is right.

Schematic summary

As you can see, these programs draw schematics that range from good to acceptable to utilitarian; Price is absolutely no indication of what to expect. On presentation quality alone, WinScheme ($179) wins. It comes closest to the professionally drawn diagrams you find in *Electronics Now*, and it has very strong schematic editing features. CircuitMaker ($299) places a strong second. And for the money ($20), the quality of Schematic Plus drawings is very good. All three are Windows applications. Ω

WHERE TO BUY

BSoft Software, Inc.
444 Coltran Rd.
Columbus, OH 43207
(614) 491-0832
CIRCLE 347 ON FREE INFORMATION CARD

Ohio Automation
7840 Angel Ridge Rd.
Athens, OH 45701
(614) 592-1810
CIRCLE 348 ON FREE INFORMATION CARD

R4 Systems Inc.
1100 Gorman St., Suite 11B-332
Newmarket, Ontario, Canada L3Y 7V1
(905) 898-0665
CIRCLE 349 ON FREE INFORMATION CARD

MicroCode Engineering
1943 North 205 West
Orem, UT 84057
(801) 226-4470
CIRCLE 350 ON FREE INFORMATION CARD

BSoft Software, Inc.
444 Coltran Rd.
Columbus, OH 43207
(614) 491-0832
CIRCLE 351 ON FREE INFORMATION CARD

Interactive Image Technologies Ltd.
111 Peter St. #801
Toronto, Ontario, Canada M5V 2H1
(800) 263-5552
CIRCLE 352 ON FREE INFORMATION CARD

Advanced Microcomputer Systems, Inc.
1460 SW 3rd St.
Pompano Beach, FL 33069
(800) 972-3733
CIRCLE 353 ON FREE INFORMATION CARD

Mental Automation Inc.
5415 136th Place S.E.
Bellevue, WA 98006
(206) 641-2141
CIRCLE 354 ON FREE INFORMATION CARD

IMSI
1938 Fourth St.
San Rafael, CA 94901
(415) 454-7101
CIRCLE 355 ON FREE INFORMATION CARD

The Great SoftWestern Co., Inc.
919 South Carroll Blvd., Suite 103
Denton, TX 76201-6869
(817) 383-4434
CIRCLE 356 ON FREE INFORMATION CARD

AUDIO AMPLIFIER

continued from page 34

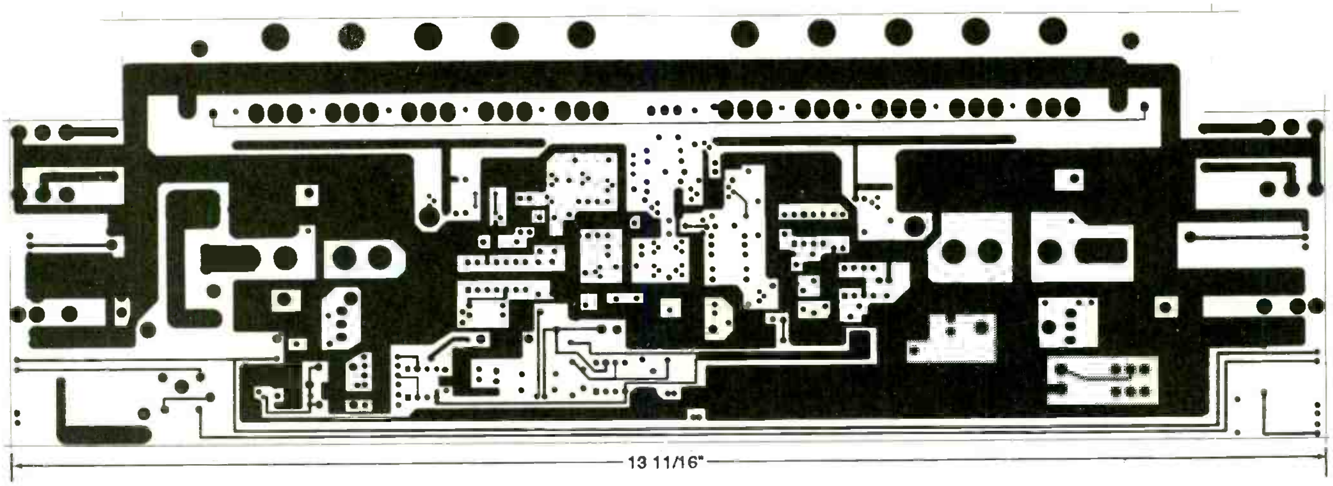
unity gain, splitting the approximately 8-volt bias generated by Q24 and applying it to the output transistor gates referenced to the power supply rails. Transistor Q24 is mounted on the heatsink to allow the bias to track the output stage temperature. Transistors Q14 and Q15 are emitter followers that drive the output transistors Q16-Q23. Finally, the output is obtained from the drains of the output transistors through relay RY1.

The output signal follows two feedback paths: the first is through resistor R36 to resistors R31, R32, and R35, setting the output stage voltage gain at about 30. The second feedback path, resistors R37 to R14 and the input differential amplifier, sets the overall amplifier gain at about 29, with a closed-loop bandwidth of about 350 kHz. This completes the primary signal path from the input terminals input to the speakers.

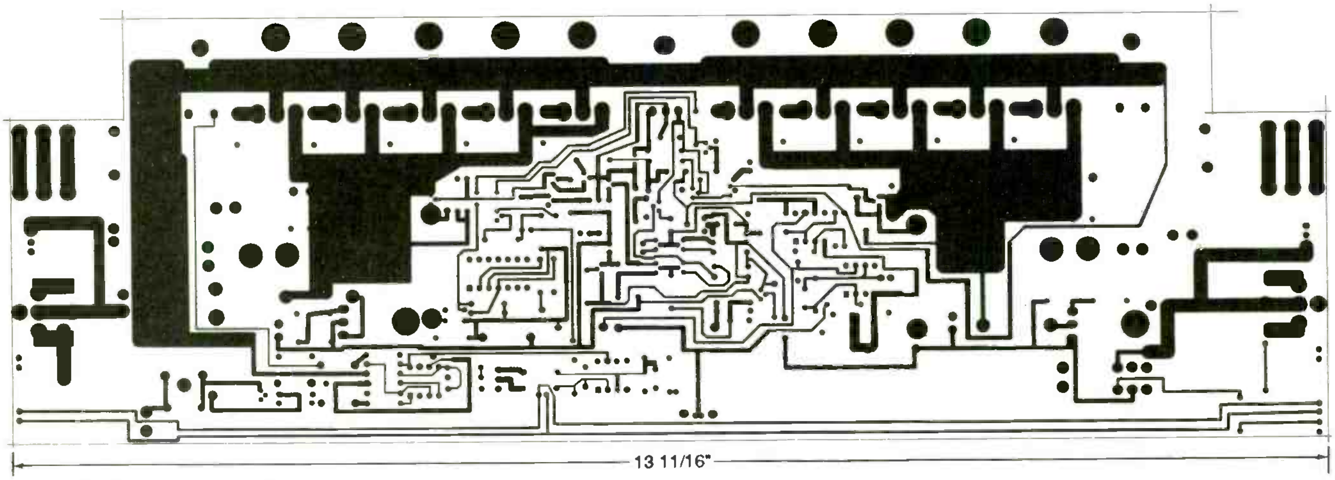
The amplifier circuit board also performs several other functions in addition to processing the audio signal. The first of these other functions is automatic servo-nulling of DC input offset voltages, performed by IC4, an LF411 JFET opera-

TABLE 1
AMPLIFIER SPECIFICATIONS

Power Output: (RMS/Channel) (Both channels driven)	>300 W into 8 ohms, >600 W into 4 ohms >700 W into 2 ohms
Frequency Response:	2 Hz - 300 kHz, +0, −1 dB
Total Harmonic Distortion	<0.05% 20 Hz - 20 kHz
Slew Rate:	200 V/μs (typical)
Rise Time:	500 ns (typical), 600 ns (rail-to-rail)
Pulse output current capability:	>50 A into 1 ohm
Damping Factor:	>200
Signal-to-noise ratio:	100 dB, 20Hz - 20 kHz
Dimensions (case with fans)	16.5×14×3.5 inches (19-inch rack mountable)
(case without fans)	16.5×14x×5.5 inches
Weight:	18 pounds



AMPLIFIER CIRCUIT BOARD PATTERN, component side.



AMPLIFIER CIRCUIT BOARD PATTERN, wiring side.

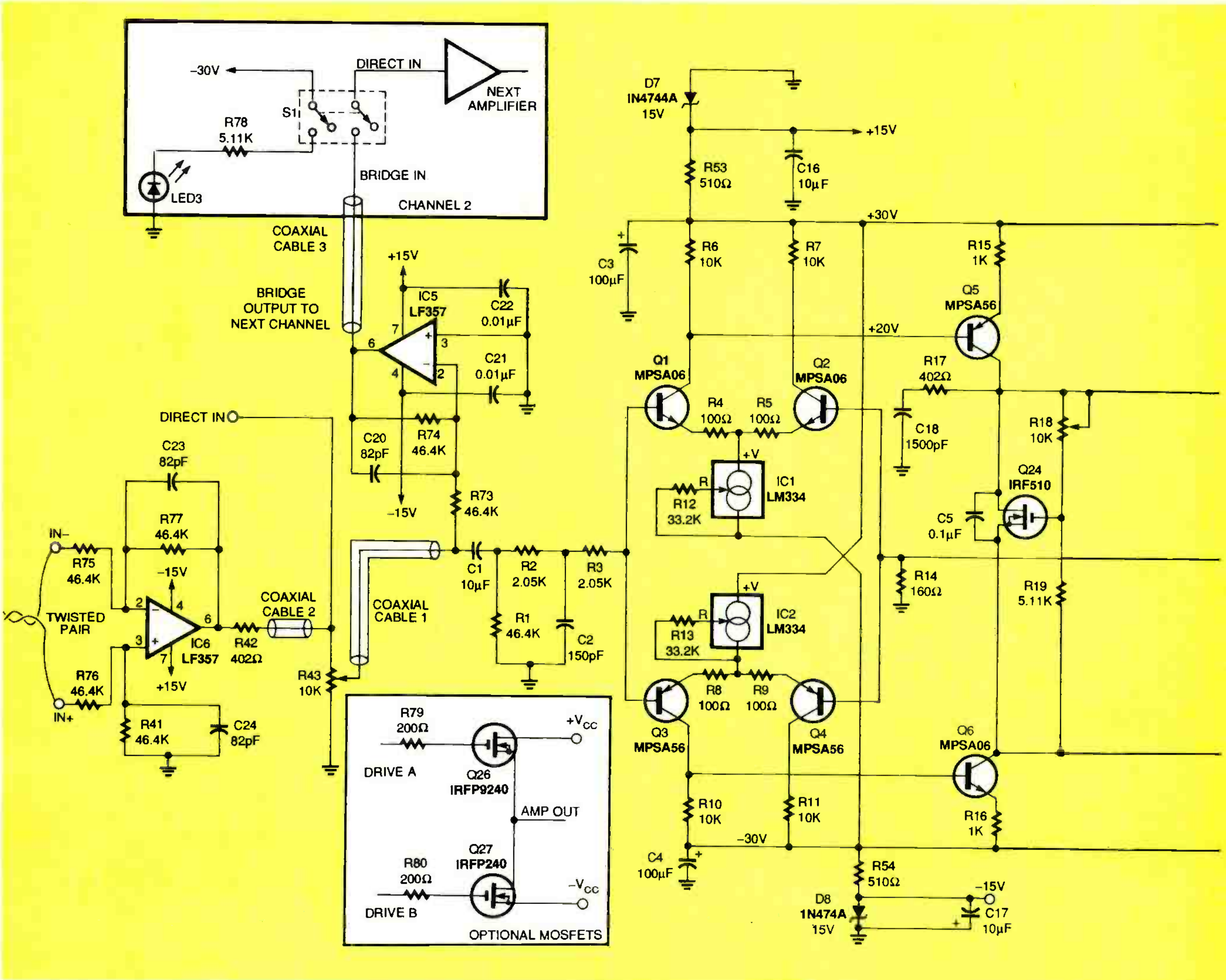


FIG. 2—SCHEMATIC FOR TWO AMPLIFIER CHANNELS. Bridge circuitry in box (upper left) shows bridging circuitry between channels.

PARTS LIST—AMPLIFIER BOARD

All resistors are ¼-watt, 1%, unless otherwise specified.

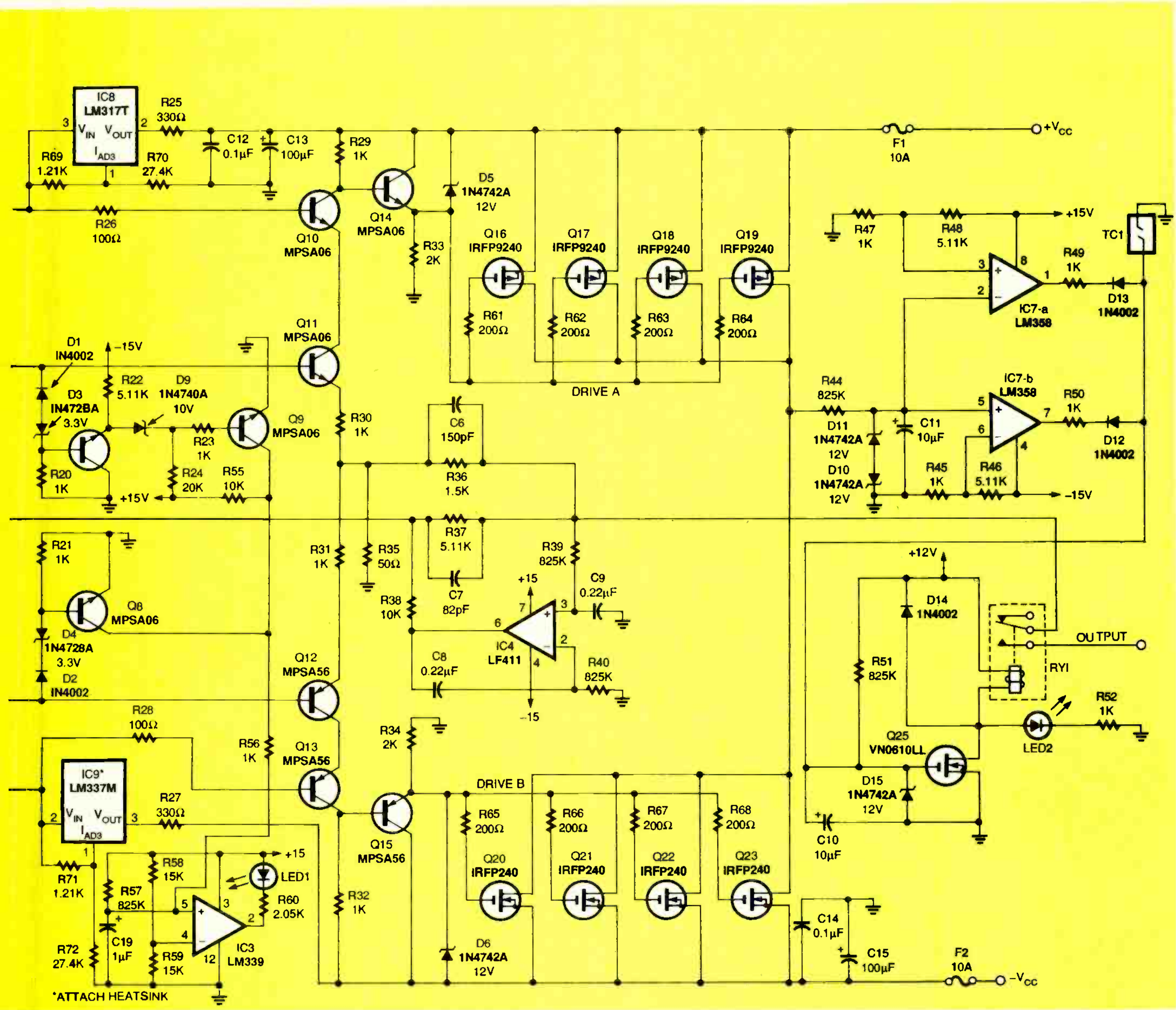
R1, R73, R74, R75, R76, R77—46,400 ohms
R2, R3, R60—2050 ohms
R4, R5, R8, R9, R26, R28—100 ohms
R6, R7, R10, R11, R38, R55—10,000 ohms
R12, R13—33.2 ohms
R14—162 ohms
R15, R16, R20, R21, R23, R29, R30, R31, R32, R45, R47, R49, R50, R52, R56—1000 ohms
R17—402 ohms
R18, R43—10,000 ohms, trimmer potentiometer, PCB mount, top adjust Clarostat 408N103
R19, R22, R46, R48, R78—5110 ohms
R24—20,000 ohms
R25, R27—330 ohms, 3 watt, 10%
R33, R34—2000 ohms, 5 watts, 10%
R35—50 ohms
R36—1500 ohms, 2 watts, 10%
R37—5110 ohms, ½ watt, 10 %
R39, R40, R44, R51, R57—825,000 ohms
R41—46,400 ohms
R42—402 ohms
R53, R54—510 ohms, 1 watt, 10 %
R58, R59—15,000 ohms
R61, R62, R63, R64, R65, R66, R67, R68, R79, R80—200 ohms
R69, R71—1210 ohms
R70, R72—27,400 ohms
R79, R80—200 ohms (optional)

