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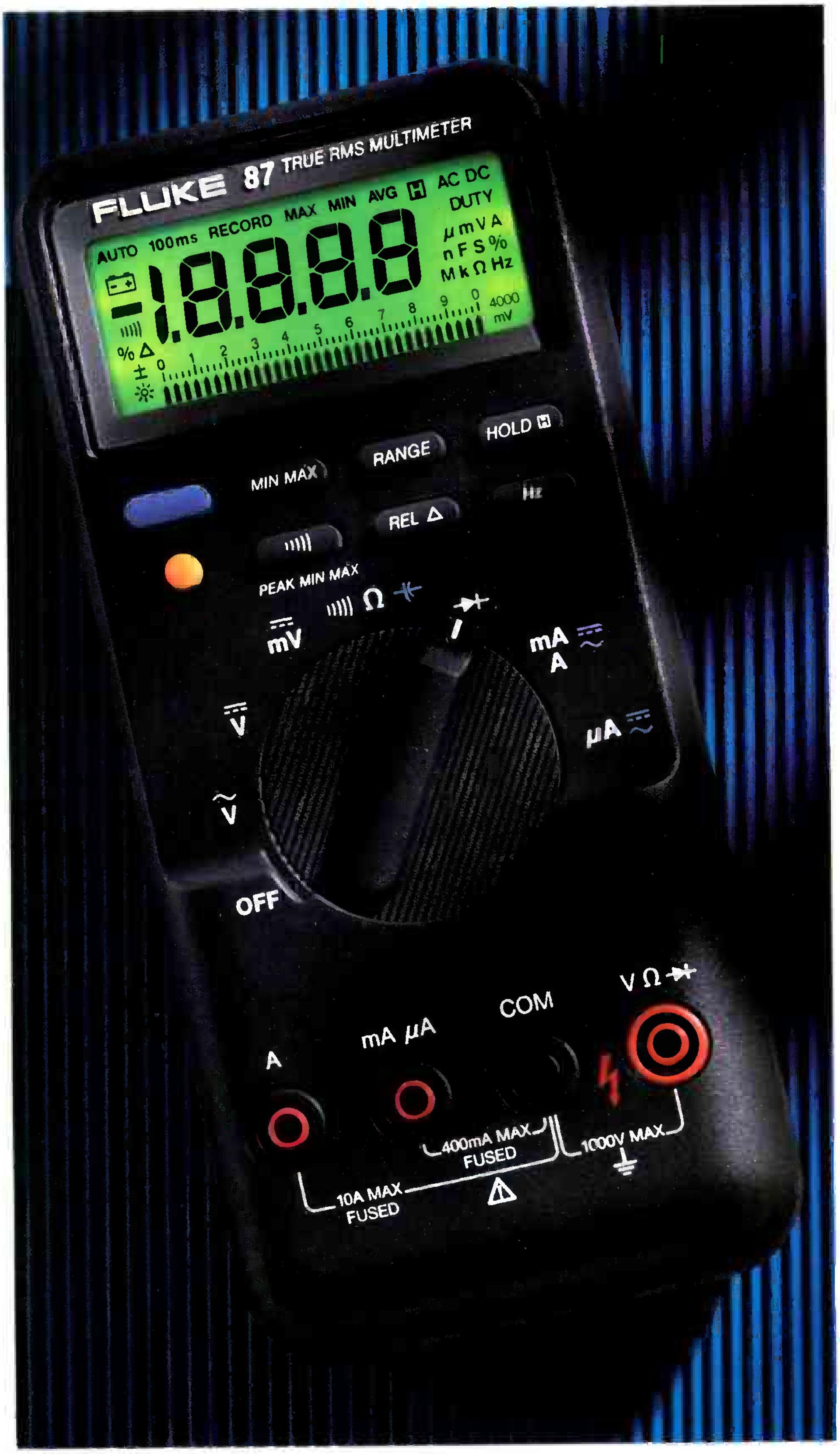

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ON THE COVER

Wouldn't it be great to have full-room audio sound everywhere in your house? Unfortunately, it's not practical to have separate audio systems in every room, and transmitting audio from one room to another usually entails the time-consuming (and messy) task of running cables to auxiliary speakers. The carrier-current transmitter pictured on the cover is a better solution. Combined with one of two receivers that we'll show you next month, it allows you to transmit an audio signal through your house's existing AC wiring. Then simply plug the receiver into any electrical outlet and you'll receive that signal—anywhere in the house. Turn to page 55 for details.

COMING NEXT MONTH

THE FEBRUARY ISSUE IS ON SALE JANUARY 3

HDTV
A look at the major contenders in high-definition TV.

PHONLINK II
Use your telephone to control your home.

CIRCUIT COOKBOOK
Recipes for pre-setable down-counter circuits.

ACTIVE ANTENNA
An easy-to-build antenna amplifier for improved shortwave reception.

USING WWV AS A CALIBRATION STANDARD
It's really traceable to the National Bureau of Standards!

COMPUTERDIGEST
More on Intel's 80386.

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Advertising Sales Offices listed on page 122.

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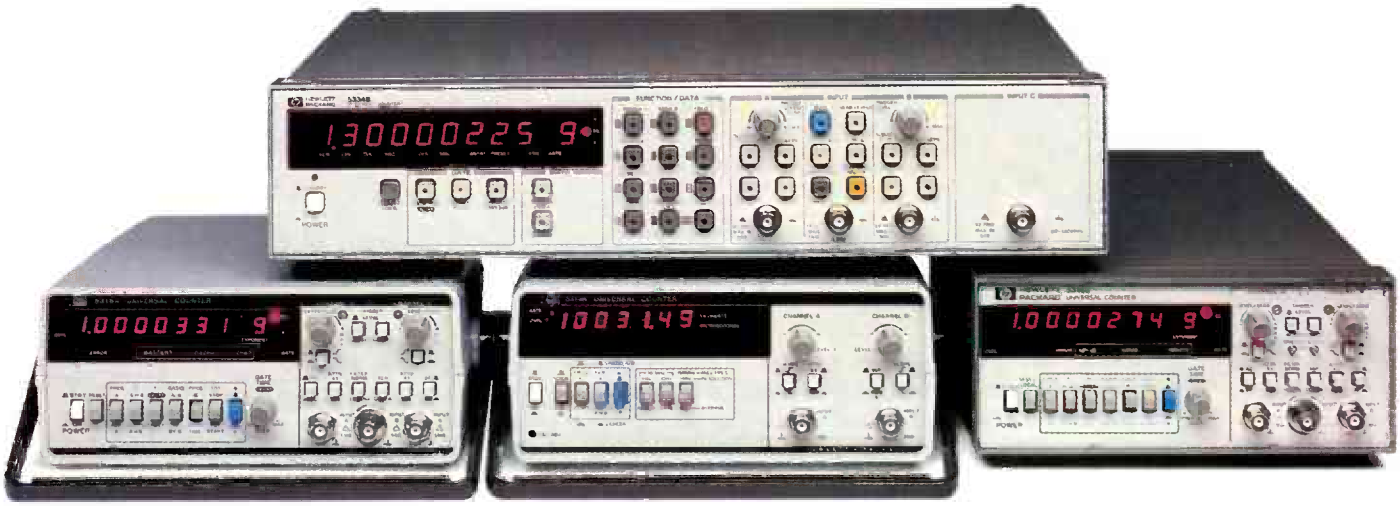

Hewlett-Packard Universal Counters

Model	HP 5314A	HP 5315A	HP 5316B	HP 5334B
Functions	Basic†	Basic† plus TI Delay & TI Averaging	Basic† plus TI Delay & TI Averaging	Basic† plus TI Delay, Rise/Fall Time, Pulse Width, AC Peak/DC Volts, TI Averaging
Freq. Range (Optional)	100 MHz	100 MHz (1 GHz)	100 MHz (1 GHz)	100 MHz (1.3 GHz)
Freq. Resolution (1 sec. gate time)	1 Hz	7 digits	7 digits	9 digits
TI Resolution Single shot/Averaging	100ns/NA	100ns/10ps	100ns/10ps	2ns/200ps
Best Sensitivity	25 mV	10 mV	10 mV	15 mV
Timebases: Standard TCXO option Oven option	 $<3\times10^{-7}$ /mo. $<1\times10^{-7}$ /mo. N/A	 $<3\times10^{-7}$ /mo. $<1\times10^{-7}$ /mo. $<3\times10^{-8}$ /mo.	 $<3\times10^{-7}$ /mo. $<1\times10^{-7}$ /mo. $<3\times10^{-8}$ /mo.	 $<3\times10^{-7}$ /mo. N/A $<5\times10^{-10}$ /day
HP-IB Programmable Controls	N/A	N/A	Function, Trigger Level, Slope	All
Battery Operation	Optional	Optional	N/A	N/A
Ordering Information* Without Options	HP 5314A ~~$600~~ $540	HP 5315A ~~$1250~~ $1125	HP 5316B ~~$1475~~ $1327.50	HP 5334B ~~$1950~~ $1755
With Options (prices include mainframe and option(s))	Opt. 001 TCXO ~~$780~~ $702 Opt. 002 Battery ~~$780~~ $702	Opt. 001 TCXO ~~$1430~~ $1287 Opt. 002 Battery ~~$1550~~ $1395 Opt. 003 1 GHz ~~$1650~~ $1485 Opt. 004 Oven ~~$1850~~ $1665 Opt. 001 TCXO & Opt. 003 1 GHz ~~$1830~~ $1647	Opt. 001 TCXO ~~$1655~~ $1489.50 Opt. 003 1 GHz ~~$1875~~ $1687.50 Opt. 004 Oven ~~$2075~~ $1867.50 Opt. 001 TCXO & Opt. 003 1 GHz ~~$2055~~ $1849.50 Opt. 003 1 GHz & Opt. 004 Oven ~~$2475~~ $2227.50	Opt. 010 Oven ~~$2750~~ $2475 Opt. 030 1.3 GHz ~~$2500~~ $2250 Opt. 060 Rear terminals ~~$2075~~ $1867.50 Opt. 010 Oven & Opt. 030 1.3 GHz ~~$3300~~ $2970 Opt. 010 Oven & Opt. 060 Rear terminals ~~$2875~~ $2587.50 Opt. 010 Oven & Opt. 030 1.3 GHz & Opt. 060 Rear terminals ~~$3425~~ $3082.50

† Basic Functions: Frequency, Period, Time Interval (TI), Totalize, Ratio

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EDITORIAL

It is with deep sorrow that I announce the passing of a great writer and editor, Herb Friedman.

Herb was a contributer to countless magazines, writing on a wide range of topics—but he was most at home with electronics. He wrote his first article for Radio-Electronics sixteen years ago, and started his "Communications Corner" column almost a decade ago. You may well remember the stories he did for us on computers, power conditioners, blue boxes, facsimile, paging technology, and more. In coming months, you'll be seeing some of the stories that Herb had been working on recently.

Three years ago, Herb retired from the New York City school system where he was an engineer at radio station WNYE. Of course, Herb's idea of retirement included joining our staff and working full time for Radio-Electronics.

Herb was not one to keep quiet and sit back. A dynamic man, and never content to leave well enough alone, he was always looking for better ways to do things, whether that meant setting up an in-house photo studio or installing better connectors on our computer network cabling.

He constantly challenged the status quo. Of course, that made my job more difficult. But it kept me on my toes, and made the magazine better for you—the people Herb was most concerned with.

Herb will be missed not only in our pages, but on the floor of Gernsback Publications, where his stories, comments, criticisms, and jokes were enjoyed immensely. And where his experience amd his love of new technology taught us all.

Brian C. Fenton
Editor

WHAT'S NEWS

Magnetic resonance opens new frontiers

EXPERIMENTAL MAGNETIC RESONANCE SCANNER based on a 50-ton superconducting magnet, has twice the power of any used now, producing a uniform magnetic field of 4 Tesla in its 1-meter bore. Drs. John F. Schenck (left) and Rowland W. Redington are shown examining a coil used in making 4-Tesla magnetic resonance images of the head.

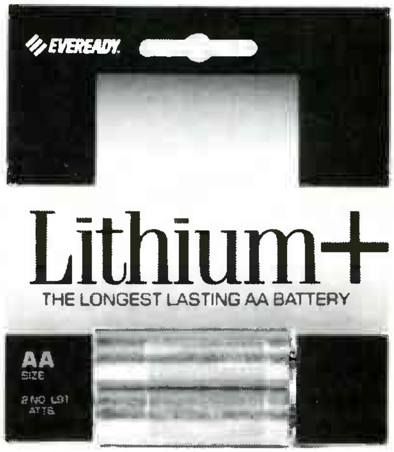
General Electric researchers reported important advances in magnetic resonance technology at the Magnetic Resonance in Medicine meeting in San Francisco last August. Reports were based upon work done with a 50-ton superconductor-magnet scanner with a field of 4 Tesla—80,000 times the strength of Earth's magnetic field. (The experimental scanner is one of three 4-Tesla scanners in the world, and the only one in the United States.)

In magnetic resonance scanning, the subject is positioned in the cylindrical bore of the magnet and probed with high-frequency radio signals. Those penetrate into the body and, under the influence of the strong magnetic field, cause the nuclei of selected atoms to resonate and produce faint radio signals. Those are picked up and transmitted to a sophisticated process computer for interpretation.

The new scanner has a signal-to-noise ratio that is double that of the 1.5-Tesla scanners presently in use. With the higher resolution, the GE scientists are discovering more of the diagnostic capability of magnetic resonance. Knowledge gained with the 4-Tesla scanner will enhance the performance of today's machines.

AA lithium batteries for consumers

Eveready Battery Company has developed the industry's first AA 1.5-volt lithium battery. Dubbed *Lithium+*, it is expected to move lithium technology out of the specialty-battery field and into the mainstream of consumer usage. When it is introduced in early 1989, Lithium+ will be the highest-energy AA battery available. It will last up to double the length of alkaline batteries in many applications, weigh one-third less, and have a shelf-life of 10 years or more.



EVEREADY BRINGS THE POWER lithium into the mainstream with Lithium+, the industry's first AA 1.5-volt lithium batteries.