Capacitors

C1—10µF, polyester film
C2, C6—150 pF ceramic monolithic
C3, C4—100µF, 50 V, aluminum electrolytic
C5—0.1µF, 50V, polyester film
C7, C20, C23, C24—82 pF ceramic monolithic
C8, C9—0.22µF, 50 volts polyester film
C10, C16, C17—10µF, 25 volts aluminum elecrtrolytic
C11—10µF, 35 volts aluminum electrolytic
C12, C14—0.1µF, 100 volts polyester film
C13, C15—100µF 100 volts, aluminum electrolytic
C18—1500 pF ceramic monolithic
C19—1µF, 25 volts volts, aluminum electrolytic
C21, C22—0.01µF, 50 volts, polyester film

Semiconductors

D1, D2, D12, D13, D14—1N4002 sil-



icon diode
D3, D4— 1N4728A silicon diode, 3.3V
D5, D6, D10, D11, D15—1N4742A silicon diode;12 V
D7, D8—1N4744A, silicon diode, 15V
D9—1N4740A silicon diode, 10V
LED 1, LED 2, LED 3—light-emitting diode T-1-3/4, red or green
Q1, Q2, Q6, Q8, Q9, Q10, Q11, Q14—NPN transistor, Motorola MPSA06, or equiv.
Q3, Q4, Q5, Q7, Q12, Q13, Q15—PNP transistor Motorola MPSA56, or equiv.
Q16, Q17, Q18, Q19—P-channel, depletion mode MOSFET, International Rectifier IRFP9240 or equiv. (Q26 optional—see text)
Q20, Q21, Q22, Q23—N-channel, depletion-mode MOSFET, International Rectifier IRFP240 or equiv. (Q27 optional—see text)
Q24—N-channel MOSFET, depletion mode, International Rectifier IRF510 equiv.
Q25—VN0610LL N-channel MOSFET switch (TO-92) Motorola or equiv.
IC1, IC2—LM334Z constant-current source, National or equiv.
IC3—LM339AN quad comparator, National or equiv.
IC4—LF411CN JFET input op-amp Texas Instruments or equiv.
IC5, IC6—LF357N JFET input op-amp, National or equiv.
IC7—LM358 dual low power op-amp National or equiv.
IC8—LM317T medium-current, three terminal adjustable positive voltage regulator, Motorola or equiv.
IC9— LM337M medium current,3-terminal adjustable negative voltage regulator, Motorola or equiv.

Other components

F1, F2—fuse, 10 A
J1—jack, RCA-style
J2—jack, ¼ inch Rean No. 550-20301 or equiv.
RY1—relay, PCB, Potter & Brumfield T90N5D12-12 or equiv.
S1—switch, DPDT, E-Switch TA2EECAU or equiv.
TC1—thermostat, 80°, Airpax 67F080 or equiv.

Miscellaneous (amplifier board): amplifier circuit board, two heatsinks for TO-220 devices, five dual screw terminal blocks, OST, Inc. No. 16 and No. 18 insulated hookup wire, solder

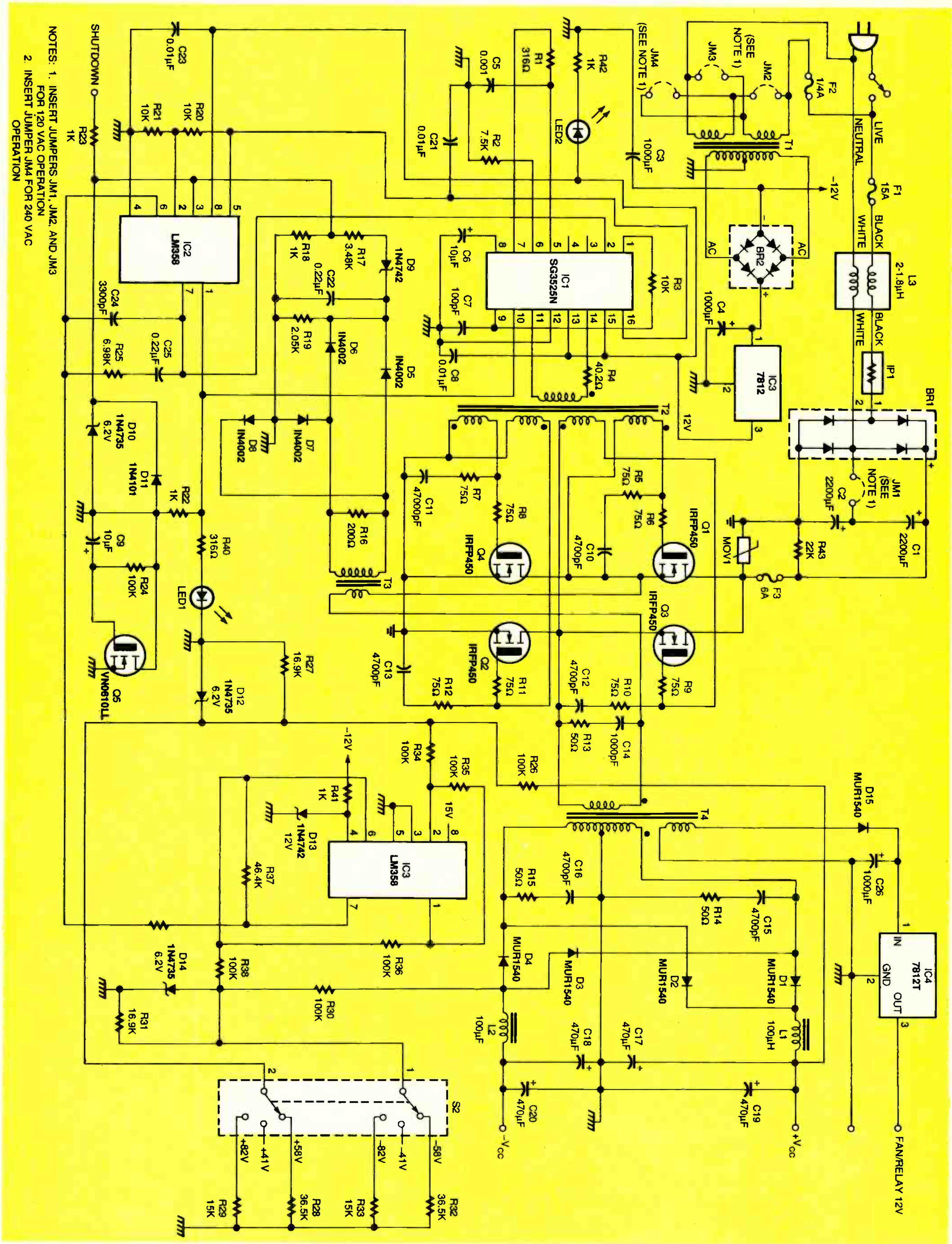


FIG. 3—SCHEMATIC FOR SWITCHING POWER SUPPLY. Circuit is a full bridge configuration that switches at 75 kHz based on four power MOSFETs.

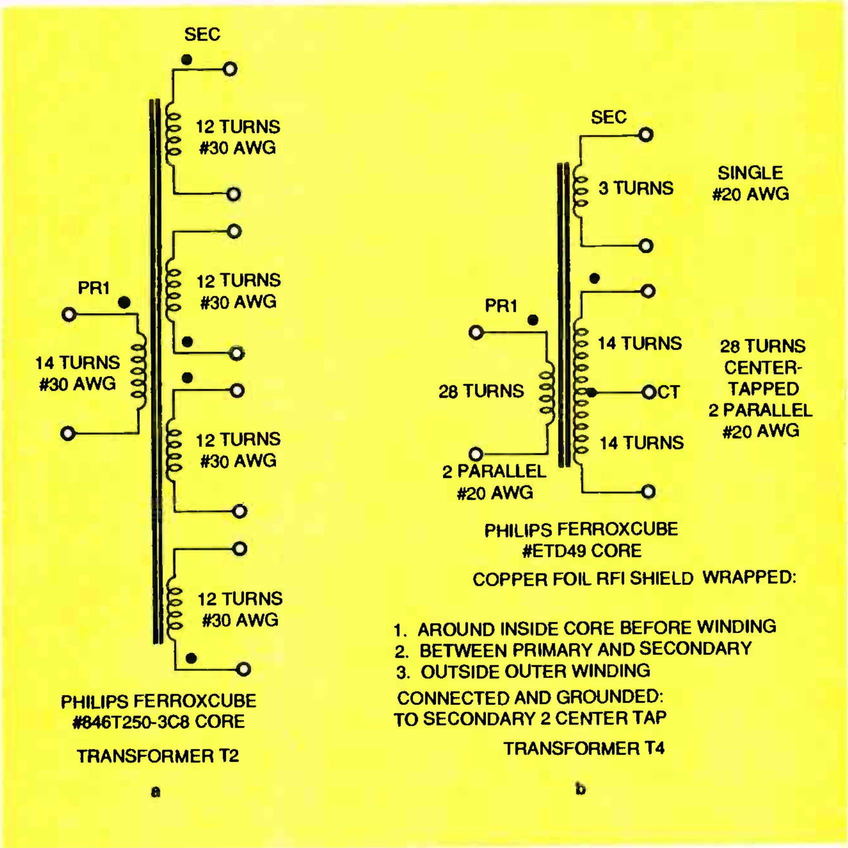


FIG. 4—TRANSFORMER WINDING INSTRUCTIONS for custom-made transformers T2 (a) and T4 (b).

tional amplifier that eliminates any DC at the output of the amplifier. This op-amp senses any DC at the output, and injects a compensating current through R38 into the feedback side of the input differential amplifier.

Next, transistors Q7 to Q9 detect amplifier clipping by sensing excessive internal drive signals that could occur when the feedback loop becomes nonlinear under overload conditions. Op-amp IC3, C19, and R57 capture any clipping that occurs and light LED1 for a minimum duration of 1 second.

Both sections of IC4(a and b) detect the presence of any DC offset at the output of the amplifier, and will de-energize relay RY1 to protect the speaker. TC1 is a thermal protector, which can also de-energize RY1 if the amplifier is overheating.

Voltage regulators IC8 and IC9 maintain the supply voltage for the input stages at ±30 volts. However, the output stage supply voltage can vary from ±41 volts to ±82 volts, as determined by the switching power supply setting. Diodes D11 and D12 regulate the ±15 volts for the operational amplifiers.

Switching power supply

Figure 3 is the schematic for the switching power supply. It is an off-line, full bridge circuit with both output current protection and shutdown capability and it offers three output voltage-setting options.

Line power input is filtered and rectified by inductor L3, full-wave bridge BR1, and capacitors C1 and C2. With jumper JM1 in place, bridge BR1 and C1 and C2 form a voltage doubler. MOSFETs Q1 to Q4 form a bridge with Q1 and Q2 and Q3 and Q4 conducting alternately in pairs. The bridge is driven by pulse transformer T2 from the SG3525N Silicon General monolithic pulse-width modulator/driver IC1. Transformer T4, the main power transformer, is driven by Q1 to Q4. Its output is rectified by fast-recovery rectifiers D1 to D4 and filtered by capacitors C17 to C20.

The positive output is divided by resistors R26 and R27. Resistor R27 is in parallel with either resistors R32 and R33, or no resistor. The feedback signal is fed to one section of the LM358 dual, low-power operational amplifier, IC3-a, acting as an inverting buffer amplifier. Its output is summed with a similar divider fed from the negative supply bus.

Operational amplifier IC3-b is an inverting summer whose gain of 0.42 is set by the ratio of the value of resistor R37 to that of R36. Zener diodes D12 and D14 ensure that neither power rail supplies more than approximately half of the 11.9 volt summed input necessary to generate the +5 volt sum output. The voltage at pin 7 of IC3-b is fed back to the pulse-width modulator comparator input pin 2 of IC1, where it is compared with the internal voltage reference applied to pin 1.

The feedback path includes a compensation network consisting of one section of an LM358 dual, low-power op-amp IC2-b, R25, C24, C25, and R39. Current in the bridge inverter is sensed by current transformer T3, whose output is rectified and filtered by silicon diodes D5 to D8 and capacitor C22. The transformer output is 2 volts for every ampere of current.

The result is compared with a fixed 2.5-volt reference by IC2-a, and if excessive current is detected, a shutdown signal is sent to pin 10 of IC1 and LED1 lights. The shutdown condition is latched through the diode D11 feedback path, until C26 charges. When C26 is charged, transistor Q5 resets the shutdown condition.

A small, low-voltage power supply consisting of transformer T1, full-wave bridge BR2 and monolithic regulator IC4 generates +15 volts to power the inverter's control circuits. Power for the 12-volt tubeaxial cooling fans is obtained from a separate winding on transformer T4 after being rectified by diode D15 and regulated by voltage regulator IC4.

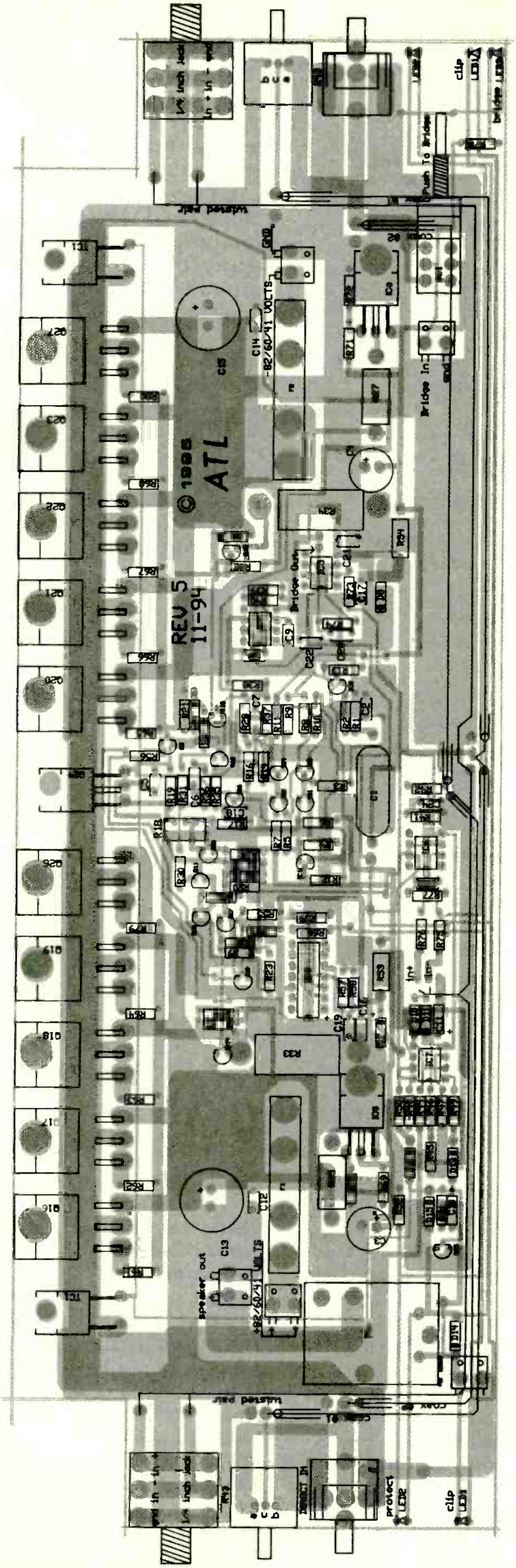


FIG. 5—AMPLIFIER PARTS PLACEMENT DIAGRAM, component side.

Custom transformers

Two of the transformers in the power supply, ferrite toroidal transformer T2 and ferrite E-core transformer T4 must be custom wound for this project. Refer to Fig. 4 for the winding details of these two transformers. Wind the copper foil shielding carefully on transformer T4 to prevent any short circuits with the windings. The copper foils must be wrapped so they remain "open-turn" to avoid short-circuiting transformer T4. The primary side of the transformer has 28 turns. These are to be split so that there are 14 turns on each side of the secondary.