Lithium-battery technology, pioneered by Eveready in the 1960's, has had narrow applications in specialty batteries, including photo cells and the declining 9-volt segment. Lithium+'s unique design allows the power of lithium in the popular 1.5-volt cell format, creating a battery with unmatched energy density. Besides the advantages to consumers, Eveready expects the new batteries to prompt innovations in electronics design in the form of more compact and complex battery-powered devices. **R-E**

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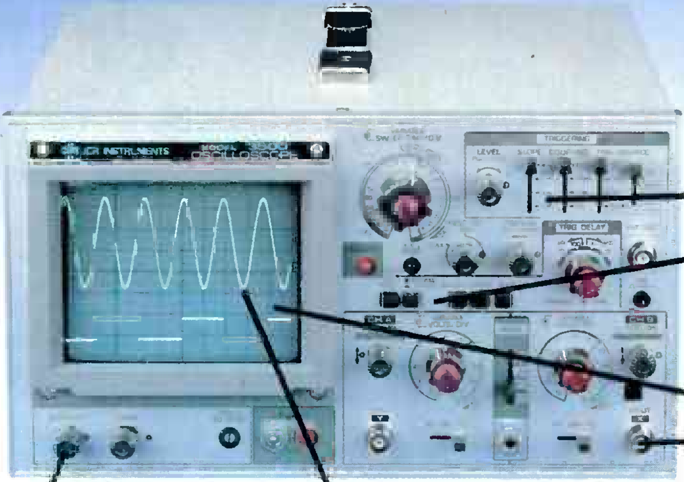


Wide bandwidth and exceptional 1mV/DIV sensitivity make the Model 3500 a powerful diagnostic tool for engineers or technicians at a remarkable price. Delayed triggering allows any portion of a waveform to be isolated and expanded for closer inspection. Variable Holdoff allows stable viewing of complex waveforms.

DMM-300 $79.95

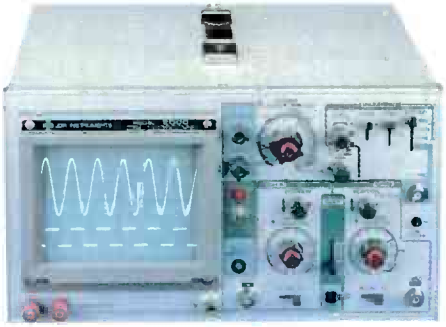
3.5 DIGIT DMM/MULTITESTER

This full function 3.5 digit DMM offers highly accurate performance and a host of added features like audible continuity, capacitance, transistor, temperature, and conductance to help you do the job—fast. Temperature probe, test leads and battery included.

- Basic DC accuracy: plus/minus 0.25%
- DC voltage: 200mv–1000V, 5 ranges
- AC voltage: 200mv–750V, 5 ranges
- Resistance: 200 ohms–20M ohms, 6 ranges
- Capacitance: 2000pf–20 µf, 3 ranges
- Transistor Tester: 0°–2000°F
- Conductance: 200ns
- Fully overload protected
- Input impedance: 10M ohm.

MODEL 2000 $389.95

20 MHz DUAL TRACE OSCILLOSCOPE



Model 2000 makes frequency calculation and phase measurement quick and easy. The component tester aids in fast troubleshooting. Service technicians appreciate the TV Sync circuits for viewing TV-V and TV-H and accurate synchronization of the video signal, Blanking, VITS, and V/H sync pulses.

- Exceptionally bright 5″ CRT
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DMM-100 $29.95

3.5 DIGIT POCKET SIZE DMM

Perfect for the field service technician. Shirt pocket size without compromising features or accuracy. Large, easy to read ½″ LCD display. Fully overload protected for safety. 2000 hour battery life with standard 9v cell. Probes and battery included.

- Basic DC accuracy: plus/minus 0.5%
- DC voltage: 2v–1000v, 4 ranges
- AC voltage: 200v–750v, 2 ranges
- Resistance: 2k ohms–2M ohms, 4 ranges
- DC current: 2mA–2A, 4 ranges
- Input impedance: 10M ohm
- Fully overload protected
- Approx. 5″ x 3″ x 1″. Under 7 ozs.

DMM-200 $49.95

3.5 DIGIT FULL FUNCTION DMM

Get highly accurate performance at a very affordable price. Rugged construction, 20 amp current capability and 22 ranges make it a perfect choice for serious field or bench work. Low battery indicator and tilt-stand. Probes and 2000 hour battery included.

- Basic DC accuracy: plus or minus 0.25%
- DC voltage: 200mv–1000V, 5 ranges
- AC voltage: 200mv–750V, 5 ranges
- Resistance: 200 ohms–20M ohms, 6 ranges
- AC/DC current: 200µA–20A, 6 ranges
- Input impedance: 10M ohm
- Fully overload protected
- Approx. 7″ x 3½″ x 1½″. Wt. 11 ozs.

DPM-1000 $54.95

3.5 DIGIT PROBE TYPE DMM

Custom 80 pin LSI chip provides accuracy and reliability in such a compact size. Autoranging, audible continuity and data hold feature help you pinpoint the problem quickly. Case and batteries included.

- Basic DC accuracy: plus/minus 1%
- DC voltage: 2v–500v, autoranging
- AC voltage: 2v–500v, autoranging
- Resistance: 2k ohms–2M ohms, autoranging
- Fully overload protected
- Input impedance: 11M ohm
- Approx 6½″ x 1″ x ¾″. Under 3 ozs.

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VIDEO NEWS

DAVID LACHENBRUCH,
CONTRIBUTING EDITOR

• **HDTV and EDTV.** Japan is the first country to broadcast in high-definition TV (HDTV) and almost certainly will be the first to transmit extended-definition TV (EDTV). The HDTV transmissions started unofficially with government-chartered NHK (Japan Broadcasting Co.) satellite telecasts of the Olympics from Seoul, Korea. So far there are no concrete plans to broadcast HDTV from conventional terrestrial TV stations. Japan's commercial broadcasters, meanwhile, hope to start transmitting EDTV in April. That system involves a signal that is compatible with standard-NTSC broadcasts and, therefore, receivable on standard TV sets (**Radio-Electronics**, April 1987). But special digital EDTV sets would get a much better picture. The tentative EDTV standards involve the use of a higher resolution picture source, detail-corrected high-saturation images, adaptive emphasis, and three-dimensional Y/C (luma/chroma) separation at the broadcast end. The receiver will use non-interlaced progressive scanning and digital ghost cancellation. A second phase of EDTV is expected to involve the transmission of a compatible wide-screen picture.

• **LCD TV projector.** Eastman Kodak is now offering a tubeless video projector at $3,500. Believed to be the forerunner of a new generation of consumer projection TV's, the projector uses three liquid-crystal displays as lightvalves—one for each primary color. The three color images are brought together into a single lens by a series of mirrors that are sensitive to each type of light. The entire system can be focused, and Kodak claims it can project a picture up to 12-feet wide on a wall or external screen. It can take any video or computer signal as input, is small enough to fit under an airline seat, and weighs 13 pounds. The system is made by Seiko for Kodak (**Radio-Electronics**, January 1987). Several other manufacturers, including Sharp, Toshiba, and Sanyo, have demonstrated prototype LCD projectors. The pictures projected by all of those are currently too coarse to be satisfactory for home use, but it probably is only a matter of time before improved tubeless lightvalve projectors make their way into consumer use.

• **Still video arrives.** Although it's been used by professional news photographers for several years, still video has just arrived on the consumer market. Several manufacturers introduced home models at the recent Photokina exposition in Cologne, Germany. Still-video cameras all use the 2-inch "video floppy," a tiny disc which can store 50 TV fields or 25 full frames. All of them have accessory videoplayers that will place the still picture on the TV screen, and printers are available to make hard color copies. Canon introduced a still electronic camera at under $800 retail, to be available early in 1989. Fuji's version will cost about $1,270. Sony is more moderately priced at about $520 in Japan (probably more when it reaches the U.S.), while Konica's is $740. When you consider that the still-video cameras have relatively low resolution and require such accessories as the TV player and printer, film photography begins to look like a bargain.

• **Super' Laservision.** Until Super VHS came along, Laservision optical videodiscs provided the best picture available on the home screen. Then S-VHS—with its 400-line-plus resolution and, particularly, its separate chrominance and luminance signals—arrived and pre-empted that position. Now Laservision is fighting back with new Laserdisc players from Pioneer that have the same split-Y/C output as S-VHS recorders. Of course, to get the good picture quality you'll need high-resolution TV sets with the special Y/C-input terminals that are designed for S-VHS. Another added attraction in the new videodisc players is the ability to play both sides of the disc without turning it over. And one upcoming player will take two discs and will automatically play both sides of each in sequence. That will allow the potato to remain on the couch for the entire duration of both movies. **R-E**

ASK R-E

WRITE TO:

ASK R-E
Radio-Electronics
500-B Bi-County Blvd.
Farmingdale, NY 11735

POWER-SUPPLY WOES

I need some help with a variable power supply that I built. I'm using a 2-amp transformer, but the circuit gets hot and I've already burnt out one regulator on the positive side. I want a 12-volt 2-amp supply using a center-tapped transformer—any ideas? And what gauge wire should I be using?—R.J.N., Ridge Manor, FL

Your letter leaves me with almost as many questions as you're asking. I'm guessing that you're producing a bipolar supply since you talked about the "positive side," and you specifically mentioned using a center-tapped transformer. Since you haven't burnt out the negative side, you're either not regulating it or you aren't drawing much current there anyway.

The issue, therefore, is to work out a circuit that will generate a variable supply with a 12-volt ceiling that's capable of supplying 2 amps. If that's the case, here's the deal.

Because you're only looking for 2 amps, the easiest way is to use any standard three-legged regulator, like the 7805, and hang it on the plus side of the diode bridge. There's more to it than that, of course, and the schematic in Fig. 1 should answer most of your questions. By using the potentiometer on the ground leg, you can raise the voltage well above the IC's rated 5 volts. The output will go from about 5 to 15 volts at the top, but make sure you heat-sink it properly or the regulator will suffer the same fate as the one you had in the circuit originally.

If you need to get below 5 volts, use the schematic in Fig. 1 but substitute an LM 317, because it's designed to produce an output from about 1.2 to 25 volts and it, like the 78XX series, can safely handle a maximum of 1.5 amps. As in the earlier example, you MUST heat-sink the chip properly.

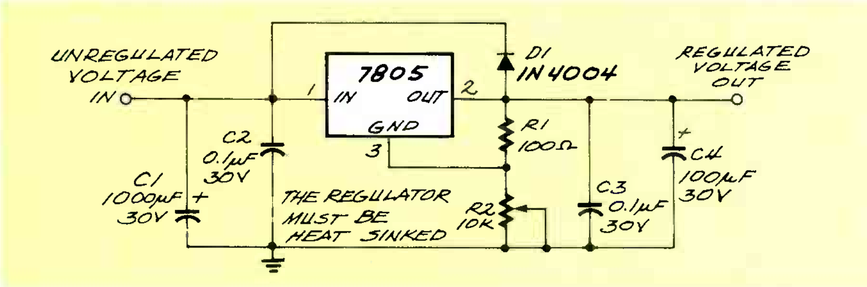

FIG. 1

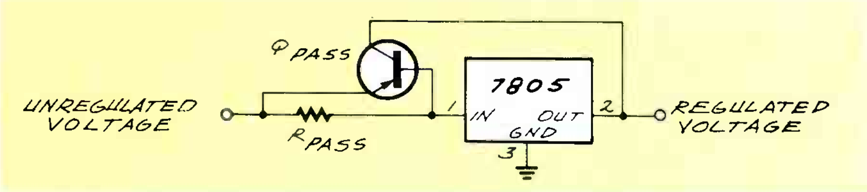

FIG. 2

You didn't specify the range of voltages you wanted but if you need something that goes down to zero volts, you've got a big problem because that's a major design job.

You mentioned that you needed 2 amps. Remember that you can only get 2 amps from a supply if you have a transformer that's capable of producing it in the first place. Since you're using a center-tapped transformer and obviously producing a split supply, you're asking half the transformer to supply more than 25 watts of power.

That's a lot of juice!

The circuit in Fig. 2 show you the basics of designing with a pass transistor. When the current through the resistor gets high enough, the voltage drop will turn on the transistor and pass current to the output of the supply. There's not enough room here to get into all the design considerations but you should be able to find them in most of the "voltage regulator" data sheets. A complete discussion on how to design power supplies like these appeared in the "Drawing Board" columns that were published from May to August of 1983.

LIGHT-ACTIVATED SCR

I'm having a lot of trouble locating a light-activated SCR. Most of the companies don't seem to carry them. Can you tell me where I can go to get those parts?—A.A., Queens, NY

Once upon a time just about every one carried those things—even Radio Shack—but times have changed. I guess people aren't interested in building slave units for

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Uniden Corporation of America has purchased the consumer products line of Regency Electronics Inc. for $12,000,000. To celebrate this purchase, we're having our largest scanner sale in history! Use the coupon in this ad for big savings. Hurry...offer ends February 28, 1989.

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List price $189.95/**CE price $94.95/SPECIAL**
10-Band, 16 Channel • No-crystal scanner Priority control • Weather search • AC/DC
Bands: 29-54, 136-174, 406-512 MHz.
The *Bearcat* 145XL is a 16 channel, programmable scanner covering ten frequency bands. The unit features a built-in delay function that adds a three second delay on all channels to prevent missed transmissions. A mobile version called the **BC560XLT-T** featuring priority, weather search, channel lockout and more is available for $94.95. CEI's package price includes mobile mounting bracket and mobile power cord.

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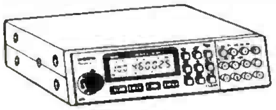

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photostrobes any longer. In any event, most large suppliers should still be carrying LSCR's.

If you're not sure what to order—and there are lots of different LSCR's—you can ask the suppliers if they carry an MRD-920. That is a fairly standard LSCR and should work in most applications.

If it should turn out that you can't find anyone who carries that part, (or its equivalent), you can always try Radio Shack. They don't have any LSCR's in their current catalog but they do claim to be able to get "any semiconductor or tube." This is a good way to put them to the test: Just walk into your local branch and ask them to get you an MRD-920.

Your absolute last resort is to build an LSCR. That isn't hard to do, because an LSCR is really nothing more than a light-activated SCR that's capable of handling 120-volt loads. Examine the variables in your application and use just about any phototransistor to turn on a standard SCR that meets your circuit specifications.

HARDWARE AND A Z-80

I'm interested in developing hardware around the Z-80 but a lot of the software I've been looking at requires RAM at 0000h. The problem is that that is also the Z-80's power-up location. Is there some way to either change the power-up location or store a permanent jump there to some other location in RAM? Also, can anything be done about the Z-80's built-in jump to 0066h for an NMI?—C. Long Baltimore, MD

The first thing to realize is that there's absolutely no way, short of surgery, to change the Z-80's internal jump locations. They're an inherent part of the microcode and there's not one thing you can do about it. Given that, let's see what the options are for working around it.

Most small systems, including home-built Z-80 circuits such as a controller, development system, or the like, follow the path of least resistance and draw up a memory map with ROM at the bottom and RAM at the top—and that is still the best way to go about it.