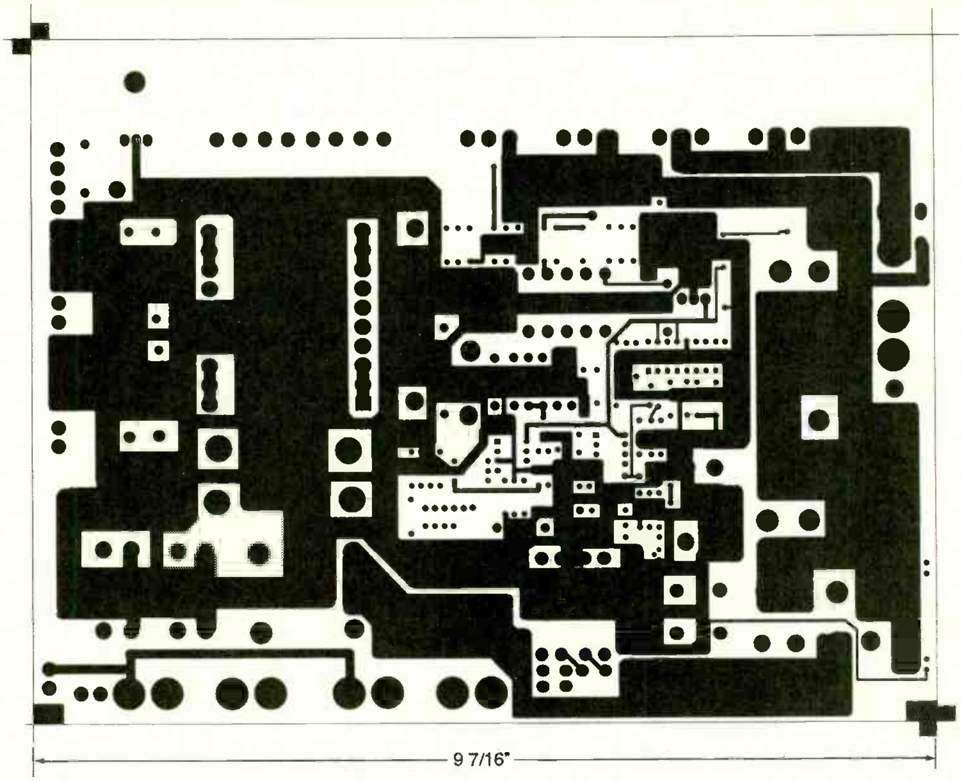
The secondary turns are to be sandwiched between the two halves of the primary turns. In other words, first wind 14 turns of the primary, then wind both

All resistors are ¼-watt, 1%, unless otherwise specified.

R1, R40—316 ohms
R2—7500 ohms
R3, R20, R21—10,000 ohms
R4—40.2 ohms
R5, R6, R7, R8, R9 R10, R11, R12—75 ohms
R13—50 ohms , 10 W
R14, R15—50 ohms, 5 W
R16—200 ohms, 0.5 W
R17—3480 ohms
R18, R22, R23, R42—1000 ohms
R19—2050 ohms
R24, R26, R30 R34, R35, R36, R38—100,000 ohms
R25—6980 ohms
R27, R31—16,900 ohms
R28, R32—36,500 ohms
R29, R33—15,000 ohms
R37—46,400 ohms
R39—4990 ohms
R41—1000 ohms, 0.5W
R43—22,000 ohms ,10 W

Capacitors

C1, C2—2200μF, aluminum electrolytic, 200 volts
C3—1000μF, 25 volts, electrolytic
C4—1000μF, 50 volts, electrolytic
C5—0.001μF, monolithic ceramic
C6—10μF, 25 volt, aluminum electrolytic
C7—100 pF, 50 volts ceramic
C8—0.01μF, polyester film
C9—10μF, 25 volts, aluminum electrolytic



POWER SUPPLY CIRCUIT BOARD PATTERN, component side

PARTS LIST—POWER SUPPLY

C10, C11, C12, C13,—4700pF, 50 volts, monolithic ceramic
C14—1000 pF, 500 volts,monolithic ceramic
C15, C16—4700pF, 500 volts
C17, C18, C19, C20—470μF, 100 volts, aluminum electrolytic
C21—0.01μF, 50 volts monolithic ceramic
C22, C25—0.22μF, 50 volts, monolithic ceramic
C23—0.01, 50 volts
C24—3300 pF . 50 volts, monolithic ceramic
C26—1000μF, 25 volts, aluminum electrolytic

Semiconductors

D1, D2, D3, D4, D15—MUR1540 Motorola
D5, D6, D7, D8, D11—1N4002
D9—Zener diode, 1N4742A,12 volt
D10, D12, D14—Zener diode, 1N4735A, 6.2 volt
MOV1—metal-oxide varistor Panasonic ERZ-V20D431 or equiv.
BR1—full-wave bridge rectifier, 600 volts, 6 amperes, General Instruments KBPC3506 or equiv.
BR2—full wave bridge rectifier, 200 volts, 6 amperes, General Instruments GBPC606CT or equiv.
LED1, LED2—light-emitting diode, T-1-3/4 package, one red, one green
Q1, Q2, Q3, Q4—N-channel MOSFET, depletion-mode International Rectifier IRFP450 or equiv.
Q5—N-channel MOSFET, depletion mode, TO-92, Motorola VN0610LLG or equiv.
IC1—SG3525N Pulse-width modulator, Silicon General or equiv.
IC2, IC3—LM358 dual low-power op-amp, National or equiv.
IC4, IC5—7812, 12-volt voltage regulator, Motorola or equiv.

Magnetics

L1, L2—coil 100μH, Pulse Engineering PE-92112 or equiv.
L3—dual coil, 1.8μH Pulse Engineering PE-96188 or equiv.
T1—low-voltage transformer, Microtran MT3137 or equiv.
T2—drive transformer, custom wound (see text)
T3—current transformer, Coilcraft D1871 or equiv.
T4—power transformer, custom wound (see text)

Other components

F1—fuse, 15 ampere, 250 volt, 3AG style
F2—fuse, ¼, 250 volt, 3AG style
F3—fuse, 6 ampere, 250 volt, 3AG style
S2—switch , DPDT PCboard, C&K 7201P3YZQE
IP1—inrush protector, Keystone KC001L-ND or equiv.

Miscellaneous (power supply): circuit board, 10 terminal blocks OST, Inc., No. 16 AWG insulated hookup wire, solder, 2 fuse clips.

Note: The following parts are available from A and T Labs, Box 4884, Wheaton , IL 60189

- **Amplifier printed circuit board for one channel, double-sided, plated-through holes, silk screened, solder masked (two required) (K6PCB1)—$39.00**
- **Switching power supply board,double-sided, plated-through holes, silk screened, solder masked (one required) (K6PCB2)—$42.00**
- **Switching power supply power transformer (K6T4)—$52.00**
- **Switching power supply driver transformer (K6T2)—$15.00**
- **Power supply inductors L1, L2 and L3 (K6L)—$32.00**
- **Heatsink set for convection-cooled case (K6HS1)—$110.00**
- **Heatsink set for forced-air cooled case (K6HS2)—$110.00**
- **Set of 8 matched MOSFETs for 1 amplifier channel (K6Q)—$90.00**

Add 5% U.S. or 12% Canada for shipping and handling.

Checks, money order, and VISA or Mastercard credit cards accepted.Illinois residents please add 6.75% local sales tax.

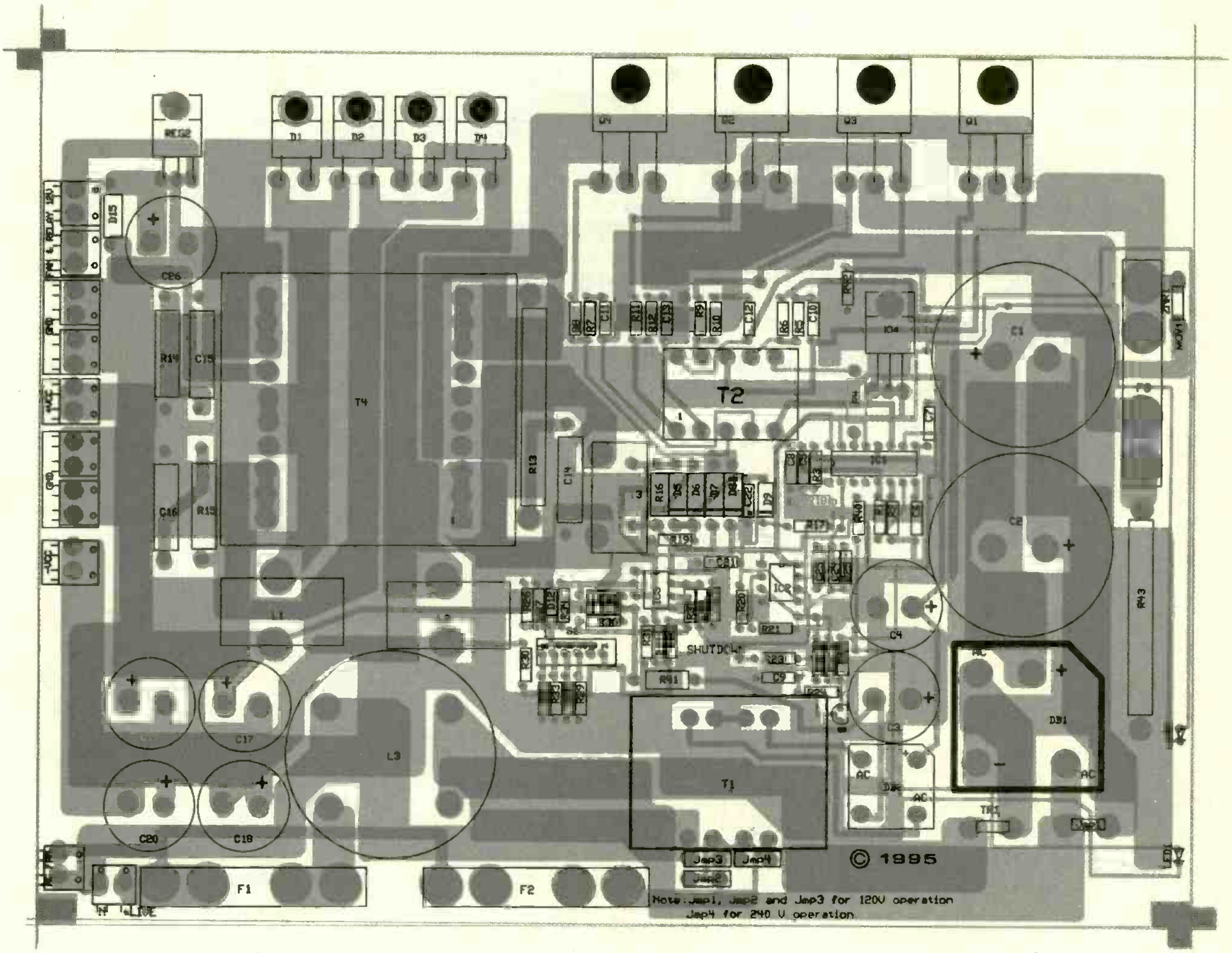
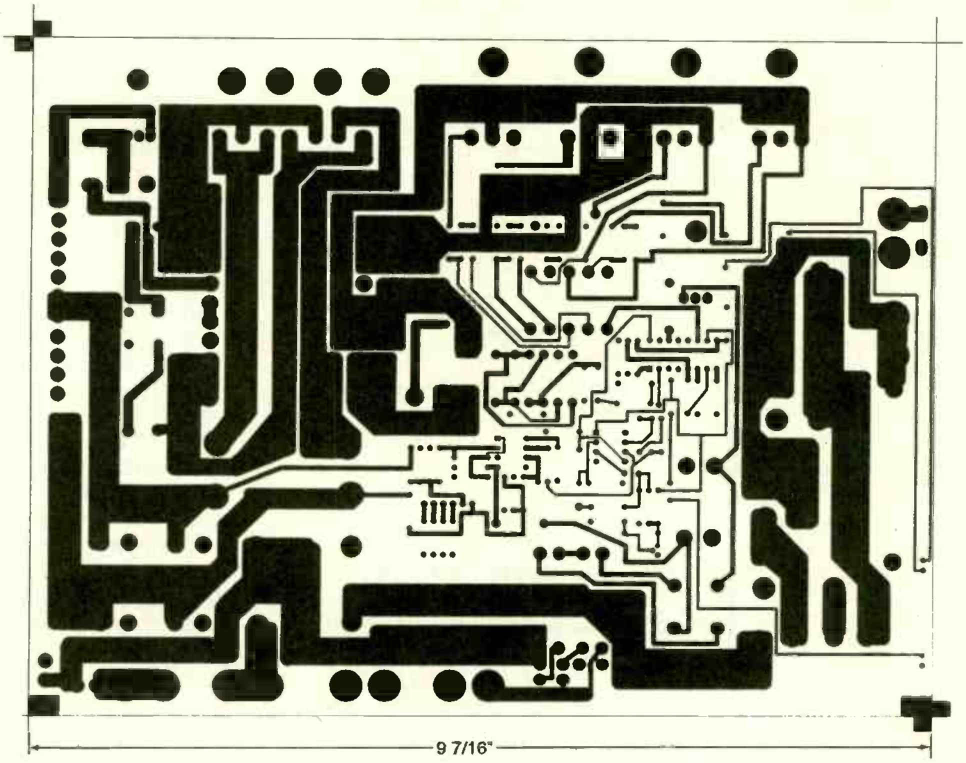


FIG. 6—POWER SUPPLY PARTS PLACEMENT DIAGRAM, component side.



POWER SUPPLY CIRCUIT BOARD PATTERN, wiring side secondaries. After that, continue to wind the remaining 14 turns of the primary.

Be sure to apply a small amount of epoxy or silicone adhesive in a thin layer to bond the two halves of the ferrite core to each other. They must be bonded together to prevent the ferrite "E" core from producing an audible hum. Connect the three separate foil shields and ground them to the center tap of the secondary of transformer T4.

Building the amplifier boards

As stated earlier, both amplifier channels for this stereo amplifier are identical. Circuit boards are recommended for constructing to eliminate the tedious work of point-to-point wiring and for more reliable operation. Several features, such as bridging capability, are optional. The components related to these options will be identified in the description of the construction procedures.

The procedure that follows assumes that circuit boards are either purchased from the source given in the Parts List or the builder has either made them or obtained them from another source.

Begin amplifier board assembly by inserting and soldering all resistors, capacitors, and diodes in their specified locations, as shown on the parts placement diagram, Fig. 5. Verify the values of all components before inserting them, and be sure to identify the polarities of all diodes and electrolytic capacitors.

Next, insert and solder all small-signal transistors and ICs. Adjust trimmer potentiometer R18 to its approximate middle position. Note that transistor Q24 must be mounted later to the aluminum heatsink adapter. Install it at this time so that the transistor will be positioned at the correct distance above the board so that it can later be fastened to the angle stock with a screw and nut. A mica insulator and silicone grease will be between the MOSFET's tab and the aluminum surface.

Install the RCA input jack J1 and the level-set trimmer potentiometer R43 at the appropriate end of each channel circuit board. The clipping and protection indicating LEDs are mounted on the opposite ends of the board. If you plan to install bridging, include the bridging circuit on one of the channel boards, and switch S1 and LED 3 on the other.

For differential input capability, include the ¼-inch jacks on the appropriate ends of the boards, as well as the twisted wire pair from the jack to the center of the board. If you do not plan to install differential input, omit the length of coaxial cable No. 2, the LM357 IC6, and the components associated with it. As the last step, install the length of coaxial cable No. 1 and the relay RY1. Do not install the output transistors Q16 to Q19 and Q20 to Q23 until after preliminary testing is completed. (This will be covered in part 2 of this article.)

Power supply board

Refer to the power supply parts placement diagram Fig. 6 and follow the general procedure previously given for building the two amplifier channel circuit boards. Insert and soldering resistors, capacitors, and diodes first, carefully checking values and orientations. Install the small-signal transistors and integrated circuits next, followed by the transformers, the switch S1 and the fuse holders.

Bend the leads of the power transistors Q1 to Q4 and rectifiers D1 to D5 at right angles so the tabs are parallel with the circuit board but projecting outboard with a gap that will permit them to be fastened to the aluminum angle heatsink adapter. Solder them in position so that they can be aligned with the heatsink channels.

The second part of this article will cover: the selection of appropriate cases to house the configuration of your choice; the installation of the boards to the aluminum heatsink adapters; and the wiring to off-board, panel-mounted components. Ω

POWERED SUBWOOFER
continued from page 38

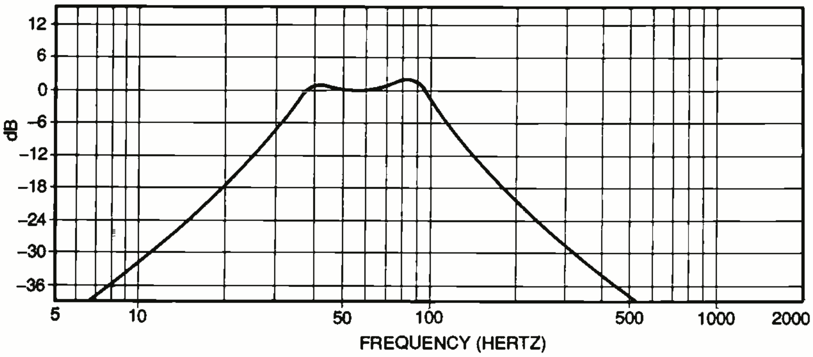
1.2 cubic feet.

The speaker cabinet is positioned so the speaker cone faces the floor. Rails on each side of the cabinet hold it 1½-inches off the floor to create a front chamber with a volume of 0.2 cubic feet. The open ends created by the rails act as two ports, each measuring 1½ × 12½ inches. The frequency response of the bandpass cabinet is also shown in Fig. 3.

Construction

The Little Earthquake crossover/amplifier circuit is built on a single-sided printed-circuit board, which can be etched from the template provided, or purchased from the source given in the Parts List. Use the parts-placement diagram in Fig. 4 as a guide for building the circuit board. The power transistors Q3 and Q4 must be heatsinked. The transformer and circuit board are mounted on an 8½ × 4- × ¼-inch sheet of aluminum.

Figure 5 shows how to drill the heatsink plate, and Fig. 6 shows how to mount the circuit board to the plate. Transistors Q3 and Q4 are inserted and soldered from the foil side of the board and should be formed so they make contact with the heatsink when the circuit board is mounted on ¼-inch spacers. Even though the tabs of Q3 and Q4 are the collectors, which are electrically connected in the circuit, mount them to the heatsink with insulating washers and bushings anyway. By doing so, the heatsink can be earth grounded for safety. Figure 7 shows how to drill a piece of ABS plastic, measuring 8- × 2½- × ⅛-inch, to form a panel to mount parts on.



SPEAKER DIAMETER = 10"
POWER HANDLING = 70 WATTS RMS, 100 WATTS PEAK
IMPEDANCE = 8 OHMS
SPL = 94 dB
F_S = 28.0 Hz
V_{AS} = 3.7 CU.FT.
Q_{TS} = 0.580

FIG. 3—THE ENCLOSURE is a critical component of the subwoofer design. The frequency response of the bandpass cabinet is based on a 10-inch speaker with the parameters shown here.

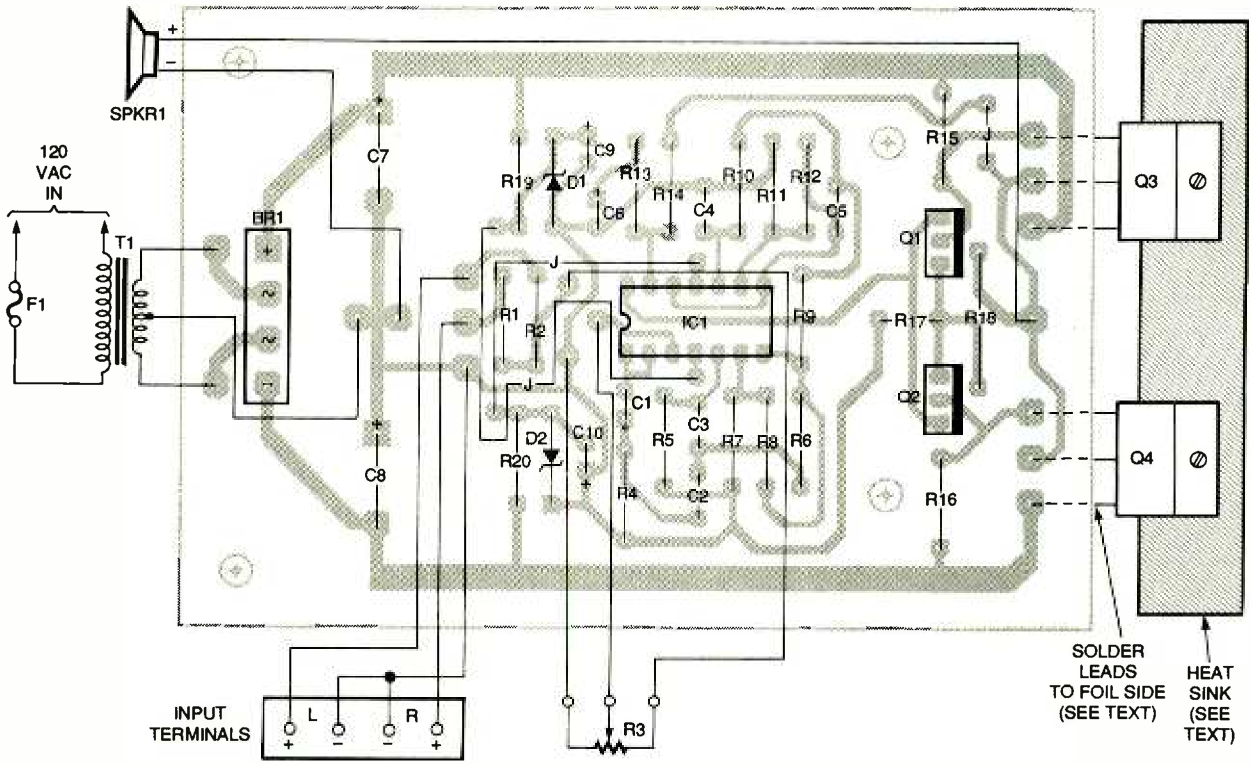


FIG. 4—PARTS-PLACEMENT DIAGRAM. Power transistors Q3 and Q4 must be heatsinked (see text and Figs. 5 and 6).

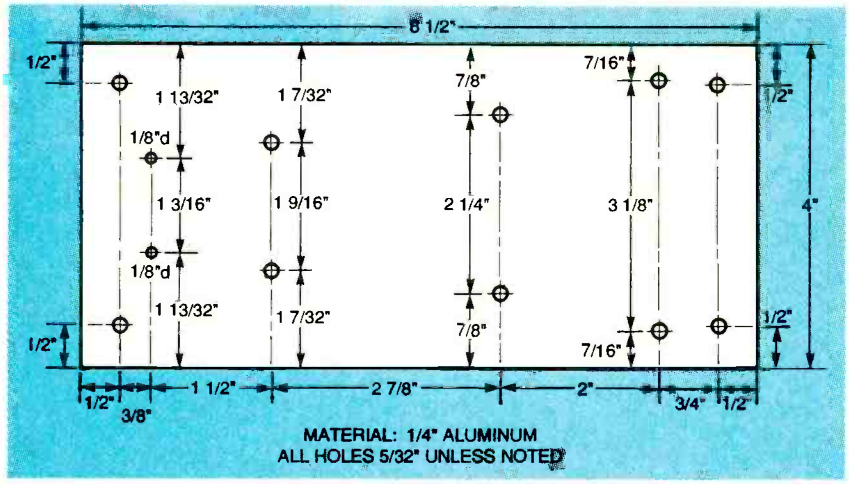


FIG. 5—DRILL THE HEATSINK PLATE (an 8½ × 4- × ¼-inch sheet of aluminum) as shown here.

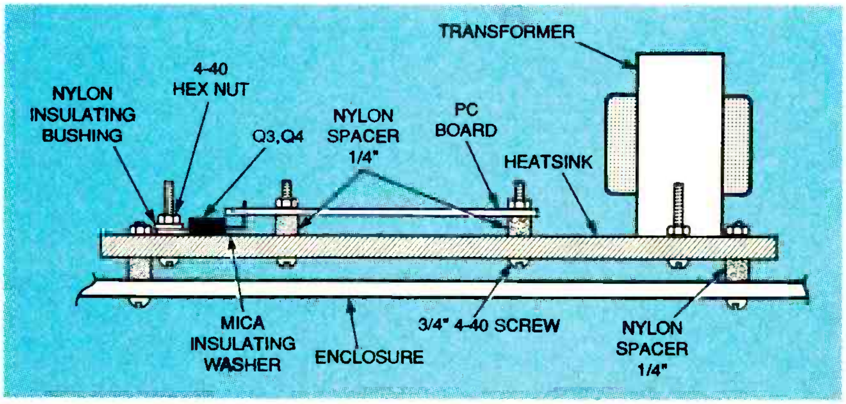


FIG. 6—TRANSISTORS Q3 AND Q4 are mounted from the foil side of the board and bent to make contact with the heatsink when the circuit board is mounted on ¼-inch spacers. Mount the transistors to the heatsink with insulating washers and bushings.

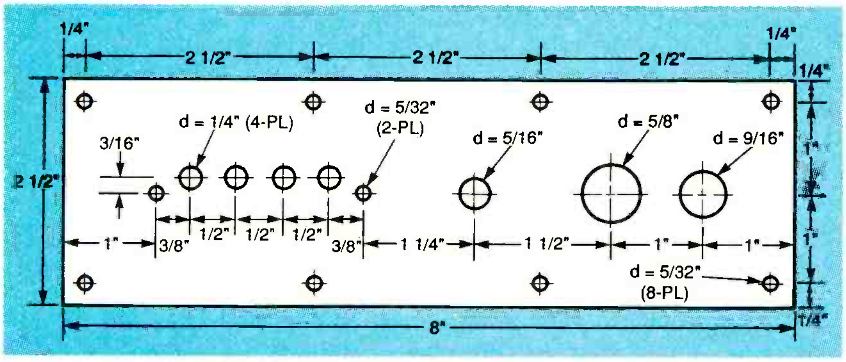


FIG. 7—DRILL A PIECE OF ABS PLASTIC, measuring 8- × 2½- × ⅛-inches, as shown here. Mount the input terminals, potentiometer R3, fuse holder, and linecord grommet on this panel.

Mount the input terminals, potentiometer R3, the fuse holder, and linecord grommet to a panel first, and then hardwire the panel to the circuit board. Then mount the panel over a rectangular cutout in the cabinet. Several tests should be made before connecting the speaker to the amplifier, so leave them disconnected for now.

Testing

The first step is to check the power supply. Verify that ±35 volts DC is supplied to the emitters of Q3 and Q4, respectively, and that IC1 has ±15 volts DC on pins 4 and 11, respectively. Also check the DC voltage at the output (the collectors of Q3 and Q4). If there is more than 0.1 volt on the output, make sure the components are installed correctly, especially C6. Too high a DC voltage on the output can damage the speaker.

If you have a function generator and an oscilloscope, verify the operation of the bandpass filter by connecting the function generator to the input terminal, and the oscilloscope to pin 8 of IC1. With a sinewave input signal of a few volts, perform a frequency sweep from 20 to 150 Hz or more, and verify that the output voltage on the oscilloscope follows the function shown in Fig. 2.

Cabinet construction

The dimensions for the cabinet were determined with computer software. The software calculations showed that inside dimensions of 17- × 14- × 8½-inches would achieve the desired sound. Any rigid wood-based material can be used to make

PARTS LIST

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

R1, R2, R5, R6, R9, R10, R14—47,000 ohms
R3—1000 ohms, panel-mount potentiometer
R4—7500 ohms
R7, R11, R15, R16—10,000 ohms
R8, R12—15,000 ohms
R13—1000 ohms
R17—56 ohms, 2-watts
R18—180 ohms, 2-watts
R19, R20—2000 ohms

Capacitors

C1—1 µF, 35 volts, electrolytic
C2, C3—0.1 µF, mylar
C4, C5—0.047 µF, mylar
C6, C9, C10—47 µF, 35 volts, electrolytic
C7, C8—3300 µF, 50 volts, electrolytic

Semiconductors

BR1—Bridge rectifier, 4 amps, 100 PIV (KBL01 or equivalent)
D1, D2—1N4744 15-volt Zener diode, 1 watt
Q1—TIP111 NPN Darlington transistor
Q2—TIP116 PNP Darlington transistor
Q3—TIP34B PNP power transistor
Q4—TIP33B NPN power transistor
IC1—TL074 quad op-amp

Other components

T1—120-to 48-volt centertapped

FIG. 8—CUT A 9-INCH DIAMETER HOLE in the bottom panel for the speaker and make a 7- × 1½-inch cutout for the control panel. Rails formed from 1- × 2-inch furring strips are glued to the bottom panel to hold the subwoofer above the floor.

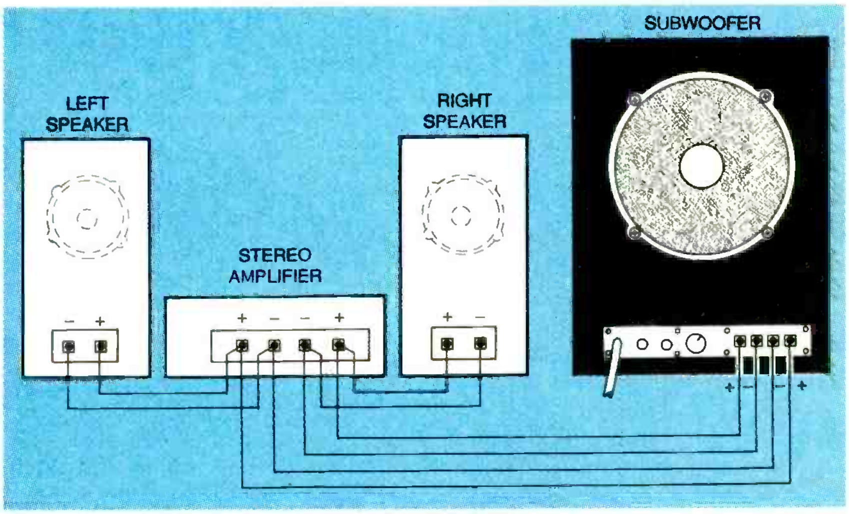
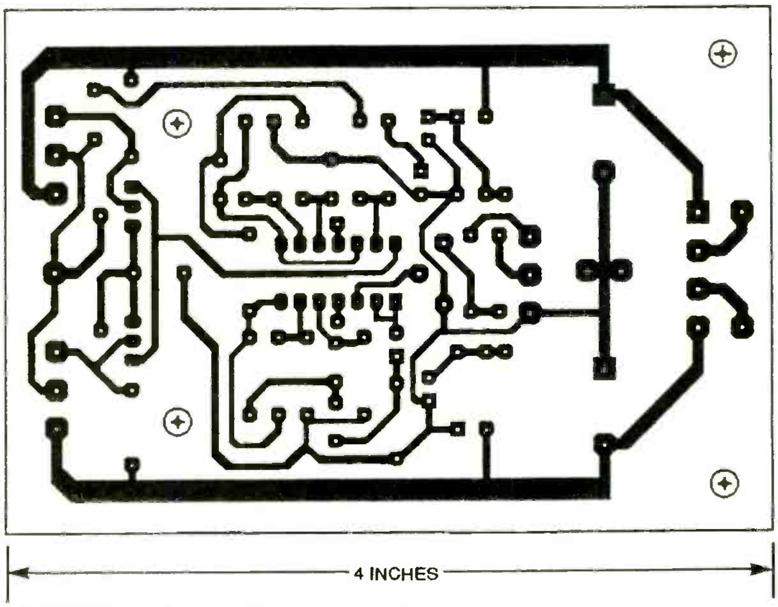


FIG. 9—IT IS VERY IMPORTANT that the subwoofer be connected properly to the stereo amplifier, or else the amplifier can be damaged.



FOIL PATTERN for the amplifier/crossover board.

the cabinet, as long as the inside dimensions remain the same. The prototype cabinet was constructed from ¼-inch birch veneer plywood with 1- × 1-inch furring strips for reinforcement along every inside seam.

The bottom panel, which holds the speaker and control panel, was made from ½-inch particle board for added strength. A 9-inch diameter hole was cut out of the bottom panel for the speaker, and a 7- × 1½-inch cutout was made for the control panel. Rails to hold the subwoofer unit above the floor were formed from 1- × 2-inch furring strips glued to the long edges of the bottom panel. Glue and screw every seam of the cabinet and seal the seams inside with silicone caulking. Solid construction of the cabinet will prevent annoying rattling and buzzing noises while the subwoofer is operating. Figure 8 shows the underside of the completed cabinet. For those who prefer to avoid woodworking, an assembled and sealed cabinet is available from the source given in the Parts List.

transformer, 1.2 amps
F1—1-amp fuse
SPKR1—8-ohm, 10-inch speaker
Miscellaneous: PC board, line cord and strain-relief bushing, panel-mount fuse holder, 4-position spring terminals, knob for R3, 8½ × 4- × ¼-inch aluminum heatsink plate, 8- × 2½- × ⅛-inch ABS plastic for control panel, hardware, nylon spacers, wire, assembled speaker enclosure with 17- × 14- × 8½-inch inside dimensions.

Note: The following items are available from Lynn-Eren Electronics, 17093 SW Lynnly Way, Sherwood, OR 97140, 503-625-2205:

- **Complete kit including speaker, assembled cabinet, and all parts—$169**
- **Assembled and tested subwoofer unit—$199**
- **Drilled heatsink plate and plastic control panel—$20**
- **PC board only—$15**

Check, money order, VISA, and MasterCard are accepted. Add $10 S&H to orders that include cabinets or speakers. All cabinets are supplied unpainted.

Final assembly

Install the speaker last so that the speaker mounting hole can provide access to the inside of the cabinet to install the heatsink assembly and control panel. Securely fasten the control panel to the cutout in the bottom panel of the cabinet with eight No. 6 screws to prevent it from vibrating. Mount the heatsink/PC board assembly to the side panel of the cabinet adjacent to the control panel with four No. 6 screws and ¼-inch nylon spacers. The spacers allow air to pass underneath the heatsink. Once the control panel and heatsink assembly are installed, the speaker can be mounted. If the speaker buzzes or rattles, it should be sealed to the enclosure with silicone caulking.

Installation and use

Place the completed subwoofer somewhere in the listening room where the input wires and power cord can be concealed. A wiring diagram is shown in Fig. 9. It is very important that the subwoofer be connected properly to the stereo amplifier.