If you insist on sticking ROM up at the top, you need some way of getting power-up instructions down at 0000h. Most systems doing that sort of thing load 0000h with a jump to the ROM starting location that contains all the initialization code. That means you have to load three bytes at the bottom of memory since the jump uses three bytes of code.

There's no way you can have ROM and RAM occupying the same memory space, so you need some way of switching between them—automatically. Simply stated, you want the ROM active only at power up and reset, and the RAM active the rest of the time.

That can often be a real decoding nightmare but; since we know when the ROM has to be selected, the problem is a bit easier to solve. In actual fact we don't have to do any address decoding at all. There's not enough room here to go through the design of the circuit but the subject is interesting enough to cover in detail later on.

First of all, the jump instruction has to be put in some type of permanent storage device. A small bipolar PROM like a 74S288 makes sense because it's easy to program, can be tristated, and we only need three bytes of code. The circuit's core is a decade counter, such as the 4017. Why a decade counter? Well, once you realize that a jump instruction takes ten clock cycles you should understand what's going to happen.

At power up, the final output of the counter keeps the ROM enabled and the RAM disabled. The Z-80 goes to location 0000h and takes ten clock cycles to fetch the jump instruction. Meanwhile, the counter is advancing once for each clock cycle. At the end of the opcode fetch the counter has reached ten. That disables the counter, tristates the ROM, and enables the RAM that's mapped to the bottom of the memory map.

The parts count for the circuit is minimal. You'll need a PROM, a counter, and maybe a gate or two to make it all happen. If you want more than just the one instruction to execute automatically whenever the system is reset—initialize ports, test memory, etc.—you only need a larger PROM (an EPROM is ideal), and a longer counter to do the job. The rest of the circuit is the same. **R-E**

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LETTERS

THE POLITICS OF ISDN

Not mentioned in Mr. Summer's excellent article, "ISDN: The Telephone of Tomorrow" (**Radio-Electronics**, October 1988), are the potential political uses for an ISDN-based national network. Now there is reason to believe that electronic-initiative petition, referendum, and recall are not 21st-century dreams, but 20th-century possibilities.

Instead of pursuing improbable space stations, or Star Wars defense programs of dubious value to the people of this country, the government should invest in the nation's democratic future by engaging cooperatively with businesses in a technological initiative dedicated to bringing a national electronic-voting network—one that could reach every home—into existence.

I truly believe that such a system can be built. And, considering the growing impatience of the electorate with representative democracy (as evidenced by progressively lower voter turnouts), it might be just the thing to revive our flagging democracy.

DAVID A. SAULT
Taunton, MA

PATENTLY ABSURD

Congratulations on your item concerning patents in "Hardware Hacker" in the October 1988 issue. I am sure it will save many of your readers a lot of grief. Back in 1968 I published a pamphlet (reissued in 1980) called "Patent Absurdity" that expressed much the same sentiments.

I was very fortunate with the electronic-keyboard oboe that I built back in 1937 and played occasionally in orchestra groups. (It still works now, 51 years later, by the way!) I got advice about patents and kept out of the adversary situation. I later discovered that the basic idea of a vacuum-tube oscillator as a musical instrument was thought of by Lee DeForest in 1917 (the year I was born). Imagine what those patent examiners would have done to me, citing references from that far back!

More recently, I built some giant contrabass steel guitars with my own brand of pickups and a unique colored-line design on both sides of a 7- or 8-foot board. They've been exhibited in six different modern art galleries since 1977, and color pictures of them were published in *LIFE*, *Omni*, and *Connoisseur* magazines in the 1980's.

So, with the publicity my instruments received as modern art, I made a reputation without having to bother with the dreadful patent system. That's one way to escape it—and certainly a far more pleasant experience.

IVOR DARREG
San Diego, CA

RADIATION

The letter from Leslie P. McCarty, Ph.D. (**Radio-Electronics**, September 1988) raises some questions about the *Radalert* nuclear-radiation monitor (June and July, 1988) that need a response, says author Joe Jaffe.

Dr. McCarty claims that "there is a negative correlation between the presence of radon and lung cancer," and that "those areas with the highest concentration of radon have a lower incidence of lung cancer." Those claims are contradicted by a January 6, 1988 report by the National Research Council, titled "Health Risks of Radon and Other Internally Deposited Alpha-Transmitters." The report is based on a 3-year study funded by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC). Of particular importance in the report is the information that health risks from breathing radon are significantly higher for smokers, and that people can cut the risk of lung cancer from radon even after they have inhaled the radioactive gas by reducing further exposure. The Council's report did not give a specific number of excess lung-cancer deaths attributable to radon, but estimated them to be in the middle of the 5,000 to 20,000 range calculated by the EPA. And, in September, 1988, Dr. Vernon J. Houk, Assistant Surgeon General with the Public Health Service, stated, "Radon-induced lung cancer is one of today's most serious public health issues."

Dr. McCarty faults us for using John Gofman, M.D., Ph.D., as an authority on the hazards of radiation. We make no apologies for that. Dr. Gofman's credentials are impeccable. He is Professor Emeritus of Medical Physics at the University of California, Berkeley. He was a co-discoverer of Uranium 233, and developed several of the first methods for isolating plutonium for the Manhattan Project. He was Associate Director of the Lawrence Livermore Laboratory and founder of the Laboratory's Biomedical Research Division that evaluated the role of ionizing radiation in human cancer causation. The original permissible standard of average exposure of 170 millirems per person per year, over and above radiation received from natural sources, was set by the Federal Radiation Council in the early 1960's. That high level was opposed by Dr. Gofman for many years—until, finally, in 1979 the standard was reduced to 25 millirems per person per year.

Finally, Dr. McCarty says, "I don't know what the window of the GM1 tube is made of, but I can guess that alpha particles do not penetrate it." I refer Dr. McCarty to the IEEE Standard Test Procedure for Geiger-Muller Counters, which indicates standards for the detection of alpha particles. The GM1 tube used in the Radalert meets those standards.

I agree with Dr. McCarty that the *Journal of Health Physics* is a more professional source of information on the biological effect of radiation than is **Radio-Electronics**—but that should certainly not preclude your magazine from publishing such important material.

JOE JAFFE
San Diego, CA

BIOFEEDBACK MODIFICATIONS

I enjoyed Jim Barbarello's "Build A Biofeedback Monitor" in **ComputerDigest** (October 1988). It is a good example of a simple hardware/software construction project for use with an IBM PC-compatible computer. However, I believe that all of the active circuitry shown in the article's Fig. 1 can be eliminated. That would leave just the finger probes, which can be mounted on any flat surface.

Almost everyone who owns a PC-compatible has the circuit shown in Fig. 1 (four of them, in fact) built into his computer. With the exception of the values of R1 and C1, that circuit is identical to one of the four channels of the joystick interface, or "Game Control Adapter," as IBM calls it. The joystick interface is included on most multi-I/O cards for XT- and AT-compatible computers.

I simply attached the probes to pins 1 (+5 volts) and 3 (input) of the 15-pin joystick connector. Because the joystick interface is addressed as port 201 (hex), I made the following changes to the program in Listing 1: First, I deleted lines 30, 40, 420, and 430. I changed lines 50, 330, and 340 to read:

```
50 G=&H201:L=13:LOCATE 1,23,0
330 OUT G,0
340 X=X+1:IF(INP(G) AND 1)=1 THEN 340
```

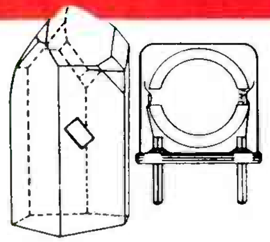
My simplified unit works just fine; however, I can no longer use the enhanced version of the compiled software that is available from Mr. Barbarello.

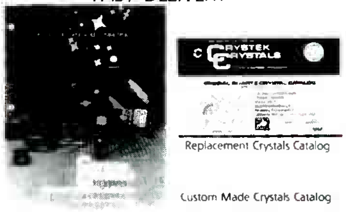
ERIC B. SCHUYLER
Snyder, NY

COMPUTER VARIETY

I would like to add my two-cents worth to the "computer variety" issue that has recently come up in the "Letters" section (**Radio-Electronics**, July, September & October 1987).

I read **Radio-Electronics** from cover to cover, and I obtain valuable information of some sort from each issue—sometimes from one column, sometimes from another. I haven't the time to build many of your projects, but I do construct some and wish that I could make more. And, although my comput-





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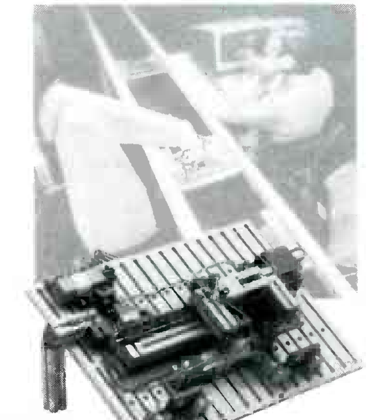
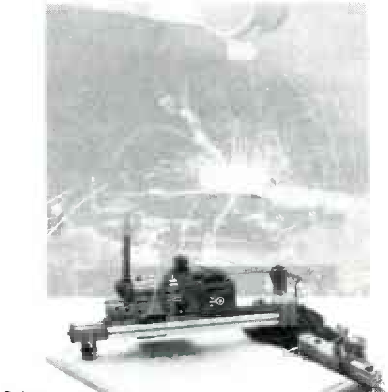
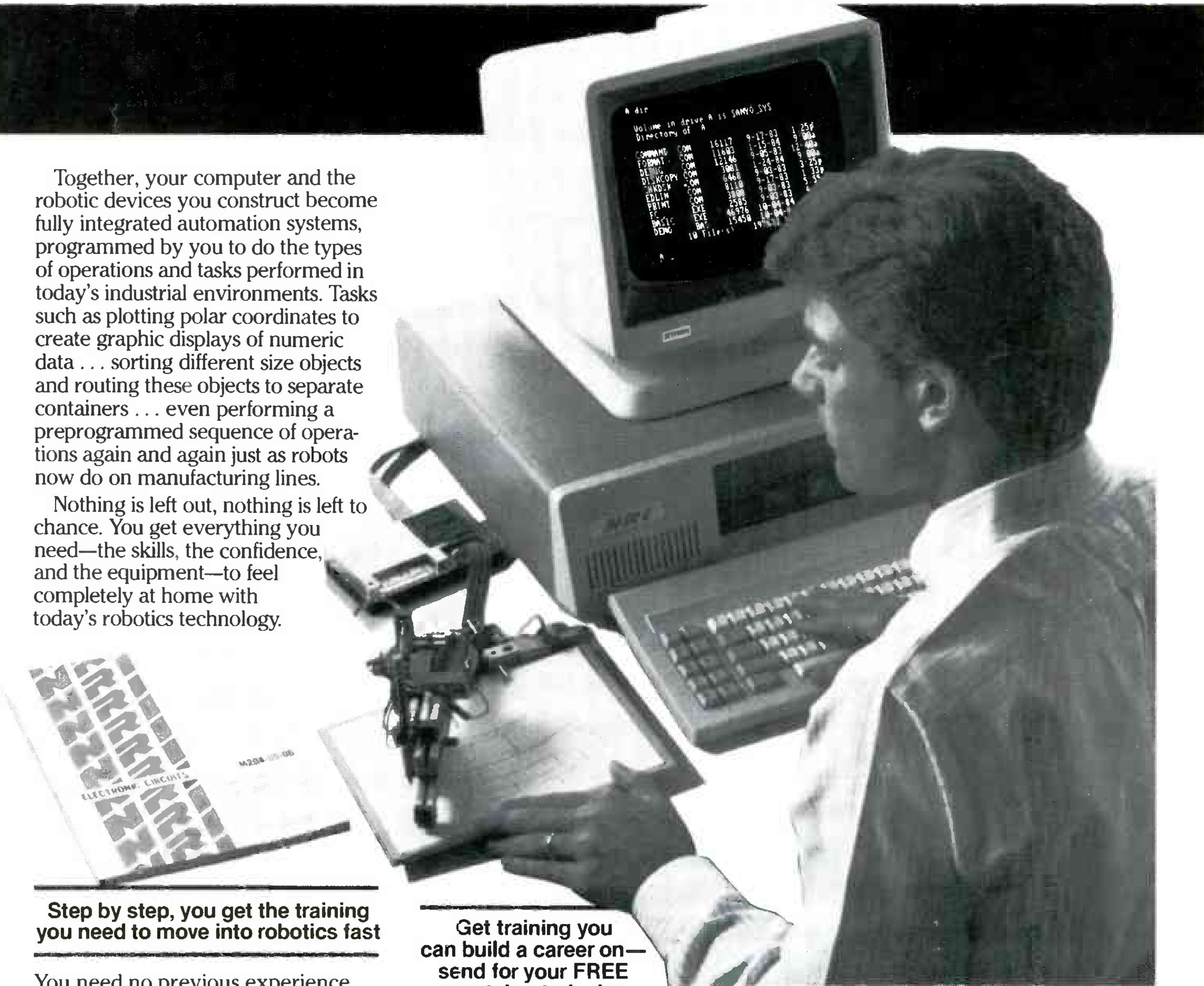


Two tasks frequently performed by robots are measuring and sorting, be it sorting eggs or eliminating scrap from a production line. You build this sorting system, then program it to accept short and long blocks, measure these blocks, and move them to the correct storage bins.



Robots are often used to display in graphic form the results of computer calculations. The polar coordinate plotter you build accepts analog data and positioning commands to create graphic displays. Your plotter uses two motors, an electromagnet, and gear mechanisms to position and activate the plotting pen, both manually and under program control.

This "teachable" robotic arm is the most complex robot model you construct. Once you manually put the robot through a sequence of operations, it will "remember" these steps and perform them whenever asked.



Together, your computer and the robotic devices you construct become fully integrated automation systems, programmed by you to do the types of operations and tasks performed in today's industrial environments. Tasks such as plotting polar coordinates to create graphic displays of numeric data . . . sorting different size objects and routing these objects to separate containers . . . even performing a preprogrammed sequence of operations again and again just as robots now do on manufacturing lines.

Nothing is left out, nothing is left to chance. You get everything you need—the skills, the confidence, and the equipment—to feel completely at home with today's robotics technology.

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We'll give you tomorrow. Accredited by the National Home Study Council er is a clone, I have learned quite a bit about computers in general while following the ongoing series, "Build the PT-68K" (**Computer-Digest**, October 1987 – December 1988).

Whether that makes me a typical reader or not, this reader votes "Yes" for the general layout of your magazine, including the content of the columns, and lends his support to your "bias" toward the 80XX/80XXX family of computers.

I would suggest to those who want to read up-to-date, informative articles that are about non-80XX/80XXX computers, that they think about subscribing to *Computer Shopper* in addition to **Radio-Electronics**. *Computer Shopper* is the best single source for so many of the "other" computer families, including Apple, Amiga, Atari, Timex, Tandy, Texas Instruments, Commodore 64/128, and even CP/M!

And, once they see the *size* of *Computer Shopper*, they might think twice before trying to argue their point—that you take on the Herculean task of covering all computers in **Radio-Electronics**—any longer.

You're doing a great job, just as the magazine is.

STEVE POLOWICHAK
Big Spring, TX

A CAREER IN ISDN

I was really impressed by the article, "ISDN: The Telephone of Tomorrow" (**Radio-Electronics**, October 1988). It sounds as if that system will be big in the future.

I've been looking for that kind of article for a few years. When I was in the U.S. Air Force, I worked on a Mode V terminal-control unit. It was Autovon-adaptable by adding cards. I simply loved the machine. Those control characters (D-Channel) were a real thrill.

Now I'm an student, going for an Associate's Degree. Is AT&T the only company that uses ISDN? I realize that in the future it will be used in homes, government, and business.

LANNY R. GATLIN
Franklinville, NC

TRULY TRUE NORTH...

spent quite a while trying to figure out why the method you described in "Ask R-E" (**Radio-Electronics**, September 1988) for locating true north actually works. I finally discovered the principle.

The sun casts its shortest shadow of the day when it is due south (at "noon"); it casts equal-length shadows at equal times before and after it is due south. The shadow will grow shorter for X minutes until "noon", then lengthen for X minutes until it again equals the earlier length. That is when it crosses the arc. Your statement that the shadow will cross the arc about an hour and fifteen minutes after "noon" is incorrect. If the arc was dug one hour before "noon", the shadow will cross it exactly one hour after "noon".

I'm using the term "noon" to refer to the time when the sun is due south. That is not always 12:00 by the clock. Standard time zones are exact only for those living on their central longitude lines. For example, Philadelphia (75°), New Or-

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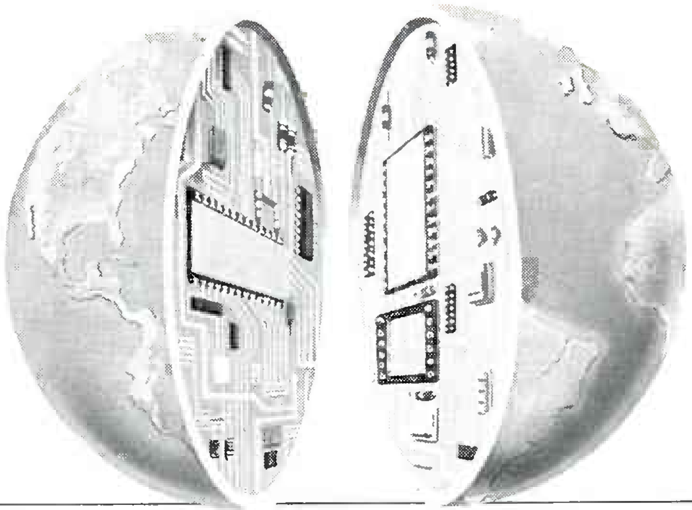

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leans (90°), Denver (105°), and Reno (120°) lie on the central lines of their respective zones. The sun passes due south four minutes earlier per degree of longitude east of the central line, or four minutes later per degree of longitude west of it.

The other reason is what astronomers and navigators refer to as the "equation of time." It arises because the Earth's orbit around the sun is not perfectly circular, but is slightly elongated; and because the Earth's axis is not perpendicular to the plane of its orbit, but is tilted. Those two factors cause the time that the sun passes due south each day to vary from about 16 minutes before 12:00 to about 14 minutes after 12:00—even for someone living on the central line of the time zone.

You can determine "noon" time adjusted for the equation of time by referring to some almanacs—pages 206–217 of the *1988 World Almanac*, for example. With a scientific calculator, you can use the following formula to quickly estimate the correct noon time to within one minute:

Angle $A1 = 30 \times (\text{month number} - 1) + \text{day number} - 3$

Angle $A2 = 2 \times (A1 - 78)$

Adjustment in minutes $= 7.6 \times \sin(A1) - 9.9 \times \sin(A2)$

Angle A1 approximates the angular distance travelled by the Earth around the sun since the day it was closest to the sun (about January 3). A1 − 78 approximates the angular distance the Earth has travelled since the beginning of spring (March 21).

For example, on November 1:

$A1 = 30 \times (11 - 1) + 1 - 3 = 298$ degrees

$A2 = 2 \times (298 - 78) = 440$ degrees

Adjustment $= 7.6 \times \sin(298) - 9.9 \times \sin(440) = -16$ minutes

Thus, for someone living on the central line of his time zone, the sun will be due south at 11:44 on November 1. For others, the other adjustment must also be made. For example, "noon" in New York City, which at 74° longitude is 1 degree east of the EST central line, will be at 11:40. If daylight savings time is in effect, add one hour.

ROBERT HINKLEY
New York, NY

R-E

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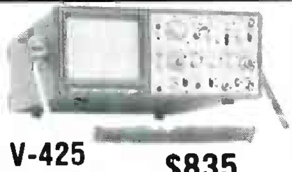

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V-660	60MHz	D.T., 2mV sens, Delayed Sweep, CRT Readout	$1,195	$990	$205
V-1065	100MHz	D.T., 2mV sens, Delayed Sweep, CRT Readout, Cursor Meas	$1,895	$1,575	$320
V-1100A	100MHz	Q.T., 1mV sens, Delayed Sweep, CRT Readout, DVM, Counter	$2,295	$1,995	$300
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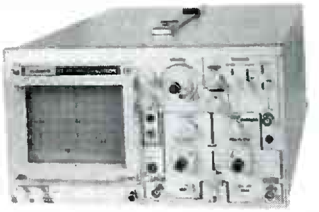

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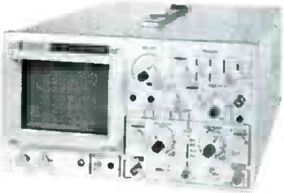

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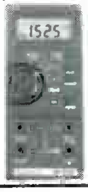

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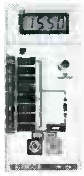

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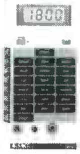

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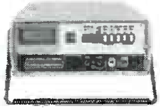

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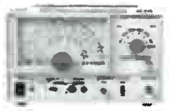

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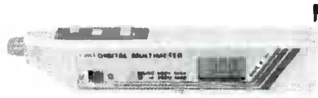

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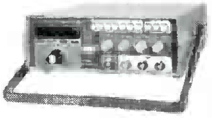

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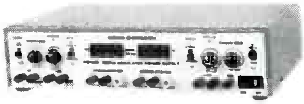

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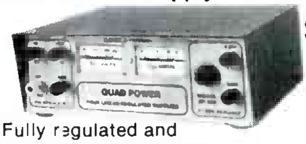

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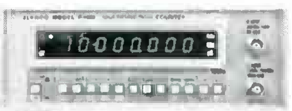

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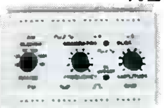

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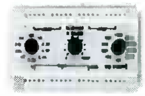

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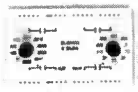

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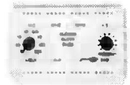

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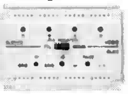

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For ease of use, the *2247A* provides auto setup, on-screen cursors, and up to 20 pre-programmed measurements. To guide users through the proper setup and measurement procedures, operator prompts and error messages appear on screen. The oscilloscope offers smooth, menu-driven operation; automatic, one-button front-panel setups; on-screen readouts on the CRT; and the ability to store and recall up to 20 setups.

"SmartCursors" track changes in the voltage, trigger, and ground level of the displayed waveform. That capability shortens setup time, single-shot triggering, peak-voltage, and DC measurements.

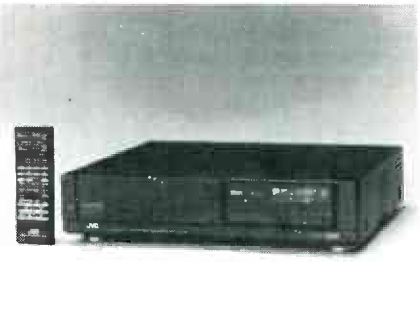
The *2247A*, with a 3-year warranty on labor and parts (including CRT), has a suggested retail price of $2795.00.—**Tektronix, Inc.**, Portable Test Instruments Division, P.O. Box 1700, Beaverton, OR 97077;1-800-426-2200.

SUPER-VHS VIDEO RECORDER. *JVC's HR-S5000U* Super-VHS VCR combines sophisticated features and a resolution of more than 400 lines with simplicity of use and sleek design. To ensure a sharp, true-to-life picture, the unit also has a built-in wide-bandwidth tuner, a "Tape-Stabilizing" head drum, and JVC's proven "Super DA-4" combination video-head system. High-fidelity stereo sound is provided by two rotary FM-audio heads and an advanced noise reduction circuit. The *HR-S5000U* also functions as an editing recorder of near-professional quality, with a flying erase head, "Zero Frame Editing" system, and an audio-dubbing circuit.

The first commercial S-VHS motion picture—*On Golden Pond*—is scheduled to be released by the end of 1988 (from Super Source Video P.O. Box 41077, San Francisco, CA 94141), with others to follow in coming months. Of course, the *HR-S5000U* is fully compatible with standard VHS format; users can enjoy all the currently available VHS tapes.

The VCR is easy to use, due to such features as the on-screen menu system that permits timer programming, clock and status setting, and channel presetting to be operated by remote control. The Half-Loading mechanism provides advanced tape-access features, including the real-time tape counter, high-speed digital program search, and "Intro Search." That function automatically locates all the indexed programs on a tape and plays back the beginning of each in fast motion for about five seconds.

Other features include a 155-



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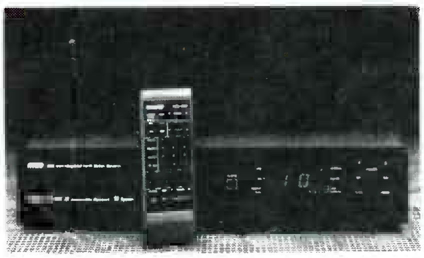
channel, cable-compatible, frequency-synthesized tuner with MTS decoder; double-speed playback, variable-speed search, noiseless still, and 5-step slow-motion playback modes; a 10-key TV/VCR unified remote control; 14-day/8-event timer; and FM-simulcast recording.

The suggested list price of the *HR-S5000U* Super-VHS VCR is $1299.00.—**JVC Company of America**, 41 Slater Drive, Elmwood Park, NJ 07407.

SATELLITE RECEIVER/DECODER. *R.L. Drake's ESR1024* is an entry-level satellite receiver with VideoCipher II decoder. Designed for newcomers to the satellite-TV market who are reluctant to invest in a deluxe system initially, the unit can be expanded into a full-featured model at a later time.

The priority-view feature allows the owner to pre-program as many as 30 channels, and parental lockout can be used to restrict children's access to objectionable programs. The microprocessor-controlled *ESR1024* can be easily programmed from the infrared remote control. (Because most functions are controlled remotely, the receiver's sleek front panel has only six buttons.) Threshold-extension circuitry provides clear pictures even in weak-signal conditions, and full-range audio tuning with digital frequency and bandwidth selections allow the owner to receive digital stereo from subscription channels. Using a 950–1450-MHz block-input frequency, the *ESR1024* features input-switching to eliminate the need for external relays. It can accommodate one C-band and one Ku-band LNB, and is compatible with all Drake LNB's and its *BDC24* downconverter.

The basic receiver can be upgraded to meet the owner's changing needs. With an optional antenna-positioning system (*APS1024*), the antenna can be moved to any of 36 pre-stored satellite positions with the push of a button. The UHF remote-control option is designed for consumers who have more than one TV set. It allows the owner to use the system from anywhere in the house, regardless of where the receiver is



CIRCLE 12 ON FREE INFORMATION CARD

placed.

The *ESR1024* integrated receiver/decoder has a suggested retail price of approximately $900.00; the optional *APS1024* antenna positioning system costs approximately $100.00.—**R.L. Drake Company**, P.O. Box 112, Miamisburg, OH 45342.

AUTOMATIC CABLE TESTER. *American Reliance's model AR-6400P* automatic cable tester can test cables and wire assemblies of up to 128 test points. Based on a microprocessor design, the

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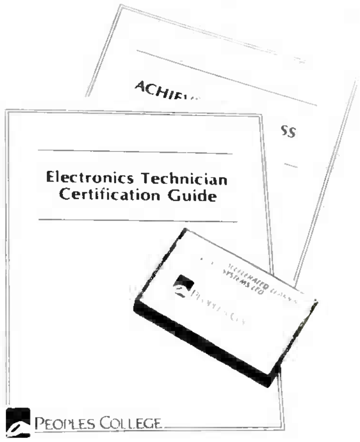

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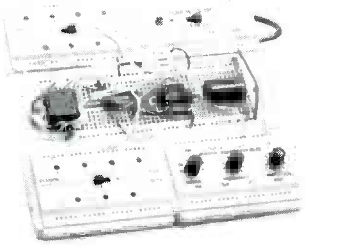

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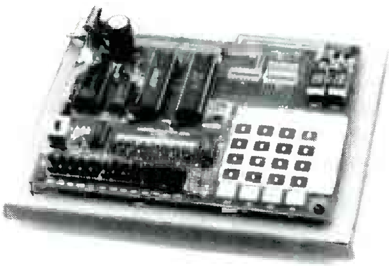

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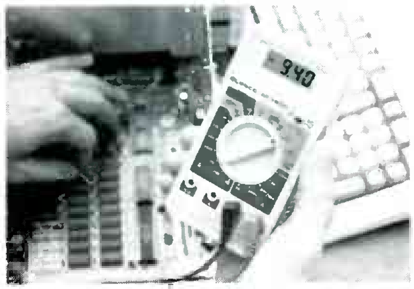

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unit is expandable to a total test capability of 512 test points by the addition of plug-in I/O boards.

The *AR-6400P* can print out test results and wire lists. Its built-in parallel-printer port will interface with virtually any Centronics-compatible parallel printer. A printer cable is also included.

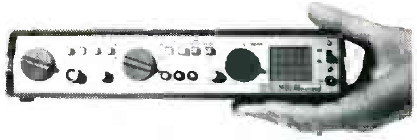
The optional *6401FX* universal test fixture allows easy testing of most major cable types. Two each of 9-, 15-, 25-, and 36-pin "D"-type, and 37- and 50-pin Centronics-type connectors are included on the fixture for a quick and easy connection to virtually any cable.