With the power off and the speakers disconnected from your stereo, place an ohmmeter across the negative terminals of your stereo amplifier. If the terminals are not shorted together, or if your stereo amplifier is operated in mono-bridged mode, connect only one input. The negative terminals of the subwoofer are shorted together to ground. Connect the negative terminals of your stereo amplifier to the negative terminals of the subwoofer. Your stereo amplifier will almost certainly be damaged if its positive output terminals are short-circuited together.

When the input connections are made, turn the volume knob down all the way and plug the subwoofer into an AC outlet. Adjust the volume on your stereo, then adjust the subwoofer volume. If you have tone controls on your stereo, fine-tune the subwoofer volume by adjusting the bass control on your stereo system.

With the Little Earthquake subwoofer, you can discover the world of sound and suspense hidden deep in the audio spectrum. Listen again to all of those great movies, and feel them at home for the first time! Ω

WHAT'S NEWS

continued from page 4

cuit, but the willingness of the broadcasters and cable operators to transmit the required identifying signal.

As envisioned, the television stations would transmit a special rating code with each program, designating whether the program contained violence, nudity, offensive language, or is otherwise unsuitable for children. The code would be carried in an unused part of the television signal—the black bar between each frame of video. (This is the same bar that appears when the horizontal hold on a TV set is faulty and the picture scrolls.)

The V-chip, when installed in a TV receiver or cable converter, would read the signal. Provision would be made for parents to program the IC to blank out specific programs or even whole channels. However, it will be possible to block only the video portions but not the audio that could contain vulgar or offensive language. An electronics industry group has proposed signal standards, but broadcasters and cable operators have not yet agreed on a rating system that the V-chip would interpret.

21st century semiconductor modeling tools

The U.S. government has not given up on trying to give a boost to American semiconductor manufacturers. The Semiconductor Research Corporation (SRC) and three U.S. Department of Energy (DOE) laboratories have begun work under a $100-million agreement aimed at preserving what they say is the U.S. lead in manufacturing semiconductors.

The objective of the cooperative research and development agreement (CRADA) is to stimulate U.S. competitiveness by improving the industry's ability to model and simulate semiconductor materials, devices, systems, and manufacturing processes.

The semiconductor market will continue to demand increased device performance, at higher densities at reduced costs. To remain competitive, semiconductor manufacturers must develop fundamentally new models of solid-state and atomic physics.

The development of modeling tools is critical because integrated-circuit manufacturing technology has outpaced the ability to model semiconductor components, a spokesman for SRC said. He added that the cost and complexity of making integrated circuits has reached a point where advanced modeling and simulation tools are an imperative.

University researchers working with the SRC have shown that computer-aided design tools would dramatically reduce the cost and time required to develop each new device generation. The cooperative research program will be conducted at Los Alamos, Sandia, and Lawrence Livermore national laboratories, in collaboration with researchers at SRC member companies.

The SRC, based in North Carolina, is a consortium of more than 60 semiconductor companies and government agencies that plans and implements an integrated program of pre-competitive research. SRC members and the DOE each will contribute $10 million a year for five years.

The CRADA includes work in five areas: (1) development of new moving, adaptive computational algorithms for modeling complex three-dimensional device structures and their manufacturing processes; (2) development of a combined equipment/wafer simulator that will describe how surface topography is affected during deposition and etch processes; (3) improved simulation tools to predict the behavior of electrons in semiconductors; (4) improved methods to predict failure in electronic contacts or interconnects based on microscopic grain characteristics; and (5) predictive codes for such semiconductor manufacturing processes as ion implantation and impurity diffusion.

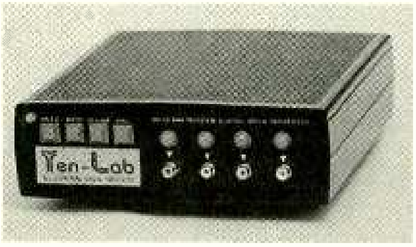
The agreement is an important step on the National Technology Roadmap for Semiconductors. It was developed in 1994 by the Semiconductor Industry Association as a common vision for semiconductor technology for the next 15 years. EN

NEW PRODUCTS

continued from page 23

DIGITAL MULTISYSTEM VIDEO CONVERTER

THE TR-10 DIGITAL MULTI-system video converter from Ten Labs accommodates NTSC, PAL, and SECAM inputs, and converts them to NTSC or PAL outputs. When paired with a PAL player-recorder, the converter permits foreign tapes to be played back on a standard U.S. monitor, PAL tapes to be copied into NTSC, or American-standard tapes to be dubbed into PAL.



CIRCLE 26 ON FREE INFORMATION CARD

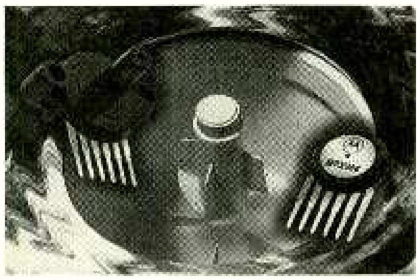
The TR-10 includes built-in time-base corrector, a digital line and field video processing/conversion, two megabytes of field memory, automatic gain control, and an auto-detecting system mode.

The TR-10 video converter is priced at $595.00

TEN-LAB
2217 Malcolm Avenue
Los Angeles, CA 90064
Phone: 310-474-6909
Fax: 310-441-1807

WATER-TOLERANT PRESSURE SENSOR

THE MPX906D PRESSURE sensors from Motorola are 6-kPa, silicon piezoresistive devices. They are compatible with water, water vapor and other wet environments without protective membranes. The low-pressure sensors are said to offer accurate linear voltage output corresponding to more than 24 inches of water, full-scale pressure range.



CIRCLE 27 ON FREE INFORMATION CARD

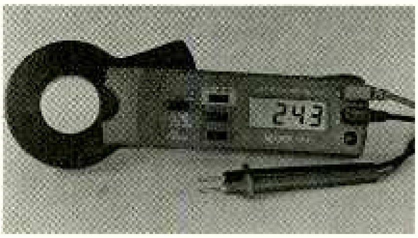
The MPX906D pressure sensors are priced at $6.50 each in small quantities.

MOTOROLA, INC.
Sensor Marketing—MD Z208
5005 East McDowell Road
Phoenix, AZ 85008
Phone: 602-244-4556
or 1-800-273-6731

MINI DC/AC CLAMP METER

THE MODEL 380915 1000 ampere, industrial grade clamp meter from Extech Instruments measures AC and DC volts, current, and resistance. Its ranges are 200 volts DC with 0.1-volt resolution, 500 volts AC with 1-volt resolution; 200 and 1000 AC or DC amperes with 0.1-ampere resolution; and 200 ohms with 0.1-ohm resolution.

The meter measures 7.1 × 1.9× 1.4 inches and its jaw has an opening of 1.2 inches. It has a 3½-digit, 0.5-inch high liquid crystal display. The 380915 can perform data hold, and it has overload protection with indication, and automatic polarity. It meets the IEC 348 safety requirements and has a test socket fuse for safety. The clamp meter is sold with a carrying case, test leads, and battery.



CIRCLE 28 ON FREE INFORMATION CARD

The Model 380915 DC/AC mini-clamp meter is priced at $159.00

EXTECH INSTRUMENTS
335 Bear Hill Road
Waltham, MA 02154-1020
Phone: 617-890-7440
Fax. 617-890-7864

EN

SUBWOOFER

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tioned in the Parts List. The board is designed to accommodate two different crossover circuits. This article is written about only one of them. That is why many of the pads on the board are unpopulated. Mount Potentiometer R13 in a socket so that its height from the board equals those of the bodies of the switches. That way it can project through an opening in the cover of the case and be adjusted with the case cover in place.

Be sure that all electrolytic capacitors, especially C10 and C11, are rated for operation at 105°C. Electrolytic capacitors rated at 85°C will deteriorate to a lower capacitance value after a few years of operating in high-temperature automotive environments.

The prototype crossover board provides two RCA output jacks (J1 and J2) for connecting the mono subwoofer signal to both inputs of a stereo amplifier. The jacks included with the kit mount on the underside of the board in holes drilled especially for them. The electrical connections to the jacks are made on the top of the board by soldering the jack leads to the two wire jumpers that span the board. This can be seen in the photo of the board shown in Fig. 4.

Make the input and power connections to the crossover board by soldering 10-inch wire leads to the pads on the underside of the board as shown in Fig. 3. Solder the leads to the board after the board is fully populated. The PC board is designed to fit perfectly in the case available from the source given in the Parts List. The case is supplied predrilled for the RCA

PARTS LIST

All resistors are ⅛-watt, 5%, unless noted.
R1–R4—47,000 ohms
R5, R6, R19, R21—10,000 ohms
R7—20,000 ohms
R8—16,000 ohms
R9—3300 ohms
R10, R11—9100 ohms
R12, R14, R16, R23—2200 ohms
R13—10,000 ohms, linear taper potentiometer
R15—100,000 ohms
R17—5100 ohms
R18—1000 ohms
R20—47 ohms
R22—18,000 ohms

Capacitors
C1, C2—0.22 µF, Mylar
C3—0.047 µF, Mylar
C4, C6, C7—0.1 µF, Mylar
C5—0.01 µF, Mylar
C8, C9—0.22 µF, Mylar
C10—1 µF, 25 volts, radial electrolytic, 105 degrees C
C11, C13—10 µF, 25 volts, radial electrolytic, 105 degrees C
C12—220 µF, 25 volts, axial electrolytic

Semiconductors
Q1, Q3–Q5—2N3904 NPN transistor
Q2—2N3906 PNP transistor
D1, D2—1N914 diode
IC1—MF4CN-100 switched capacitor filter
IC2—78L08 voltage regulator

Other Components
S1—DPDT switch
S2—SPST switch
J1, J2—RCA jack, PC mount
Miscellaneous: PC board, project case, hardware, 18 AWG stranded wire

Note: The following items are available from MFR Engineering, 10308 Indian Lake Blvd S., Indianapolis IN 46236:
- **Crossover PC board (drilled and plated)—$10**
- **PC board and IC1 and IC2—$14**
- **PC board and all electrical components including switches and jacks—$29**
- **Complete kit of all parts (includes PC board, all parts, and project case—$39**
- **Assembled and tested crossover unit—$59**

Shipping and handling is included in all prices (Continental U.S.). Certified or cashiers checks, money orders, and personal checks accepted. (Shipping will be delayed until personal checks clear.)

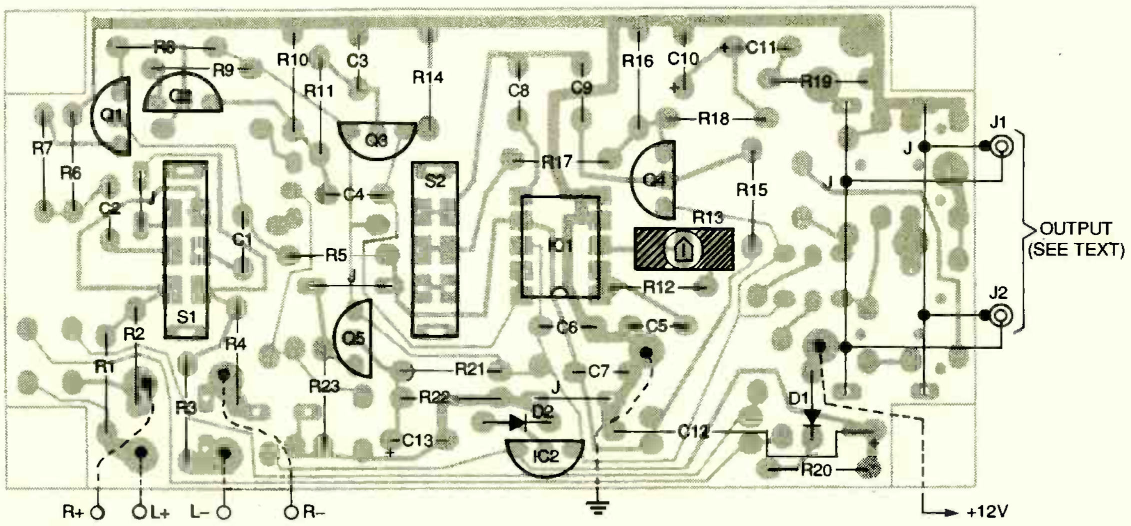


FIG. 3—PARTS-PLACEMENT DIAGRAM for the crossover PC board. The board is designed to accommodate two different crossover circuits; That's why many parts appear to be left out.

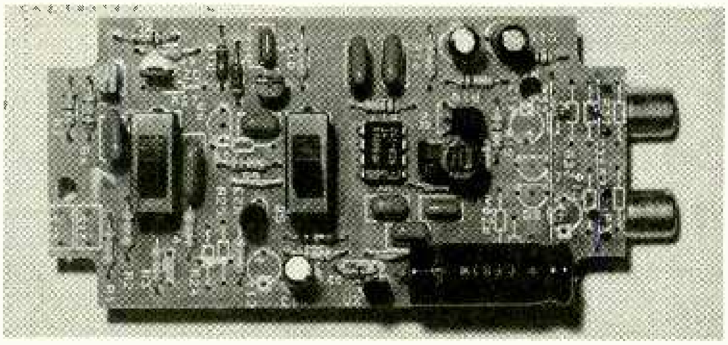


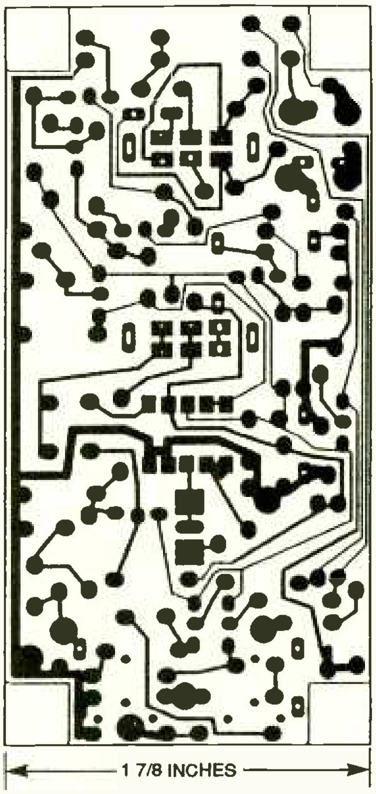
FIG. 4—PROTOTYPE CROSSOVER BOARD. The two RCA output jacks are mounted on the underside of the board, and the electrical connections are made by soldering the jack leads to the two wire jumpers that span the board.

FIG. 5—THE BOARD IS HELD IN PLACE by the RCA jacks on one end. The other end of the board rests on the grommet. The case cover holds the board down by pressing on the switch bodies.

jacks and includes a rubber grommet for the input and power leads.

The board is held in place in the case by the RCA jacks on one end. The other end of the board rests on the grommet. The case cover holds the board down by pressing on the bodies of the switches.

After checking your soldering, pass the input and power leads through the single opening in one end of the case, fit the RCA jacks through the openings on the other side of the case, and push the board down into place. Pull any excess wire out of the case before installing the grommet. Figure 5 shows what the assembled case looks like.



SUBWOOFER CROSSOVER foil pattern shown full size.

TABLE 1

	Lower Limit	Upper Limit	Units
Test 1: Supply Current			
• Measure power supply current	7	12	mA
Test 2: Output Level			
• Verify that output is sinusoidal			
• Measure output level	.80	.90	VRMS
Test 3: Polarity Switch			
• Change polarity switch to up position			
• Measure output level change	–.05	+.05	VRMS
Test 4. Frequency Response			
• Change signal frequency to find lower –3 dB frequency	19	23	Hz
Test 5: Equalization Frequency			
• Set Eq. switch to boost position			
• Change signal frequency to find peak frequency	37	44	Hz
Test 6. Equalization Boost			
• Set Eq. switch to flat position			
• Measure output level decrease	4	6	dB
Test 7: Filter Range			
• Set signal frequency to 50 Hz			
• Rotate pot fully CCW			
• Measure output level change	–7	–3	dB
Test 8· Regulator Dropout			
• Monitor DC at 8.6V regulator output, TP7			
• Reduce power supply until DC decreases .1V			
• Measure power supply voltage	10.5	11.7	VDC

Crossover test

The following test procedure will thoroughly check the operation of the subwoofer crossover before installation. Test points are shown in the schematic in Fig. 2.

As an initial setup, apply 15 volts DC to TP5 and ground TP6. Apply a 3-volt RMS, 130-Hz signal the left and right inputs (TP1–TP4). Ground the low side of the signal source. The output impedance should be about 600 ohms. Set potentiometer R13 fully clockwise and open switch S2. The polarity switch (S1) should be in the "down" position. Monitor the output signal at TP8 with an oscilloscope, and follow the instructions given in Table 1.

Amplifier

A 2 × 18-watt automotive stereo amplifier will provide a good match for original equipment factory or aftermarket stereos and provide the best price/

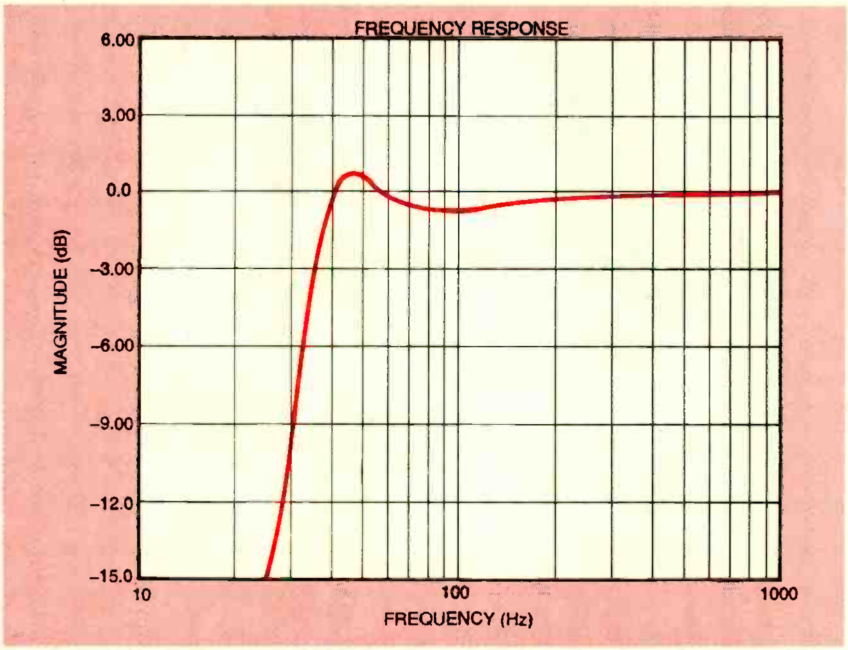
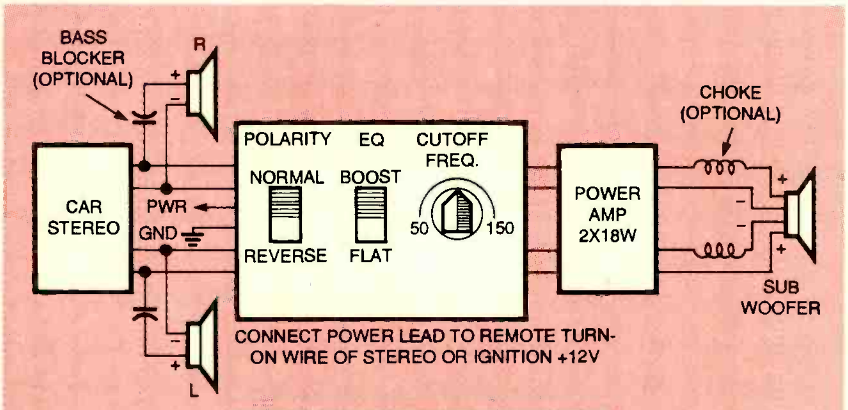


FIG. 6—COMPUTER-GENERATED FREQUENCY RESPONSE CURVE of the Madisound 81524DVC speaker in a 1.25 cubic foot enclosure.



FREQUENCY (Hz)	CAPACITANCE (µF)
265	150
200	200
135	300
100	400

(SEE TEXT)

FIG. 7—CONNECTION DIAGRAM. Bass-blocking capacitors will reduce the burden of producing deep bass on the main speakers. The capacitor values for popular bass-blocking frequencies are listed below. The choke coils will prevent power amplifier oscillation problems.

power ratio. For systems with higher power separate components, a larger power amplifier and subwoofer should be considered to equal out the system.

Speaker and enclosure

To get the best value here, build your own enclosure and use a dual-voice coil speaker. A dual-voice coil speaker can be connected directly to both outputs of a 2×18 amplifier, eliminating the need for two speakers. This essentially cuts the cost in half. A single 8- to 12-inch dual-voice-coil woofer is adequate for systems that will not have to entertain the whole neighborhood.

Choosing the right speaker is important. Polypropylene cone speakers are preferred because they are resistant to moisture. The author used a Madisound No. 81524DVC speaker which has an 8-inch diameter polypropylene woofer and dual 4-ohm voice coils. It is available from Madisound for $34.

Building your own cabinet not only saves a lot of money, it also lets you build cabinet with exactly the size and shape cabinet you want for your vehicle. This is important where space is tight or where an unusual interior would let you take advantage of some obscure location. Avoid installing the crossover and power amplifier where they are subject to excessive temperature (such as in direct sunlight) or where they are exposed to moisture or dirt. For a professional touch, speaker box carpet is available in colors to match almost any vehicle's interior, and it can be applied to the outside of the enclosure. If you prefer to use a premade speaker box, it can be purchased from Crutchfield, Parts Express, MCM Electronics, and other audio-supply distributors.

The prototype subwoofer is housed in a 1.25 cubic foot enclosure, which is the best tradeoff between size and bass response. This box volume provides a cutoff frequency of 37 Hz.

The prototype's enclosure was constructed of ¾-inch particle board, and a port was made from a 7½-inch length of 3-inch diameter PVC pipe. The computer-generated frequency response curve of the Madisound 81524DVC speaker in this enclosure is shown in Fig. 6.

Installation

The subwoofer can be mounted inside the vehicle or in a trunk. If you install it in a trunk, use quick-connects for the wiring and adjustable straps or Velcro to keep the subwoofer from sliding around. This will also allow you to take the subwoofer out easily when you need the extra trunk room.

Connect the crossover inputs to the left and right speaker outputs of the car stereo, as shown in Fig. 7. If the stereo has front and rear outputs, use the out-

Continued on page 94

BRIDGE CIRCUITS

continued from page 44

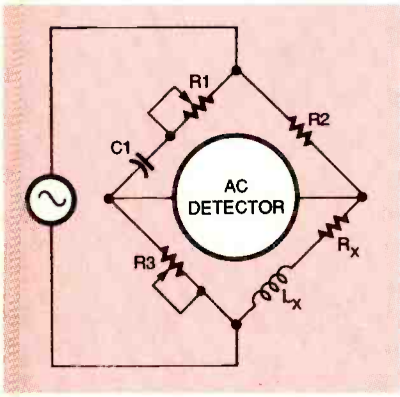
TABLE 3
RESISTANCE VS. R, C, and L RANGE VALUES
LABORATORY STANDARD BRIDGE

Switch S2 Range	Resistor R2 Value	Bridge Range Resistance	Capacitance	Inductance
1	10 Ω	0 - 10 Ω	0 - 10 μF	0 - 1 mH
2	00 Ω	0 - 159 Ω	0 - 1 μF	0 - 10 mH
3	1.0 K	0 - 1.59K	0 - 0.1 μF	0 - 100 mH
4	10 K	0 - 15.9 K	0 - 0.01 μF	0 - 1 H
5	100 K	0 - 159 K	0 - 1.0 μF	0 - 10 H
6	1 MEG	0 - 1.59 MEG	0 - 100 pF	0 - 100 H

the resistance value of the bridge's potentiometer R_S.

Inductance bridges

The two most popular bridges for measuring inductance are the *Maxwell bridge* (also known as the *Maxwell-Wien* bridge), shown in Fig 3 and the *Hay* bridge (also known as the *opposite-angle* bridge), shown in Fig. 4. Both operate on the principle of balancing the inductive phase shift of the unknown inductor L_X against a capacitive shift of the same magnitude in the opposite arm of the bridge.



FIG, 4—THE HAY BRIDGE can measure the values of high-Q coils.

The Maxwell bridge, shown in Fig. 3, is widely used for accurate inductance measurements. It determines unknown inductance values with a standard capacitor, which has an advantage over a standard inductor because it is less likely to be influenced by external fields and is easier to shield. Moreover, the field set up by a capacitor is negligible. Standard capacitors are small and inexpensive. The Maxwell bridge is useful for measuring coils with Q values below 10. The important Maxwell bridge formula's are:

$L_X = R2 \times R3 \times C1$
$R_X = (R2 \times R3)/R1$
$Q_X = 2\pi f(L_X/R_X)$
$= 2\pi f C1 \times R1$

Note: All Q values are influenced by the source frequency. Thus, a coil that has a Q of 100 with a high source frequency might have a Q of 1 or less at 1 kHz.

The *Hay bridge* is similar to the Maxwell bridge and is used for measuring inductances that have large values of Q (greater than 10) or whose resistance is a small fraction of the reactance X_L. The Hay bridge can also determine the incremental inductance of iron-cored reactors. The important formulas for the Hay bridge are:

$Q_X = 1/2\pi f \times C1 \times R1$
$L_X = C1 \times R1 \times R3 \times (1/1 + 1/Q^2$
$R_X = 2\pi f \times L_X/Q$

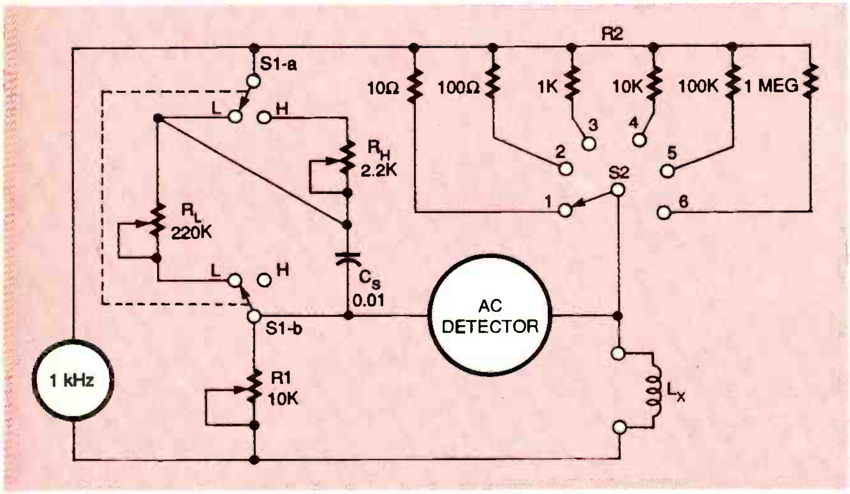


FIG. 5—THIS HAY-MAXWELL BRIDGE has six ranges.

Figure 5 is the schematic for a combined Hay and Maxwell inductance bridge that spans the range of 10 microhenrys to 100 henrys in six ranges. The Hay circuit makes high-Q measurements when switch S1-a and S1-b re set in the "H" position. When switch S1-a and S1-b is set in the "L" or Maxwell position, the bridge measures low values of Q.

In this circuit, AC voltages at both ends of the detector approach the half-supply value at balance. The AC detector here can also be a simple device such as headphones. Table 2 relates the selected switch channel to the inductance range, related

TABLE 2
RESISTANCE VS. INDUCTANCE RANGE VALUES
HAY/MAXWELL INDUCTANCE BRIDGE

Switch S1 Range	Bridge Range	Resistor R2 Value	Z_X Full Scale 1 kHz
1	0 - 1 mH	10 Ω	15.9 Ω
2	0 - 10 mH	100 Ω	159 Ω
3	0 - 100 mH	1.0 K	1.59 K
4	0 - 1 H	10 K	15.9 K
5	0 - 10 H	100 K	159 K
6	0 - 100 H	1 MEG	1.59 MEG

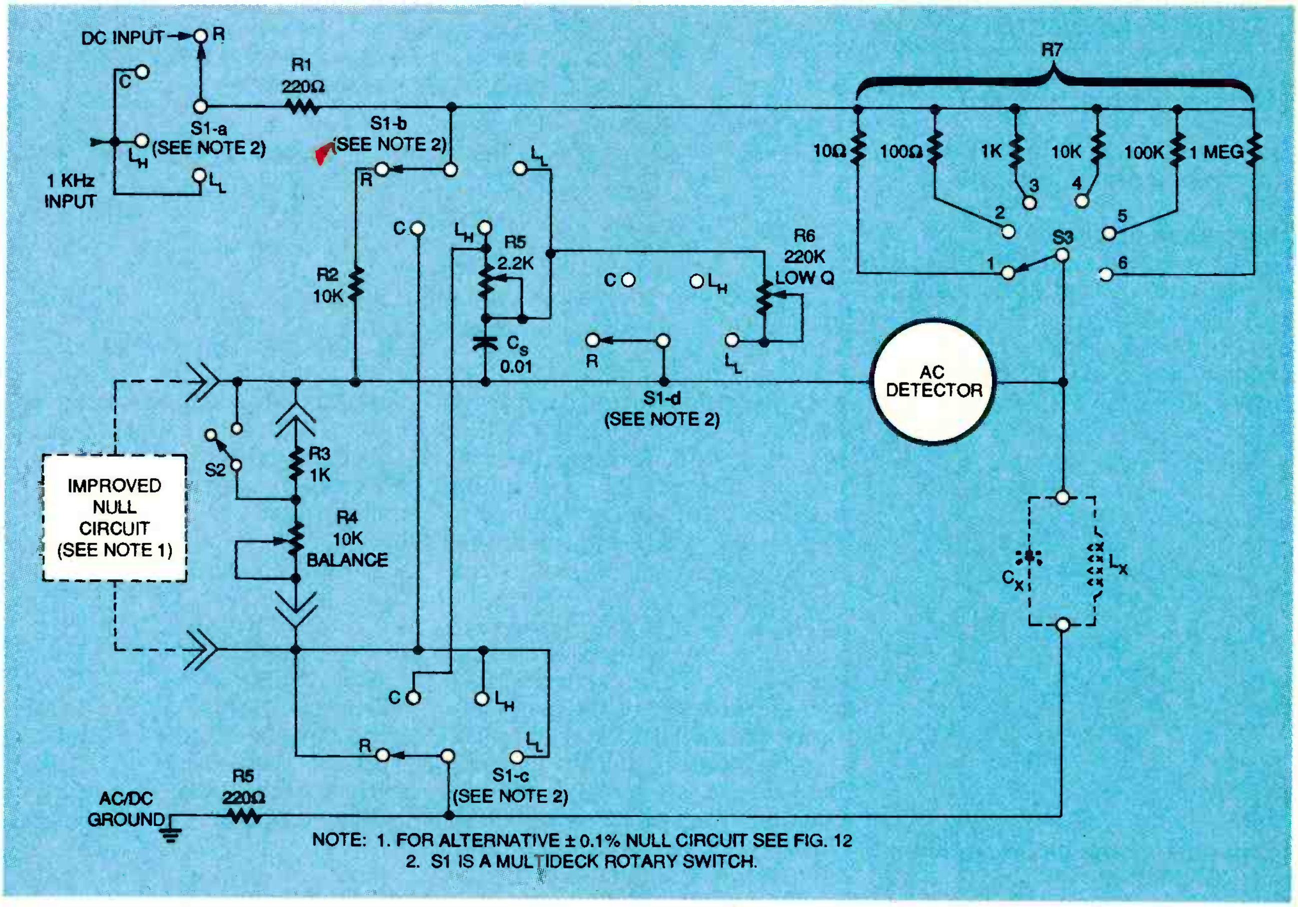


FIG. 6—THIS LABORATORY-STANDARD LCR BRIDGE has 18-ranges.

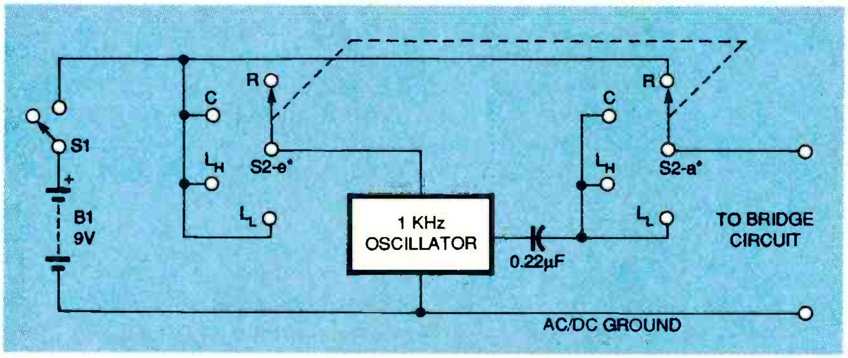


FIG. 7—AN AC/DC SOURCE for the 18-range laboratory-standard LCR bridge.

resistance value, and full-scale impedance.

Precision LCR bridge

Figure 6 is the schematic for a precision 18-range LCR bridge that combines the circuits of Figs. 5 and 2 with a Wheatstone bridge. Although this bridge is very sensitive, it requires only a simple AC balance detector. This could be an analog volt-ammeter on its DC-sourced resistance ranges, or a headphone on its the AC-sourced capacitance and inductance

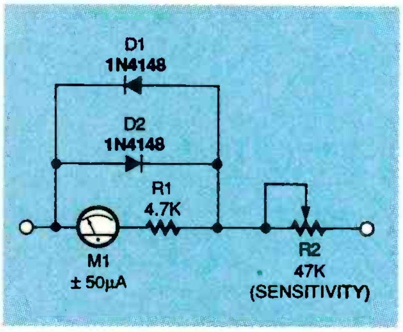


FIG. 8—A DC-NULL DETECTION circuit.

ranges. A simple radio receiver will also work when the ear is not sensitive enough to discriminate against harmonics.

The null-balance network of this circuit has been modified by the addition of a 1-kilohm resistor R3 and switch S2, which permit the span of each range to be extended by 10%.