CIRCLE 13 ON FREE INFORMATION CARD

The *AR-6400P* cable tester and the *6401FX* universal test fixture, both with a one-year warranty, sell for $995.00 and $99.95, respectively.—**American Reliance Inc.**, 9241 East Valley Blvd., Rosemead, CA 91770.

"MINI" OSCILLOSCOPE. Weighing in at only 2 pounds and measuring a compact 10.2 × 6 × 2-inches, *HMC's model 1010* is truly a portable oscilloscope. Designed for field-service applications, the scope can easily fit into a tool kit and is enclosed in a rugged housing for durability.

The model *1010* offers DC to 10-MHz bandwidth, 12 sensitivity ranges, and 21 timebase ranges. The user can select vertical sensitivity from 10-mV/div to 50-V/div; timebase can be varied from 0.1-µsec/div to 0.5-sec/div. The scope features internal and external triggering with sensitivity of <1 div internal and <1 volt external. It has AC, DC, TV-frame, and TV-line coupling modes.



CIRCLE 14 ON FREE INFORMATION CARD

The "mini scope" contains a bright blue/white 1 × 1.5-inch display, containing 5-horizontal × 4-vertical divisions. Its features include a built-in calibration circuit and a full complement of adjustments. The model *1010* can be powered with disposable batteries, rechargeable batteries, or AC adapter. (The power source must be purchased separately.)

The model *1010* portable oscilloscope costs $450.00.—**HUB Material Company**, P.O. Box 526, Canton, MA 02021.

LOW-VOLTAGE CABLE TESTERS. *Weetech's model 22 and model 23* low-voltage interconnection testers are designed for evaluating cables, cable harnesses, backplanes, and wiring systems. Each has the ability to measure continuity and such components as resistors, diodes, and switches. Test voltage for both units is 10-volts DC, with current ranges of 0.1 to 10 milliamps. Threshold values can be selected between 200 ohms and 90 kilohms, and test speeds of 500 test points per second are typical.

Models *22* and *23* are controlled by an XT-compatible computer using MS-DOS. The computer can be networked via RS-232C multiuser links at 9.6K bits per second, for either on- or off-line programming and test data management. Using a sample cable that is known to be good, each unit will program itself; or they may be manually programmed either on the tester or on a separate program station. Programs can be stored on either 3½-inch or 5¼-inch floppy disks, or—on model *23* only—a 20-Mbyte hard-disk drive.

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Each unit comes with interfaces for RS-232C, Centronics printer, and keyboard. Interfaces for monitors are available optionally. The monitor and an alphanumeric display provide clear indications of shorts, opens, component faults, and failed connection ID numbers, as well as self-test and self-diagnostic information.

Model *23* (shown) performs point-to-point tests for opens and shorts for up to 8,192 test points. Model *22* is a smaller version; it performs the same functions for up to 512 test points.

Model *22* and model *23* low-voltage interconnection testers cost $4,446.00 and $5,979.00, respectively. (Prices vary with the number of test points; test-point capability costs $448.00 per 128.)—**Weetech Inc.**, 300 Pine Street, Canton, MA 02021. **R-E**

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A/D converter accuracy

DID I REALLY SAY THAT? APPARENTLY I was so eager to warn you that a high-accuracy A/D converter only offers full accuracy at full scale, that I got some of the numbers wrong in the September 1988 column. At any rate, a sixteen-bit A/D having a four-volt reference can give you sixteen bits of accuracy, but only with a minimum of a four-volt input.

With a one-volt input, you only get fourteen bits of accuracy at best, and with a quarter-volt input, you will only get twelve bits.

The important point here is that you can't take a high-accuracy A/D and input a very small input signal and expect high-accuracy results. Sorry about that.

One reader did criticize me for warning you so strongly about the anti-alias filtering in A/D converters. For most hackers most of the time, it is super important that you do understand the aliasing problem and then go far out of your way to absolutely prevent any high-frequency aliasing from taking place.

But hail yaesss. Once you really understand all the rules, you will sometimes want to selectively and creatively break them. That's what hacking is all about. Break the rules and you can sometimes leap tall buildings in a single bound. Just do not let the ground get in your way when you are done.

For instance, you could build a single-conversion 60-kHz WWVB receiver by *purposely* aliasing. You peak sample your 60-kHz carrier input at a phase-locked 60-kHz rate. And out comes a baseband digitally detected time code.

Starting with this column, all our *Names and Numbers* are now being twice verified: once by an independent service bureau when my story is sent in, and once later by **Radio-Electronics** just before press time.

But there still are several of you who either insist on jamming the help line by ignoring the *Names and Numbers* entirely, or else end up calling all the names at random, rather than carefully reading the article to see who goes with whom.

As per usual, this is your column and you can get both tech help and off-the-wall networking per the phone number in the help box. Best calling times are 8–5 weekdays, Mountain Standard Time.

We return you now to our column already in progress...

Data books

This time of the year, there always seems to be a flood of brand new data books coming out. Data books are fat bound collections, chock full of integrated-circuit data sheets and applications notes. They are second only in importance to the trade journals as a major resource for all serious hardware hackers. They are tools you simply cannot ignore. An extensive collection of data books should be a major and a most important early goal for hackers.

As a preliminary backing-up-for-a-good-start, you will want to get at least one hundred different data books. And you will want to keep all of them within three years of being current.

The price of a data book varies from free to optional to nominal. You pick them up by circling the bingo cards in such trade journals as *EDN, Electronic Design, Electronic Products, E. E. Times,* and such; or by writing or phoning the manufacturers and asking for a technical literature list; or by copping some older copies from an engineer or technician friend at most any electronics company.

While virtually all the integrated-circuit manufacturers do issue data books, the really heavy publishers include *National, Motorola,* and *Texas Instruments.*

Any unbiased **Radio-Electronics** author would include *Intel* as one of those majors, but since my VW-bus license plate is 6502, I consider any integrated circuit whose part number starts with an "8" to be an intrinsically evil satanic tool.

Where to start? Certainly with National's *Linear Handbook,* with Motorola's *CMOS Data Book,* and Texas Instrument's multi-volumes of *TTL Data Books.* Then, one voltage-regulator data book from any of those companies. Unfortunately, it is hard to get free copies; just about everyone has to pay the going rate.

There's also a very useful series of limited-information data books from *ECG* that cross the bound-

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aries of the major manufacturers. They include their *Linear IC Manual*, the *Master Replacement Guide*, their *TTL Digital IC Manual*, the *Optoelectronic Manual*, and their *Linear Module Manual*.

Beyond the majors, you'll have to dig deep to ferret out...

The good guys

Of the many hundreds of useful integrated-circuit manufacturers and data-book publishers, only a very few stand out as having really neat new goodies of major interest to hardware hackers. Who are they and where are they hiding?

A few years back, *Intersil* would have headed the list, with all their outstanding clock, timer, voltmeter, stopwatch, and regulator chips.

Unfortunately, Intersil got bought out by GE, who got bought out by RCA, who has recently put the whole works up for grabs in a yard sale.

It was almost as bad as when the fourth largest minicomputer builder merged with the fifth largest minicomputer manufacturer, and then very shortly went on to become the ninth largest minicomputer manufacturer. Oh well.

So, who can we put on today's list? Here's some possibilities...

Maxim Integrated Products has some absolutely outstanding voltage regulators, micropower CMOS circuits, A/D and D/A converters, and power-supply circuits. Fortunately, to the benefit of all, *Maxim* second sources many of the *Intersil* products.

Reticon is the obvious choice for solid-state image sensors and video cameras, audio-delay lines, and for new digital filters.

Dallas Semiconductor is heavy in clock chips and on sneaky ways to make an ordinary CMOS memory non-volatile. They also have some interesting shorter-range receiver-transmitter circuits that are available.

We would have to include *SGS*, first for all their unique high-power products, and second because they ended up with all the goodies that *Mostek* and *Thomson* used to make before *SGS* took them over.

For specialized communications chips that include tone encoding and decoding, scramblers, and the like, *MX-COM* also goes on the list.

And, stuffy as they seem, *Sprague* gets the nod for their power drivers, stepper-motor control circuits, consumer IC's, and automotive chips.

Analog Devices gets included for their various converter, multiplier, and amplifier products, along with their great and free *Analog Dialog* newsletter and fine ap notes.

To round out our list, for remote controls and satellite chips, *Plessey*; for opto stuff, *Siemens*; and for various RAM and EPROM stuff, *Hitachi*.

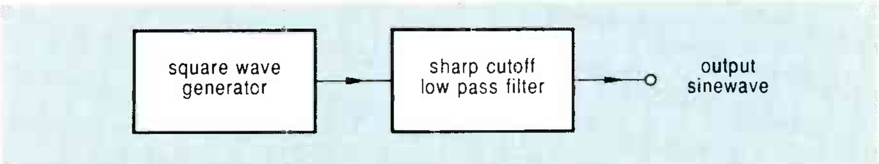

FIG. 1—BRUTE-FORCE GENERATION of a digital sine wave creates a square wave and sharply low-pass filters it. Triangular or certain "magic" waveforms can give you much better results than a square wave.

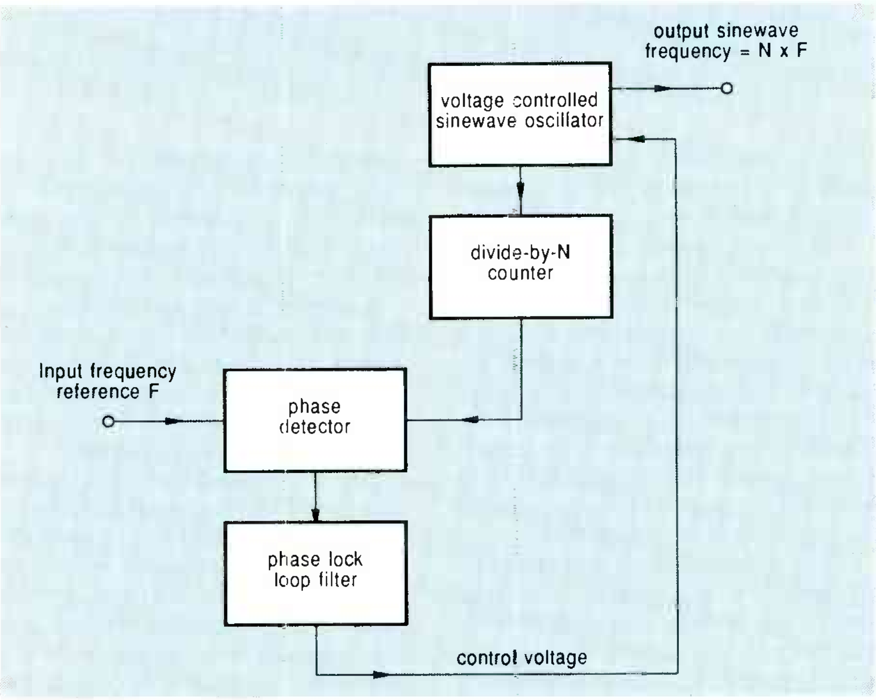

FIG. 2—The PHASE-LOCKED LOOP can generate digital sine waves and does get particularly useful where many different channels are desired for frequency synthesis. Changing "N" changes the channel selected.

NAMES AND NUMBERS

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Norwood, MA 02062
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Circuit Cellar, Inc
4 Park Street, Suite 20
Vernon, CT 06066
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Comm Specialists
426 West Taft Avenue
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Dallas Semiconductor
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Infrared Industries
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Orlando, FL 32826
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Santa Clara, CA 95051
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Intersil
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Let me know if you have any other "good guys" favorites that I've missed, so we can pass the news on.

Digital sine waves

There are lots of advantages to generating sine waves using digital techniques. One is that you can end up with extreme accuracy. A second is that you can rapidly change or sweep the frequency. A third is that multiple-related channels are easily done, and a fourth is that you can often save quite a bit on those expensive inductors and capacitors.

Pure sine waves are often needed for electronic music, for very-high-quality synthesizers, and for radio-frequency mixers. In any of those applications, any higher-frequency harmonics can lead to all sorts of serious unexpected problems.

Let's look at four different ways to generate digital sine waves. Fig. 1 shows you the brute-force method. Here you generate a digital square wave and then low-pass filter your square wave to extract that fundamental sine-wave output. The hassles here are that you'll need good filtering and that changing frequency over a wide range can get rather sticky.

One obvious improvement is to generate a waveform that has fewer or weaker low-frequency harmonics. A triangular wave is a good choice. Its lower harmonics are weaker and can be easily filtered out.

A much older trick is to route a triangular waveform of just the right amplitude through a pair of back-to-back diodes. At the right level, a high-quality sine wave will result, without any filtering at all.

A second approach is known as the *phase-locked loop* method, which appears in Fig. 2. Here you start off with a voltage-controlled sine-wave oscillator that often forms your ultimate output.

You then condition that output and divide it down with a programmable counter and then phase detect it against an input reference frequency. The output of the phase comparator is filtered and fed back to the oscillator. If the frequency is low, the oscillator frequency gets raised, and vice versa.

Phase-locked loops are handy when multiple channels are needed. For instance, to synthesize all the AM broadcast frequencies, you would start with a 530- to 1650-kHz voltage-controlled oscillator. That would get divided down by some programmable number from 53 to 165 and compared against a 10-kHz precision reference. Such a device is called a *frequency synthesizer* and they are quite commonly used for radio, TV, ham, CB, and for other communications work.

Note that only one crystal or reference is needed, no matter how many channels are available.

Popular older hacker phase-lock chips include the *Signetics* NE565 or the CMOS 4046. The "horses mouth" classic book on all that is *Phaselock Techniques* by Floyd Gardner.

Figure 3 shows us the table-lookup method. Here you route a software or hardware counter into a lookup table that computes the individual sine for each selected angle of the current count. That table-lookup value is routed into an A/D converter and then gets output as a sine wave with fine steps in it.

Filtering is quite easy since the harmonics of the steps are way above the fundamental. Often only a small capacitor is needed. Table lookup is ideal for sub-audio work such as that involved in brain-wave research and in the study of seismology.

On the other hand, table lookup is largely limited to the lower frequencies, because your input clock is some 256 or more times higher than the output sine wave.