When this bridge is set on its 0 to 100-picofarad range, errors can occur because of the effects of stray capacitance. Consequently, measurements should be made with the *incremental* method, as follows:

1.—With no component across the unknown terminals, null the bridge with potentiometer R4 and record the resulting *residual* null reading (typically about 15 pF).

2—Insert the unknown capacitor in place, obtain a balance reading (e.g., 83 pF), and then subtract the residual value (e.g., 15 pF) to obtain the true capacitor value (in this example, 68 pF).

Table 3 relates the switch range to the resistor value in the channel selected and the vari-

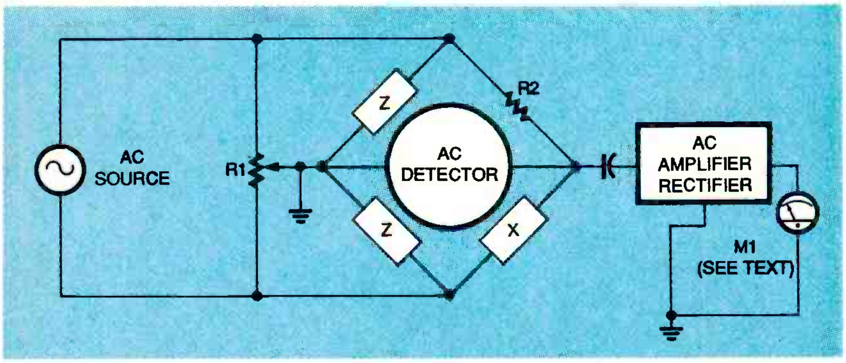


FIG. 9—A WAGNER EARTH CONNECTION in a single-ended AC null detector.

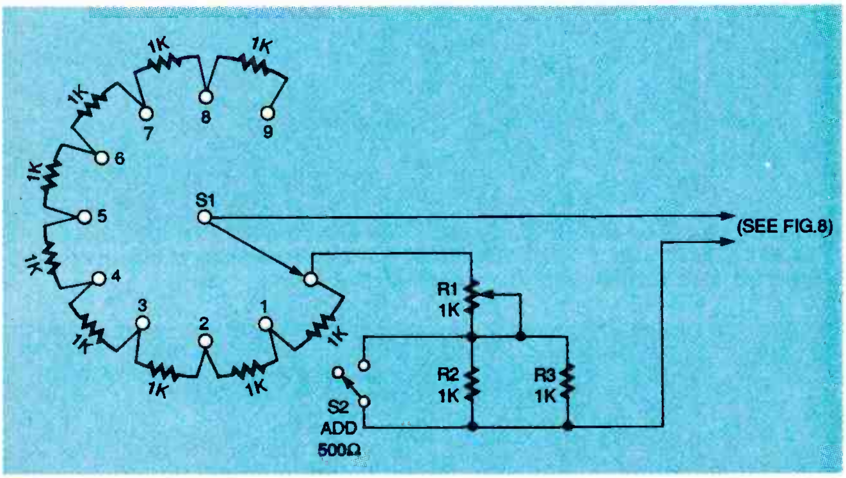


FIG. 10—CIRCUIT FOR IMPROVING null resolution of the LCR bridge to ± 0.1% of full scale.

ous ranges of resistance, capacitance, and inductance.

The bridge circuit in Fig. 6 can be built as shown for use with external AC and DC sources and null-detection circuitry, or can be modified to suit your specific requirements. Fig. 7 shows an AC/DC source that can be added if a five-wafer multideck rotary switch is installed in Fig. 6 and the "e" wafer is left blank.

Both DC and AC null-balance detectors can easily be included in the Fig. 6 circuit. The DC detector can be a microammeter capable of measuring ±50 microamperes. Figure 8 is the schematic for a microammeter protection circuit consisting of two back-to-back 1N4148 silicon diodes and R2, a 47-kilohm potentiometer for adjusting sensitivity.

Figure 9 shows a simplified schematic for an AC detector. It includes a single-ended AC analog millivoltmeter. The low input of the detector and the detector junction on the left side of the bridge can both be grounded. This diagram also shows how the AC source can be equipped with a *Wagner earth connection*, supplied by potentiometer R1. This potentiometer permits the source signal to be balanced to ground to eliminate unwanted signal interference at null.

Figure 10 is the schematic for a null resolution circuit that can be installed in the LCR bridge, shown in Fig. 6. The bridge has a resolution that is only about ±1% of full scale. This is set by the limit of readability of the R3 and R4 balance control's scale.

The circuit in Fig. 10 will improve the bridge's resolution by a factor of 10 to ±0.1% of full-scale. Remove Switch S2, resistor R3 and potentiometer R4 and install the switched and variable network of Fig. 10 at the male and female connectors shown on Fig. 6. Switch S2 permits the 1-kilohm linear potentiometer R1 to go overrange by 50%. Ω

COMPUTER CONNECTIONS

continued from page 62

large corporations. On the other hand, some people think that Notes is nothing but glorified E-mail.

Even the U.S. Department of Justice, which has been very active of late in overseeing mergers and acquisitions in the computer industry, has shown no interest in the deal.

My question is this: What about this deal would appeal to the average Microsoft customer? The computer market *is* Microsoft customers.

If two 500-pound gorillas join forces, it's still a family of gorillas. Meanwhile, the smaller, faster, and smarter chimpanzees maintain advantages for both survival and evolution.

Novell buys Borland

Which reminds me: Novell, which last year bought WordPerfect, is now trying to buy Borland. Borland does have some good products, and a loyal following of influential buyers. But what can Novell and Borland do together that they couldn't do separately?

If Novell uses Borland's tools to expand the development platform for NetWare and UnixWare *without impeding progress in the PC tools market* the company may generate additional interest in those areas. What that means is perhaps five years of market and product development before NetWare's market is completely overshadowed by some form of Windows. But if Novell meddles deeply with team Borland, I predict personal delivery of champagne and caviar by none other than Bill Gates. As a reminder, you can contact me on CompuServe as 72170, 2226, or via the Internet at 72170.2226@CompuServe.Com. EN

"I'm sorry, Larry, but our computers aren't compatible."

SEEING THE UNSEEN

continued from page 46

Thus, a succession of closely timed images following one another at brief intervals is interpreted by the brain as a seamless sequence. That is why the moving machine appears to be standing still.

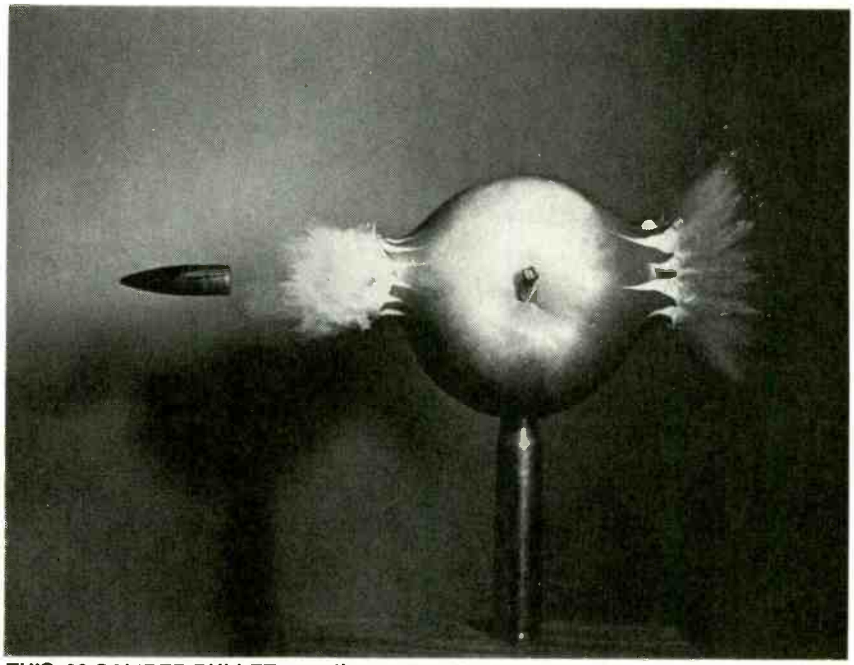
Persistence of vision is the same response that makes it possible to view movies, television, and raster-scanned computer monitors. (See "Scanning Early TV," *Electronics Now*, July 1995, page 46.) Crude stroboscopes had been available as laboratory instruments as early as 1918, but they had not been used as industrial research tools.

Stroboscope history

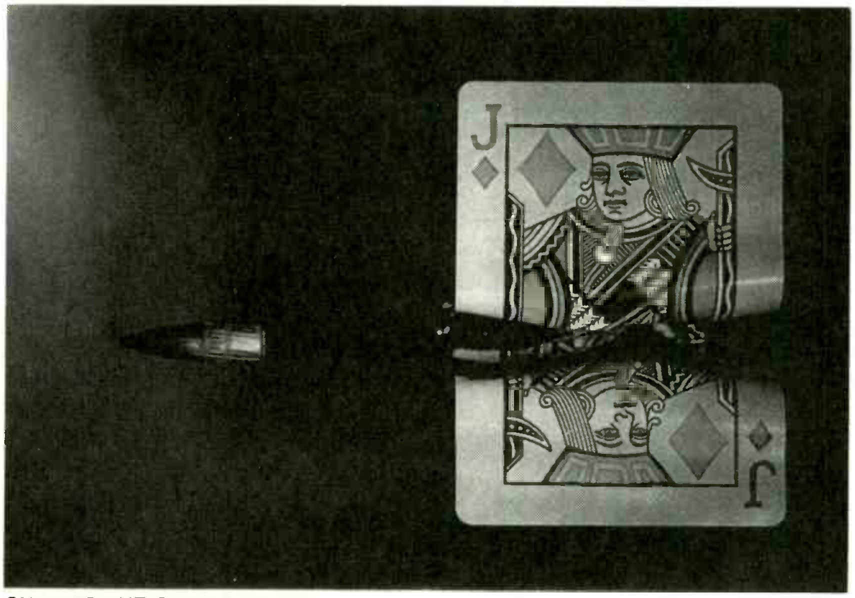
Although the name Edgerton is virtually synonymous with the stroboscope, he did not invent the device. His association with the subject hinged on his ability to find practical applications for the instrument rather than for its invention. That honor goes to Dr. Peter Roget (1779-1869), who invented a mechanical form of stroboscope while studying the effects of persistence of vision.

In later developments, the Belgian scientist, Joseph Plateau (1801-1833), built a rotating device he called the *Phenakistoscope* in 1829 that created the illusion of continuous motion. His work was based on his own observations and Roget's earlier research. At about the same time, a Viennese scientist, Simon von Stampher (1792-1864), invented a similar mechanical device that he called a *stroboscope*, a name from the Greek meaning "to view a whirling disk." Both devices were essentially whirling slotted wheels bearing little resemblance to the modern electronic strobe.

After recognizing the value of the stroboscope for analyzing faults in moving machines, Edgerton built his own bench-type electronic model. Then, after modifying his invention to make it easier to manufacture, he arranged to have General Radio Corp., Cambridge, Mass. (now GenRad, Inc.), manufacture and sell them. These instruments later evolved into standard test instruments that were widely used.



THIS .30 CALIBER BULLET, traveling at 2800 feet per second, was photographed with a one-third microsecond flash. The apple then flew apart.

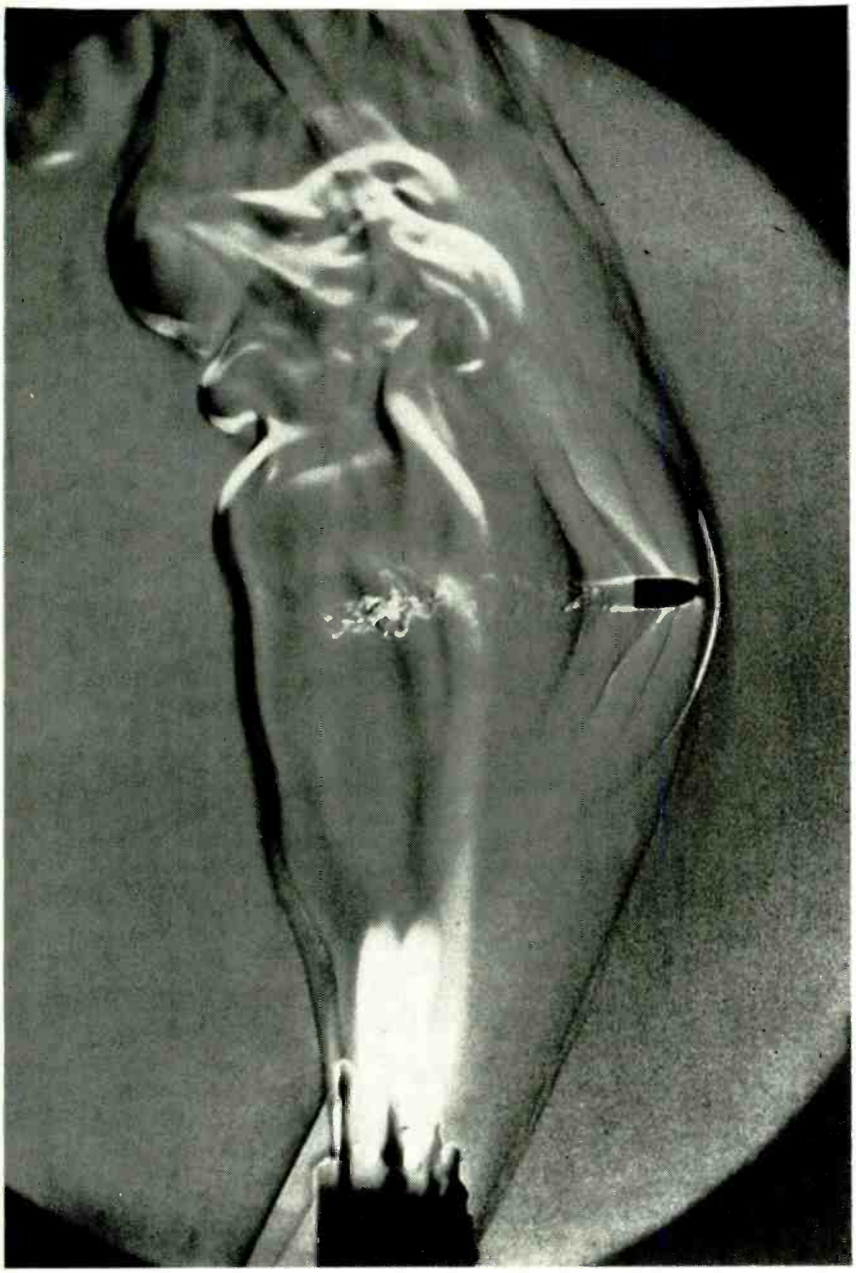


CUTTING THE CARD BY bullet.

Stop-action photography

In 1833, five years before the invention of photography, the English physicist Sir Charles Wheatstone (1802-1875), best known for his association with the bridge circuit of the same name and early forms of telegraph, suggested that short-duration light pulses from electric arcs would make fast-moving objects appear to stand still. He turned out to be right.

An early pioneer in photography, W.H. Fox Talbot (1800 to 1877), was the first person to demonstrate Wheatstone's theory. This Englishman had previously developed an independent photographic process that could print many positives from a single paper negative coated with silver iodide. Talbot made the world's first high-speed pho-



SUPERSONIC CANDLELIGHT. A photo showing a .22 caliber bullet passing through a candle flame.

tograph in 1851 when he put a copy of a newspaper on a whirling disk in a dark room and discharged a bank of Leyden jars (crude capacitors made as metal covered jars) to obtain a spark from an electrostatic discharge. The spark was bright enough to "freeze" the image of the whirling newspaper on the very slow photographic emulsions then available. The text from the newspaper captured in the photograph was readable.

The English scientist, Michael Faraday (1791-1867), also became interested in persistence of vision and stroboscopy. He is best known for his pioneering work in electromagnetic induction and as the discoverer of the basic principles of the electric motor. After observing that a moving toothed gear in a mill, when viewed through an adjacent moving toothed gear, appeared to be standing still, he built a small gear system in his laboratory (called Faraday's Wheel) to duplicate the phenomena. Although he made no real contribution to the subject, he provided Talbot with the battery and Leyden jars that were needed for his work.

High-speed photography was advanced by the invention of a gas-filled, light-emitting tube that could provide a controlled, continuous source of bright light. Its inventor, the German physicist, Heinrich Geissler (1814-1891), was seeking a continuous light source for spectroscopy. Later it was found that the Geissler tube could be pulsed.

An Austrian inventor, Ottomar Anschutz (1846-1907), devised the first practical high-speed mechanical camera shutter while attempting to animate high-speed photographs that he had sequentially photographed. His *Electrotachyscope* consisted of a large rotating disk and a Geissler tube, which he pulsed with a mechanical contactor. This apparatus made possible the generation of suitably bright, short-duration light pulses.

Other important early contributors to the wonders of strobe and stop-action photography included the English photographer, E. Muybridge (1830 to 1904), and the French physiologist Etienne Jules Marey (1830 to 1904).

Muybridge settled the ancient question about whether all four legs of a galloping horse ever leave the ground simultaneously. He set up a series of cameras a foot apart whose shutters were triggered by strings.