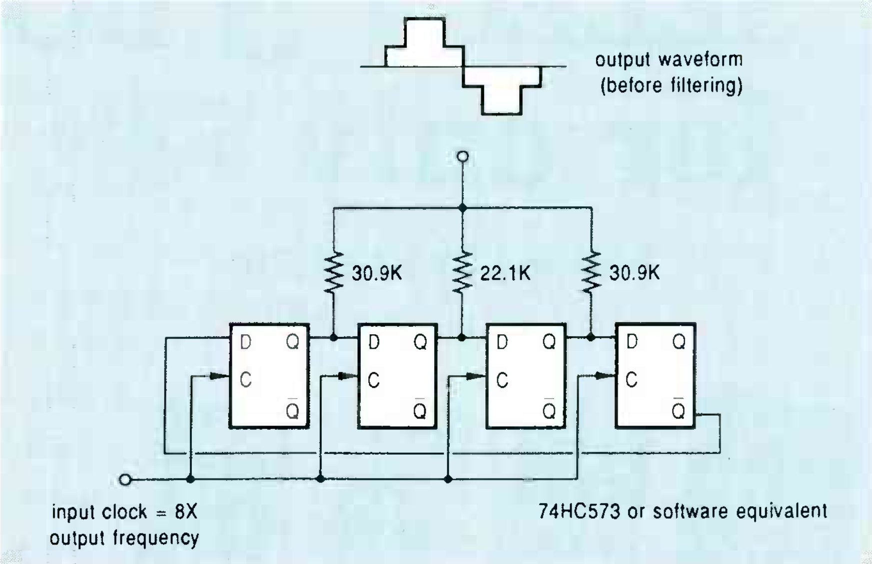

FIG. 4—A WALKING RING digital sine-wave generator of eight steps uses a "magic" waveform that has no low harmonics and thus is very easy to filter. Your first harmonic is the seventh at one/seventh and the ninth at one/ninth of the fundamental amplitude.

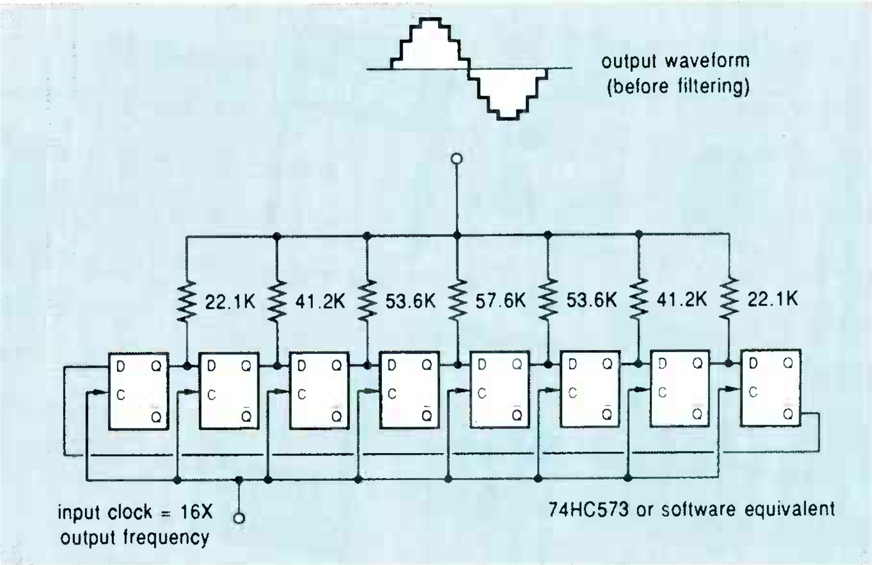

FIG. 5—A SIXTEEN-STEP walking ring digital sine-wave generator gives an even better-looking output waveform. In this circuit, the fifteenth and seventeenth are the first harmonics that are present.

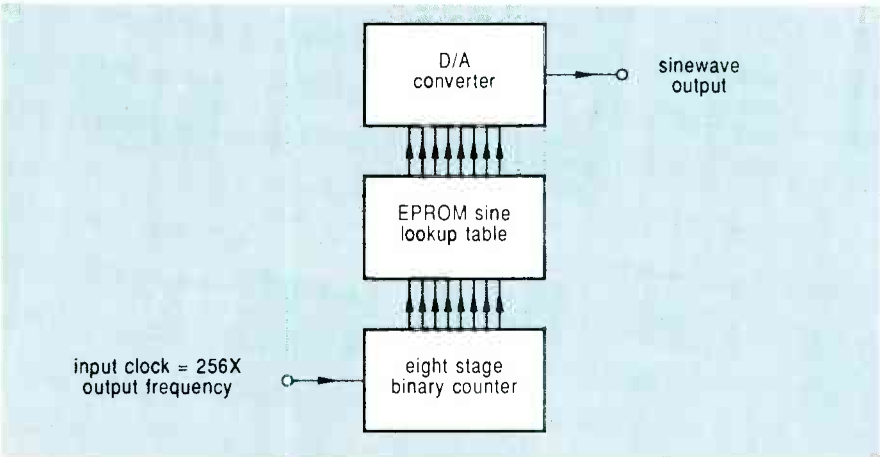

FIG. 3—THE TABLE LOOKUP OF DIGITAL SINE WAVES gives a clean waveform and high accuracy, but is often limited to lower frequencies, especially when done by using personal-computer software.

The walking-ring method

I've saved the most interesting method for last. All you need to generate digital sine waves is an unusual software or hardware counter and a few resistors. Figure 4 shows you an eight-step sine-wave generator, while Fig. 5 shows you a sixteen-step version.

The walking-ring counters, or the Johnson counters directly generate a square wave of 1/Nth of the input frequency. That can be done in your choice of either hardware or software.

For instance, here are the sequential states of a four-stage

continued on page 85

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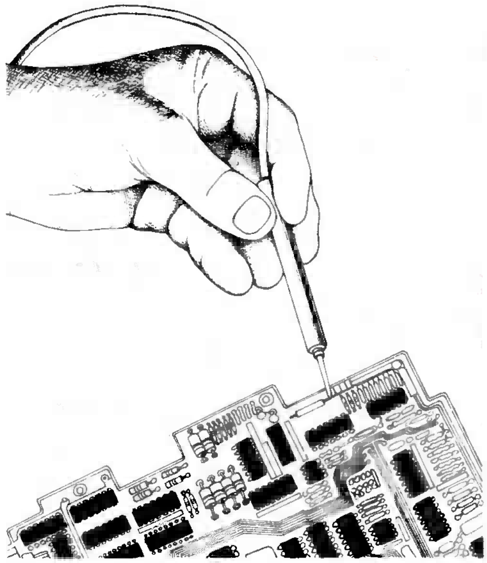

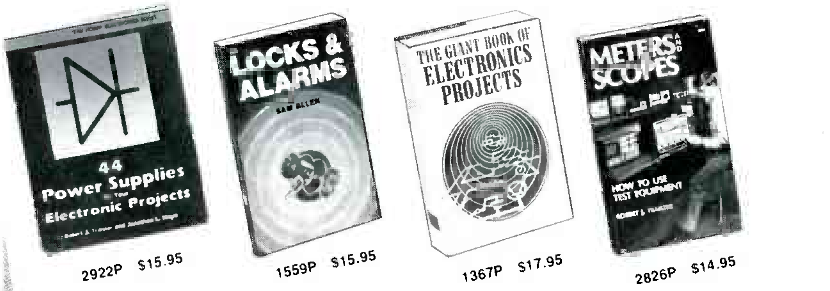

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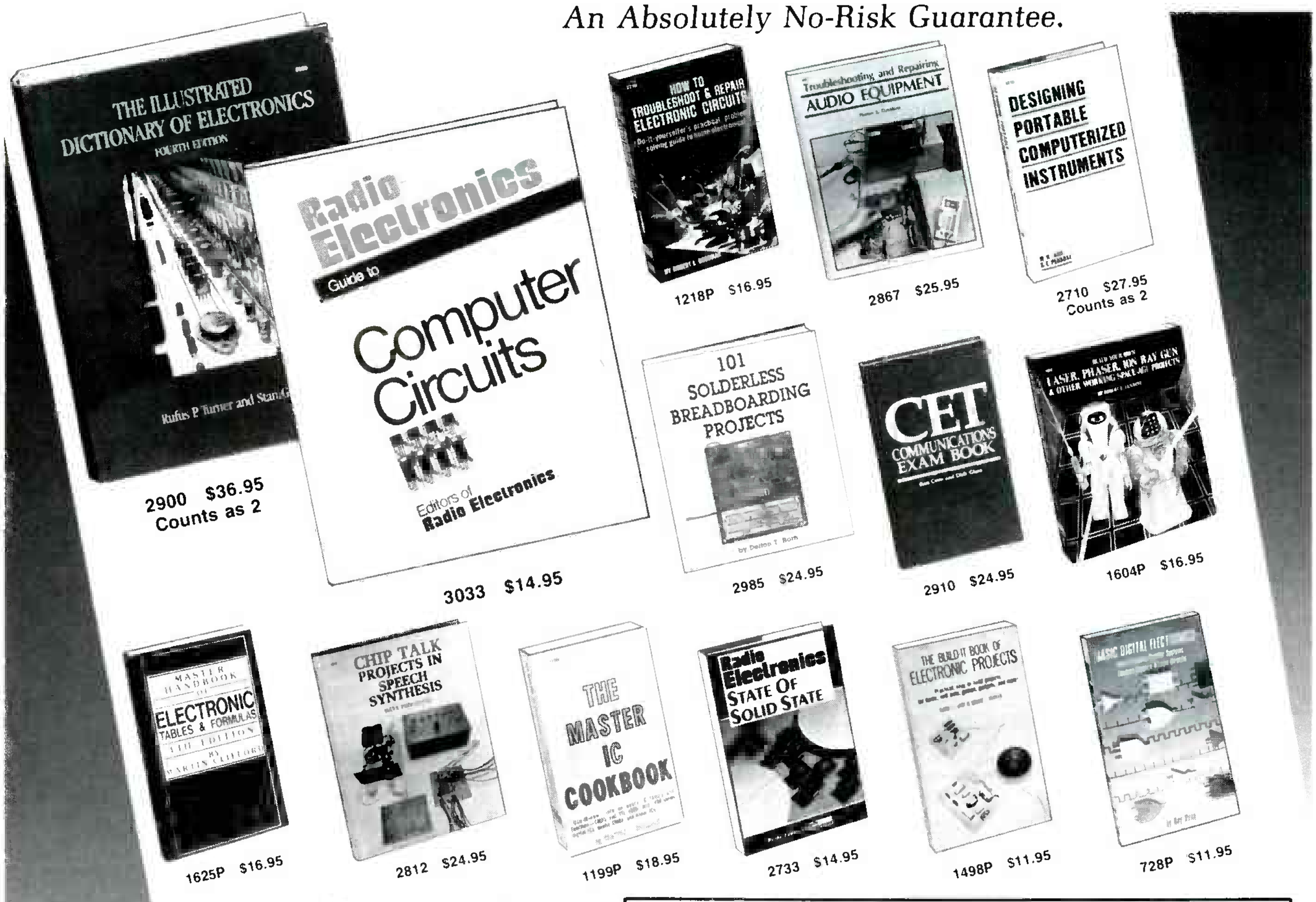

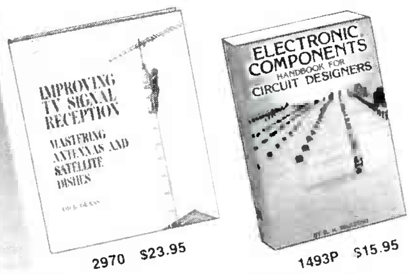

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IMPROVED DEFINITION TELE-VISION

While we wait for high-definition TV—there's improved-definition TV.

LEONARD FELDMAN

EVERYONE SEEMS TO BE TALKING ABOUT high-definition TV, or HDTV as it is generally known. We hear promises of TV pictures that will have an aspect ratio of 5:3 or 16:9 (instead of our current picture width-to-height ratio of 4:3). There's also talk of increasing the number of scanning lines per frame from 525 to 1125, or, 1050, or 825 or...you name it.

And that's exactly the problem. There are well over a dozen proposals for new TV standards, each endorsed by a particular company or by a particular country. What everyone *is* in agreement about is the fact that a better TV picture is long overdue; after all, the basic parameters of the NTSC system used in North America and in Japan are now more than 40 years old. When the 525-line TV picture was standardized, the transistor had not yet been invented, let alone today's digital computers, microprocessors, and digital storage devices.

What's wrong with NTSC TV?

When TV sets were equipped with 10-inch CRT's (or even 20-inch picture tubes), a 525-line picture wasn't too bad. The picture was reasonably good if you sat far enough away from the set so as not to see the "spaces between the lines." If the interlace of the 262.5 lines of the first scan of each frame was properly positioned relative to the second 262.5 line-scan, and if signal strength was good enough so that the resulting picture was relatively free of noise or "snow," most viewers were content.

However, given today's larger screens—up to 35-inch direct- view, and even larger projection TV images—the artifacts of the basic NTSC picture become more obvious. In addition to the "spaces between the lines," there are such visible defects as line-flicker, color-dot-crawl (a sort of shimmering effect at the demarcation lines between large areas of color), and poor color signal-to-noise ratios.

Several recent video innovations have made many people more aware of just how poor the ordinary broadcast and cable NTSC pictures are. Owing to the limited bandwidth available for the video signal information, the best horizontal resolution possible for a standard TV broadcast is only 330 lines. The introduction of Super-VHS video tapes and laser videodiscs, along with higher-resolution TV monitors and monitor/receivers, allows us to see NTSC pictures with

PHILIPS' IDTV system has improved noise reduction, 525 scan lines per field, high resolution graphics and three picture-in-picture modes.

better than 400-line horizontal resolution. But even when viewing the sharper pictures, vertical resolution remains limited by the interlace-scanning method used by the sovereign NTSC system.

Don't hold your breath

Certainly, any one of the many proposed high-definition TV systems would provide a better picture quality than our present NTSC system. But with so many systems vying for world approval, and with organized studies of those systems only just getting underway, any hope for a terrestrially delivered HDTV signal within the next five or even ten years seems overly optimistic. Evidently, several major consumer electronics companies are equally certain that HDTV is still a long way off, having turned their attention to what can best be described as "squeezing the best possible picture" out of NTSC. While specific schemes for improving NTSC reception differ somewhat, all of the companies engaged in the effort seem agreed on what to call it: IDTV, for *I*mproved *D*efinition *TV*.

The nice thing about the various IDTV systems is that they require no modifications on the part of the broadcaster. Best described as "single ended" systems, all of the IDTV schemes process the incoming video signal in the receiver (or VCR).

There are three major TV companies involved with IDTV: Toshiba, who claims to have been first with an IDTV approach; Philips, who, in this country, offer TV sets labeled Magnavox, Sylvania, and Philco, as well as Philips; and Mitsubishi.

Toshiba

Since Toshiba's announcement preceded that of the other companies, let's take a look at what they've done. A block diagram of the Toshiba IDTV is shown in Fig. 1. In that system, the signal information of each 262.5-line field is stored in a digital memory (1 Mbit × 5) and then double-scanned twice as fast as the current NTSC interlaced signal.

The most innovative element of what Toshiba calls their "Advanced Double Scanning TV" is the use of a motion-adaptive non-interlace system. The general shortcoming of a "frame memory" double-scanning system is that the image of fast-moving objects in a scene appears to be smudged or smeared (almost like a double exposure.) The phenomenon occurs because the actual broadcast signal is sent field by field. In Toshiba's motion-adaptive non-interlace system, the digital circuitry uses each pixel's location to determine whether an image is still or moving. It then applies line-memory double-scanning for the moving image, and frame-memory for the still image.

There are immediate advantages of the Toshiba system: the scanning lines are virtually unnoticeable, line-flicker is minimized, vertical resolution is effectively increased to 450 lines, and the noise level is improved by 3 dB.

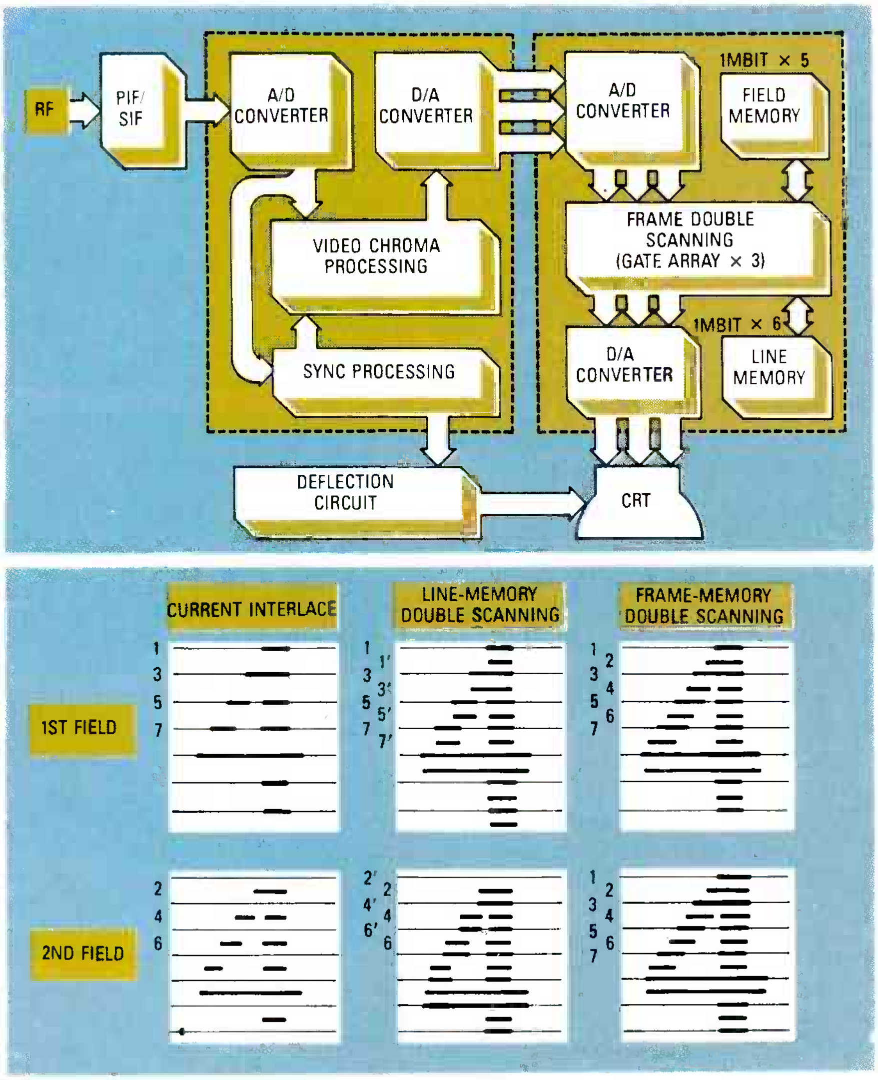

FIG. 1—IN THE TOSHIBA IDTV SYSTEM, the picture information in each line is stored digitally and then double-scanned.

The Philips system

Philips takes the IDTV idea a bit further. Like the Toshiba approach, Philips' IDTV involves non-interlaced scanning; thus there are 525 lines scanned every 1/60-second instead of 262.5 lines. In this case, however, the "extra" lines are not simply a repetition of the same field. Rather, the extra lines are digitally generated—by means of an interpolation system called a *median filter*—to fill in the "space between the lines." Video signal values for the extra lines are chosen on a pixel by pixel basis as the median or middle value of the three lines adjacent to the line being interpolated. The three lines used are the one above the interpolated line, the one below the interpolated line, and the line from the previous field that corresponds to the interpolated line. Information for the creation of the interpolated lines is obtained from digital line and field memories.

The Philips approach, according to their researchers, provides virtually all the benefits of a full-frame 525-line picture.

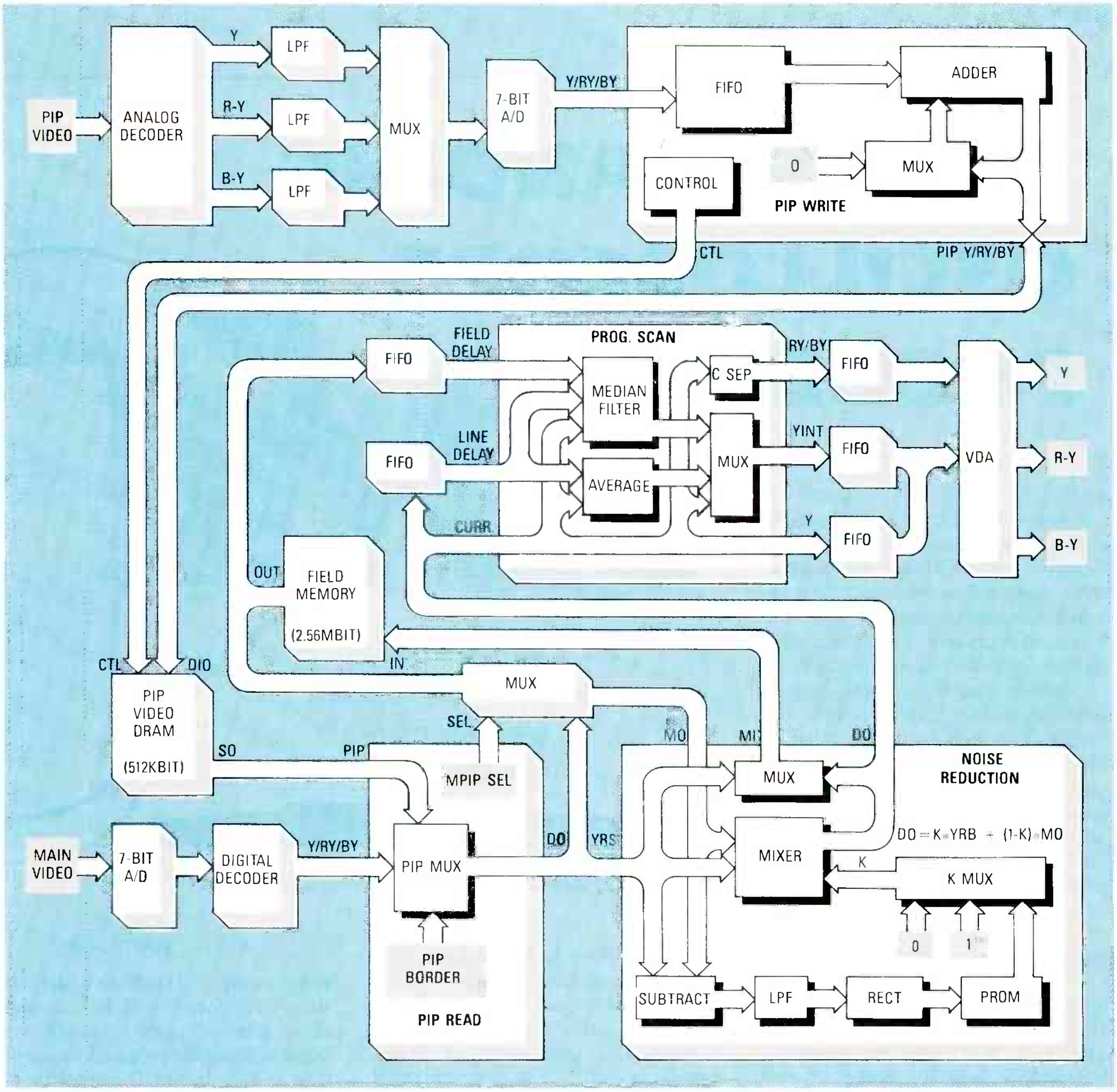

FIG. 2—THE PHILIPS IDTV SYSTEM also provides for PIP (*P*icture *I*n a *P*icture) effects.

In addition to a doubling of the scan lines through the median filter approach (which provides about 40 percent improvement in apparent vertical resolution), Philips has devised a two-level digital noise-reduction system that provides up to 10–12 dB of user-selected-level video-noise reduction, which results in sharper, crisper, and "cleaner" picture reproduction. The noise reduction is provided by a filter having a delay element of one field of video data and a motion detector that controls the depth of the filter to prevent "smearing" of moving objects. The motion detector subtracts the incoming video data from the field-stored data. As the field difference increases (indicating motion on screen), noise reduction is reduced to prevent smearing.

Finally, the Philips IDTV system also incorporates a digital comb filter, which—in comparison to a conventional comb filter—significantly reduces other NTSC interference effects, such as hanging dots and dot-crawl. At the same time, the filter allows for a full 480 lines of horizontal resolution from such local program sources as S-VHS video tapes and LV discs. TV sets incorporating this sophisticated IDTV technology will be marketed under the Philips name.

A block diagram of the entire Philips IDTV signal-processing system is shown in Fig. 2. In addition to the benefits related to IDTV, the new sets will also feature a dual TV tuner and picture-in-picture (PIP) enhancements that allow the viewer to scan what's happening on other channels while watching the main program; moreover, the viewer can watch a main program and an inset PIP program at the same time.

Mitsubishi's IDTV

The latest, and one of the most impressive examples of how NTSC-for-

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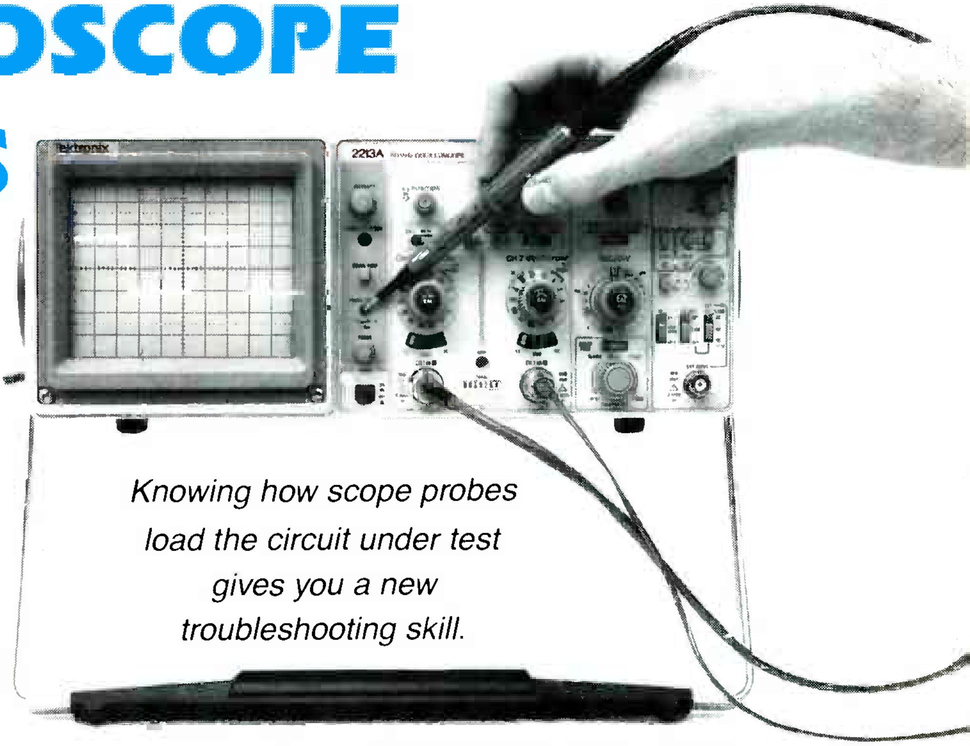
UNDERSTANDING OSCILLOSCOPE PROBES



Knowing how scope probes load the circuit under test gives you a new troubleshooting skill.

JONATHAN GORDON, ASSISTANT TECHNICAL EDITOR

THE MOST COMMON TYPE OF OScilloscope probe used by technicians is the voltage-sensing passive probe. Because passive probes are so common, and used so routinely, their peculiar effect on electronic circuits has been universally experienced—though very often misunderstood.

Nothing can replace the kind of troubleshooting knowledge that comes from viewing different waveforms from various types of circuits, such as digital, analog, and radio frequency. However, understanding how an oscilloscope probe loads the circuit under test will give you a new troubleshooting skill that no amount of experience can quite equal.

Equivalent circuits

Figure 1 is an equivalent circuit of a typical 10X scope probe and the vertical input of the associated oscilloscope. The probe's head has a 9-megohm resistor, R1, that is shunted by a 4- to 20-pF trimmer capacitor, C1. The shielded coaxial cable that connects the probe to the scope has a distributed capacitance, C3, of approximately 80 pF.

An electronic signal travels through the probe tip, the probe head and compensating network, the shielded coaxial cable, and then terminates at the scope's input connector. The input impedance of a typical scope is 1 megohm (R2) shunted by a 20-pF capacitance (C2). The scope's input characteristics are often printed near the input connector.

The idea of compensating a passive probe is to balance the probe impedance and scope impedance so their time constants are equal, as shown in the following formula:

$$R1C1 = R2(C2+C3)$$

If their time constants are equal, electrical waveforms will be communicated from the probe tip to the scope input without the probe adding distortion to the signal. The amplitude of the displayed pulse will merely depend on the resistance ratio:

$$V_{SCOPE} = [R2/(R1+R2)]V_{INPUT}$$

For example, using a 10X passive probe a 1-V_{INPUT} p-p at the probe's tip will yield a 0.1-V_{SCOPE} p-p on the scope's display. The resulting decade attenuation of the 10X probe is highly desirable because it affords a greater tip resistance (10 times the 1-megohm scope input resistance) to minimize circuit loading.