This setup provided a uniformly spaced series of photographs of a horse galloping along a track in front of the cameras. The pictures showed that there were brief periods when all four legs were off the ground.

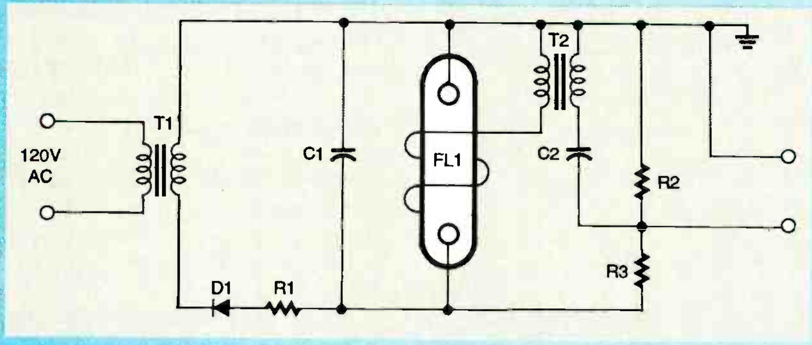
Marey introduced the principle of intermittent motion in 1882. He set up cameras that were able to make 12 exposures a second on a rotating glass plate with each exposure made at 1/720 second. His pictures of a jumper, for example, showed, on a single photographic plate, discrete changes of position as the athlete started and completed the jump. This work led,

FLASHTUBE TECHNIQUES

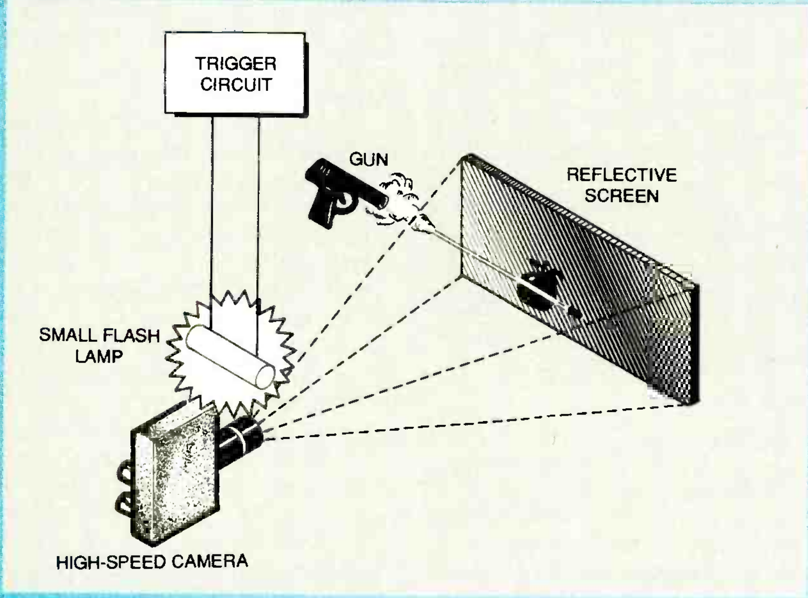
The figure shows an elementary circuit for triggering xenon-filled flash tubes with one external and two internal electrodes. The tube is connected across the main flash capacitor C1, which stores the energy that the lamp converts to light. Rectified current from transformer T1 charges capacitor C1 to a voltage equal to the peak voltage of transformer T1's secondary winding.

When switch S1 is closed, an electrical discharge begins in the flashtube. (S1 can be a contact in a synchronized camera shutter.) The pulse voltage in the secondary of the step-up transformer T2 is fed to the external electrode of the lamp to induce current in it by capacitive discharge. Once the glow on the tube walls begins, the lamp is lighted briefly but brilliantly by the capacitive discharge.

Multiflash, a term coined by Edgerton, is an electronic flash system (either single or multiple units) that can be fired manually or automatically in sequence. The interval between successive flashes and photographed images is determined by the activity being photographed. For example, when a golfer is photographed driving a ball, the flash might be fired automatically 100 or more times per second. A diver diving from a platform might be photographed only five or six times. Ω



METHOD FOR TAKING pictures of a high-frequency bullet in flight against a reflective screen.



TRIGGER CIRCUIT FOR FIRING an electronic flashtube.

more than 50 years later, to Edgerton's development of multiflash images.

Founding a consulting firm

In the years after Dr. Edgerton received his doctorate degree and became an instructor at MIT, the United States had entered a long period of economic depression. In the early 1930s, the salaries of instructors and professors were extremely low, and even the brightest college graduates had difficulty finding work in their chosen fields. Many of these people preferred to work at little or no pay rather than change fields to earn more money.

Two of Dr. Edgerton's graduate students, Kenneth Germeshausen and Herbert Grier, had completed their studies but were unable to get jobs. Edgerton was, however, able to persuade MIT to keep them on as unpaid research assistants in the Dynamo Lab.

This situation motivated Edgerton to think of ways that they could pool their knowledge and earn money as consultants to industry. He also wanted to supplement his own meager instructor's salary.

In 1931, Edgerton and Germeshausen formed a partnership to study high-speed photographic and stroboscopic techniques and their applications. Grier joined them in 1934. Edgerton, Germeshausen and Grier, Inc. was actually founded in 1947. (It later changed its name to EG&G.) However, during World War II, the Government's Manhattan Project made use of Edgerton's inventions while the three engineers were still working only as partners.

Strobes and photos

While pursuing his outside consulting activities and teaching at MIT, Dr. Edgerton was moving up the academic ladder. Something of Edgerton's personality emerges in this period of his life—his acceptance of the nickname "Doc" given to him by a colleague. It really emphasized his unique problem-solving abilities and his reputation as a mentor to graduate students rather than his possession of a doctor's degree. The MIT campus abounded with them at the time. "Doc" stuck for the rest of his life. He became a full professor of electrical engineering at MIT in 1948.

In the 1930s, Doc Edgerton's research was focused on stroboscopes for direct visual examination of moving machines. When stroboscopes were coupled to high-speed movie cameras, the stopped action could be recorded.

After investigating alternative light sources, he found that flashtubes were the only practical sources of the high-luminance, very short flashes of light suitable for ultra-high-speed photography. The light from magnesium flares could not be controlled, and the light from flashbulbs, although controllable with electronics, persisted too long.

The early experimenters in high-speed photography had used a spark gap, but it was satisfactory only where a small-volume source of very short duration is required. By contrast, the xenon-filled flashtube has an efficiency five times greater than the open spark.

The flashtube consists of a glass or quartz tube filled with gas and contains two or more electrodes. Other gases such as argon, neon, and krypton will work in flashtubes, but xenon provides the whitest light. These tubes can produce light pulses of one microsecond duration or less, and they can be fired thousands of times without needing replacement.

Because no satisfactory commercial flashtubes and trigger circuits were available commercially at the time, Edgerton invented his own. He developed a xenon-filled flashtube and trigger circuits that could produce the required high-intensity bursts of light.

Edgerton had a number of models built, and he sold them to professional photographers. This system later become a successful commercial product, and it remains the basic flash apparatus for still photography. The xenon flashtube also became an ideal stroboscope, and later xenon flashtubes would serve as optical pumps for pulsed lasers.

With his flash equipment Edgerton was able to make the photographs reproduced here. The bullets were traveling at speeds in excess of 2000 feet per second. The pictures, which possess artistic beauty, were of great interest and value to science and industry.

Aerial and undersea photos

In 1936, well before oceanography became a recognized scientific discipline, Dr. Edgerton developed his first underwater camera and lighting system suitable for use at extreme depths of a mile or more. He used a 16-inch naval shell as the container for both camera and strobe because it was strong enough to withstand the tremendous pressures at those depths. The naval shell was also large enough to house the bulky photographic equipment.

After the publication of his book *Flash: Seeing the Unseen by Ultra-High-Speed Photography*, the U.S. Army Air Force became interested in the use of strobe lamps for night aerial photography. After the United States entered World War II, strobe lamps became so important to the war effort that Edgerton was sent to England in 1944 to supervise the outfitting of aircraft with those lamps for night photography.

This equipment was used to photograph the Normandy beaches before the D-day invasion to confirm that there were no concentrations of German military equipment in the vicinity. Later Dr. Edgerton went to both France and Italy to advise the U.S. Army Air Force on night aerial photography. He was awarded the Medal of Freedom for his efforts.

Edgerton's services to the U.S. Government continued well into the post war period. During World War II, the government had used Edgerton's equipment to photograph atomic bomb explosions. After the war and the founding of Edgerton, Germeshausen and Grier, Inc., it was a natural transition for the company to support the Atomic Energy Commission (AEC) in its weapons research and development. The company was awarded contracts for managing atomic bomb testing. Edgerton-designed cameras photographed hydrogen bomb tests that were conducted both in Nevada and on Pacific Islands. These photos were vital in analyzing bomb performance.

After the war Edgerton also returned to underwater research and photography. He met with Jacques Yves Cousteau, the famed French undersea explorer and inventor of the aqualung, and began a decades-long collaboration in which Edgerton designed custom cameras for Cousteau, sometimes diving with him from Cousteau's research vessel *Calypso* to operate the equipment. The equipment was made by Edgerton, Germeshausen and Grier.

In 1953 Edgerton developed the "pinger," a high-frequency sonar projector that could determine precise locations on the ocean floor. In the process he discovered that the lower sonar frequencies partially penetrated the soft sediments on the ocean floor to reveal underlying rocks. Sonar beams from his low-frequency "boomer" located buried rocks off the coast of Puerto Rico that are believed to have been heaved up from the deepest layers of the Earth's crust.

Later, Edgerton designed the side-looking sonar that located the Union ironclad battleship *U.S.S. Monitor* (the cheesebox on a raft) which had sunk off the coast of North Carolina in a storm. This was the ironclad that had previously fought the Confederate ironclad *C.S.S. Merrimac* in the first battle between ironclads, March 9, 1862, off the Virginia coast. Edgerton was intrigued by the search for the Loch Ness monster in Scotland, so he had special sonar scanners and underwater cameras built in an attempt to track down the legendary sea serpent.

EG&G, Inc. now makes instruments and optoelectronic and mechanical components. Its products include devices that emit and detect light across the complete spectrum from ultraviolet to the far infrared. Although it still offers technical services to industry and government, it announced last year that it was ending its management and operating functions for the U.S. Department of Energy (DOE), successor to the AEC. Ω

SUBWOOFER

continued from page 86

puts that will be turned up for the loudest sound. Because the subwoofer crossover has a high input impedance, it does not load the receiver, and full power is still provided to the main speakers. The subwoofer crossover sums the signals from the left and right channels, so the left and right inputs are interchangeable.

Since the inputs of the subwoofer crossover are isolated from ground, the positive and negative inputs are also interchangeable. Be sure to observe the same polarity for both the left and right channels. This interchangeability feature is particularly useful when speaker polarity is unclear. The crossover's phase switch can reverse the input polarity to provide the correct phase.

Use a short cable to connect the subwoofer crossover to the power amplifier to prevent ignition noise pickup.

Adding bass-blocking capacitors in line with each of the main speakers is recommended, as shown in Fig. 7. This reduces the burden of reproducing deep bass on the main speakers, allowing higher volume with less distortion.

The capacitor values to use with 4-ohm speakers for popular bass-blocking frequencies are listed in Fig. 7. Bass-blocking capacitors should be non-polarized (bipolar). Use 135-Hz bass-blockers for most applications. Choose a higher frequency when the main speakers are weak in bass response.

Adding a choke coil in series with each side of the dual-voice-coil subwoofer (see Fig. 7) will prevent power amplifier oscillation problems. The inter-winding capacitance or mutual inductance of dual-voice-coil subwoofers can cause some power amplifiers to oscillate. You can purchase choke coils inexpensively, or wind your own. Twenty turns of No. 22 wire wrapped around a ¼-inch diameter steel bolt will provide an approximate value of inductance of about 20 microhenries.

Power for the subwoofer crossover and power amplifier can be supplied from the automobile's +12-volt ignition lead or from the remote turn on/power antenna lead.

First power up

Before turning the system on for the first time, set the volume controls of the subwoofer amplifier and the receiver to minimum. Set the crossover cutoff frequency control to maximum (fully clockwise).

After turn on, increase the receiver volume slightly to verify that sound is coming from each of the main speakers. If it does not, check for short circuits or open connections.

If sound comes from each of the main speakers, increase the subwoofer power amplifier level. Listen for bass from the subwoofer. If little or no sound is heard, try setting the receiver's balance control all the way to one limit. If this produces bass, one of the crossover inputs is connected backwards.

The most important step in adjusting a subwoofer system is to set (and keep) the stereo's bass control at or below the flat (middle) position. Vehicle interior acoustics are notorious for overemphasizing upper bass frequencies. By turning the bass control down, boomy-sounding upper bass is reduced. By adjusting the subwoofer crossover cutoff frequency for optimum sound, the subwoofer will fill in a deep, solid sounding bottom end.

Set the crossover polarity switch (S1) to position which gives the most bass. Set the crossover Eq. switch (S2) in the "boost" position to increase deep bass frequencies and to help extend the subwoofer's response. Use the "flat" position if you hear distortion from the subwoofer. Adjust the crossover cutoff frequency and the level control of the amplifier to provide the best sounding bass. Ω

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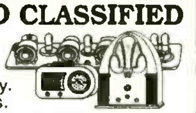

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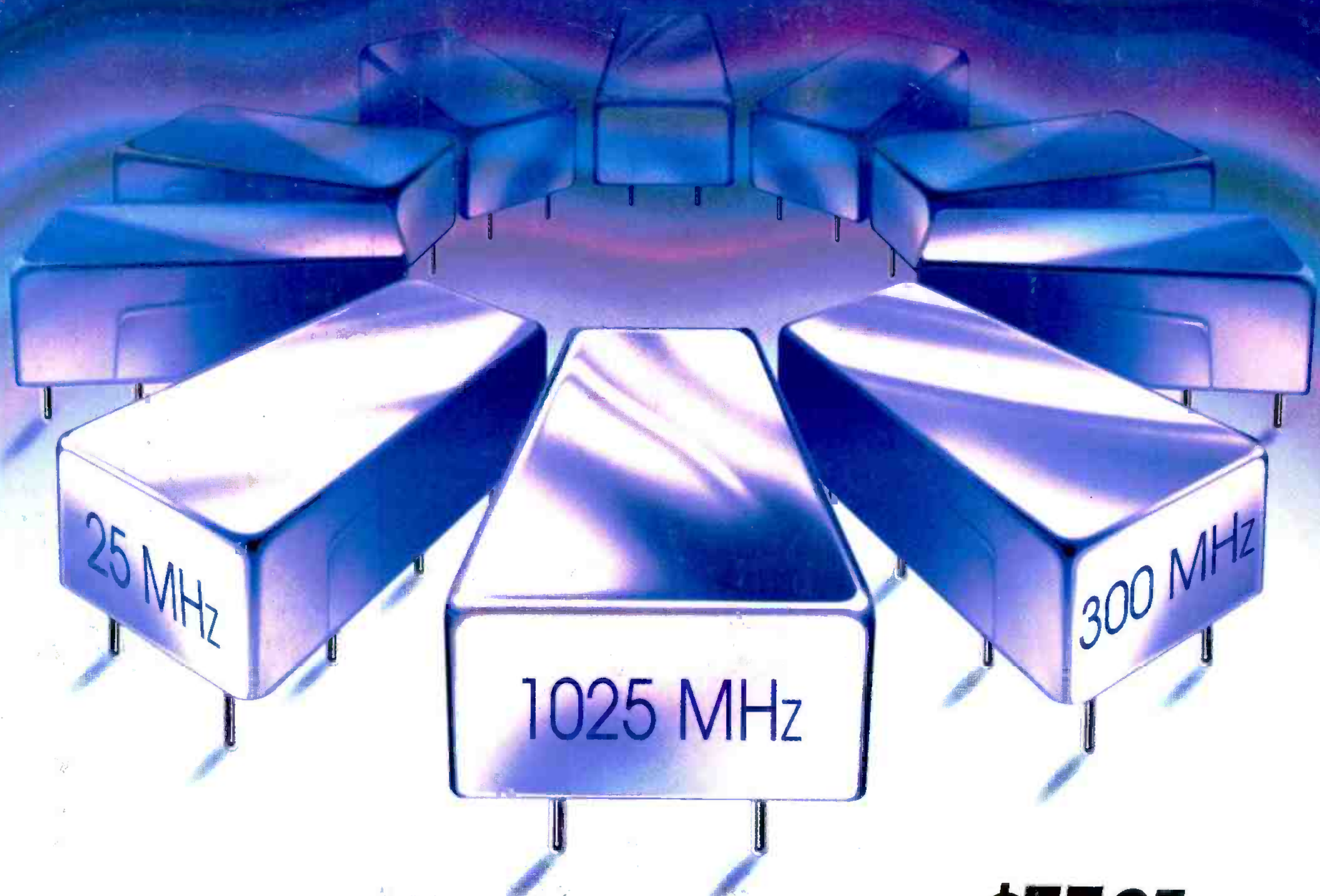

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