Once the probe has been compensated by adjusting trimmer capacitor C1, the probe and scope input are further reduced to the equivalent circuit shown in Fig. 2. Any circuit under measurement will now see a single impedance at the probe's tip of

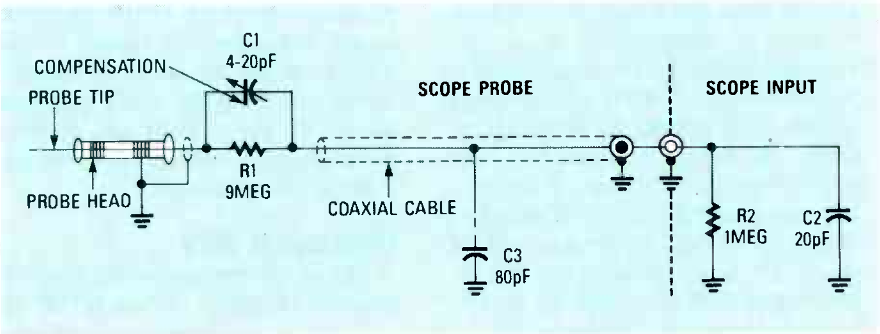


FIG. 1—INPUT EQUIVALENT CIRCUIT of 10X probe and oscilloscope.

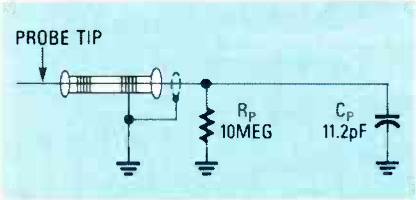


FIG. 2—INPUT EQUIVALENT CIRCUIT of 10X compensated probe as seen at the probe's tip.

10 megohms, R_P, shunted by an 11.2-pF capacitor, C_P, which is a specification that is often printed on the probe's head or compensation box.

Scope probe manufacturers have been clever in the methods they use to shunt the resistor in the probe's body. For example, Fig. 3 shows the inside of a Tektronix model *6006* 10X probe. The coaxial-cable's center conductor is extended into the probe's body where it connects to a cylinder that slides over the resistor. At one end of the resistor is a shorting slug that makes contact with the cylinder. A capacitor is formed by the cylinder and the resistor. The probe is compensated by screwing the probe's body into the locking sleeve, which is then tightened; during that adjustment, the inner-cylinder slides a varying distance over the resistor, and that varies the shunt capacitance. Lastly, the coaxial-cable's outer conductor is connected to a second cylinder for shielding.

Figure 4 shows the inside of a Tektronix model *P6105A* 10X probe. In that configuration the cylindrical tubing forms a fixed shunt capacitance across the resistor. No probe adjustment can be made in the probe's body to compensate the probe assembly. Instead, the assembly uses a compensation box at the connector end that houses a trimmer capacitor, C2, that is connected from the center conductor to ground. The capacitance C3 and trimmer C2, are in parallel.

Figure 5 shows a compensation method that uses a 4- to 20-pF trimmer capacitor to shunt the resistor in the probe's head.

Pulse waveforms

In general, probes are compared by how well they communicate an electrical pulse without causing distortion of one kind or another. But what is the real nature of an electrical pulse?

Figure 6-*a* is what a rectangular pulse looks like displayed on an oscilloscope as *amplitude* vs. *time*. However, as shown in Fig. 6-*b*, the same rectangular pulse displayed on a spectrum analyzer is transformed into a chart of *amplitude* vs. *frequency*; that is what the pulse would look like if broken up into its individual sinusoidal harmonic components. As you can see, the rectangular pulse is made up of both even and odd order sinusoidal harmonic components.

Unlike the rectangular pulse, a perfect square wave is made up of only odd-order harmonics (that is 1, 3, 5, 7, 9, etc.). For example, if a 1-kHz square wave is input to the oscilloscope, the 1-kHz fundamental (1st harmonic) sinusoid up to the 9-

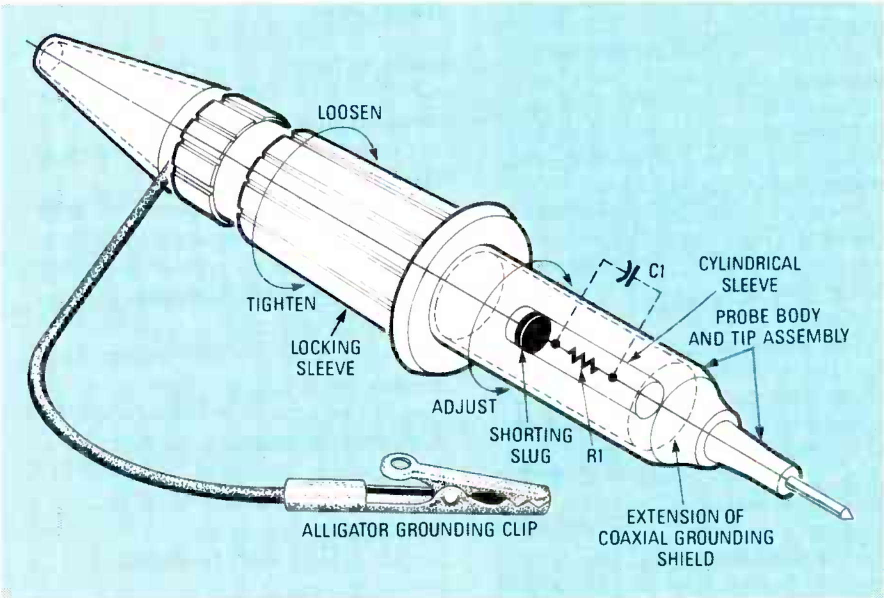


FIG. 3—THIS PROBE IS COMPENSATED by adjusting the locking sleeve.

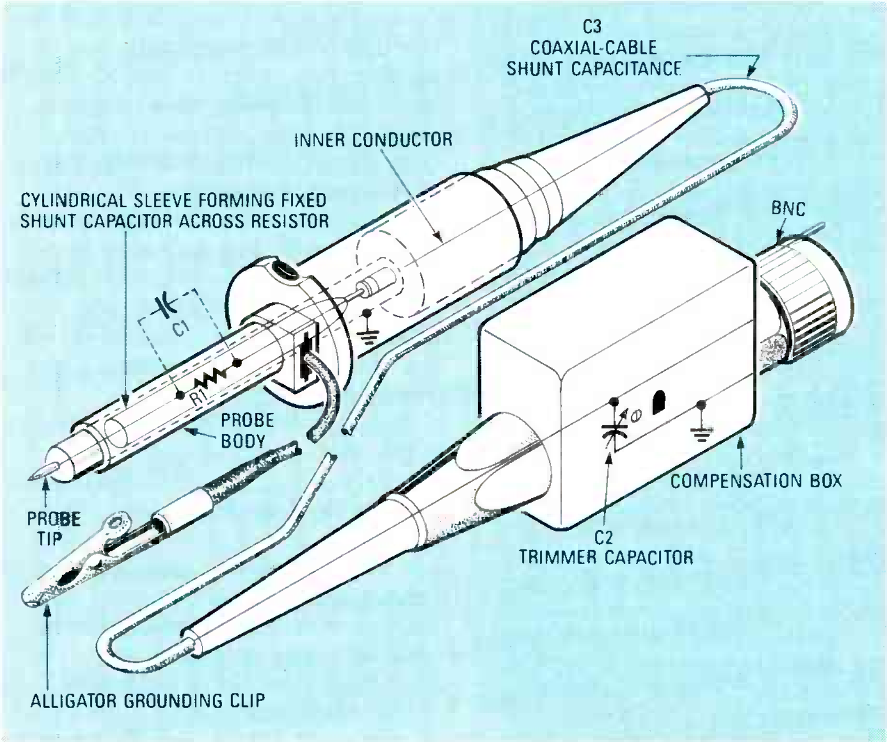


FIG. 4—THIS PROBE IS COMPENSATED by adjusting a trimmer capacitor housed in the compensation box at the end of the probe's cable.

kHz harmonic sinusoid must be reproduced without attenuation or phase shifting. As shown in Fig. 7-*a*, the 1st and 3rd harmonic components produce a rather poor square wave. In Fig. 7-*b*, the square wave looks a little better when the 1st, 3rd, and 5th harmonics are present. And, as shown in Fig. 7-*c*, the square wave looks better still when the 1st through 7th odd-order harmonic components are present. The waveform will appear sufficiently square and undistorted when frequencies are present out to about the 9th harmonic sinusoid.

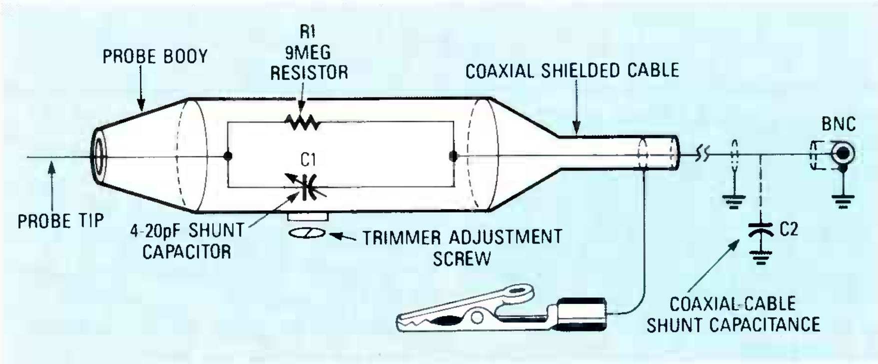


FIG. 5—THIS PROBE IS COMPENSATED by adjusting a trimmer capacitor housed in the probe's head.

Obviously, the shape of a square wave displayed on an oscilloscope depends upon the amplitude and phase relationship of the harmonic components. To accurately reproduce an electrical pulse it would be necessary to design a circuit that responds equally well to an infinite number of harmonic frequencies, so that all harmonics are included. In practice, however, that cannot be done, so a compromise between pulse shape and circuit design must be made.

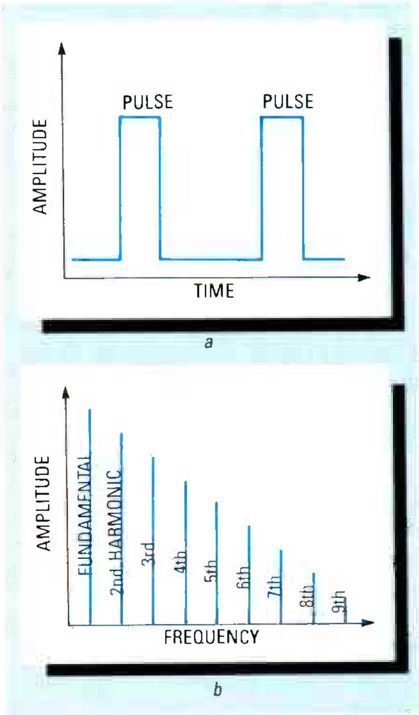


FIG. 6—THE PULSE WAVEFORM in *a* is how an oscilloscope displays the electrical pulse as amplitude vs. time. As shown in *b*, the same pulse waveform is displayed using a spectrum analyzer as amplitude vs. frequency.

Compensation

Every electronics technician has recorded pulse waveform data, such as rise time, width, amplitude, and repetition rate, only to realize—too late—that the probe wasn't compensated. Knowing that an improperly compensated probe can distort an otherwise perfect waveform, the probe's compensation capacitor must be adjusted, then the test data must be remeasured. Let's now examine how to properly compensate a probe and, additionally, how faulty compensation can affect the measurement of pulse waveforms.

Because probes should be compensated often, most scopes provide a square-wave calibration signal accessible from the front panel. There are other types of probe calibrators, like a line-frequency calibrator, a 1-kHz square-wave calibrator, and other more exotic types. However, they are used less often then the more convenient front-panel scope calibrators.

The front-panel probe calibration signal is a 1-kHz repetitive square wave. A 1-kHz square wave is used because the sinusoidal harmonic components are very close together, so the slightest offset in the probe's frequency response will effect the amplitude and phase relationship of many harmonic components all at once, resulting in a visually distorted waveform.

Figure 8-*a* shows a 1-kHz calibration signal from a properly compensated probe. Notice that the square wave is undistorted. Figure 8-*b* shows the same calibration signal from an over-compensated probe. Notice that the leading edge high-frequency harmonics are passed while some of the lower-frequency harmonics are

PROBE INFORMATION

A 25 page booklet from **Tektronix, Inc.**, the *ABC's of Probes*, is an excellent source of technical information on scope probes of all types, including passive probes, active FET probes, low-Z probes, current measuring probes, etc. The booklet will also guide you in selecting the correct probe for your application. Available free on request from **Tektronix National Marketing Center**, P.O. Box 500 Group 94, Beaverton, OR 97077. Phone: (800) 426-2200.

Also available from **Tektronix** is their free *Accessory Selecting Guide*, which lists their complete line of scope probes and attachments such as retractable-hook tip, grounding clips, coaxial attenuators, IC grabbers, colored-band markers, etc. Tektronix offers modular probes, subminiature probes to negotiate dense circuitry, high-voltage probes, active probes, current probes, specialty probes for every application, and card-mountable microprobes.

An 8-page product catalog is available from **Test Probes, Inc.**, 9178 Brown Deer Road, San Diego, CA 92121. Phone: (800) 368-5719, in CA call (800) 643-8382. TPI offers replacement probes for all oscilloscopes including Tektronix, HP, Philips, B&K, Leader and others. They are intended for use by engineers and technicians who need accuracy and durability at an economical price. Also available are RF-detector probes, high-voltage probes, modular oscilloscope probes, 50-ohm attenuators, patch cords and accessories.

A 22-page product catalog is available from **Probe Master, Inc.**, 4898 Ronson Ct., San Diego, CA 92111. Phone: (800) 854-1519, in CA call (800) 772-1519. Probe Master offers monolithic probes with gold-plated probe tip, gold-plated sprung hook, gold-plated ground lead, and all other critical contacts are gold plated too. Other products include test-lead kits, BNC-adaptor kits, precision BNC cables, and attenuators.

slightly attenuated. Some phase shifting has also occurred. The greater the drooping effect of the waveform, the more low-frequency harmonic attenuation and phase shifting has occurred. Figure 8-*c* shows the same calibration signal from an under-compensated probe. Notice the lack of high-frequency components in the leading edge of the square wave. Now let's examine the relationship between pulse shape, rise time, and the capacitance of the circuit.

When the driving pulse has a slow rise time, or the pulse width is comparatively wide, then stray shunt capacitance can have a fairly high value without producing objectionable distortion. That's because slower rise times and greater pulse widths correspond to fewer high-frequency harmonics. The same value of stray capacitance can become intolerable when the driving pulse has extremely fast rise times, or a very narrow width. The wave shape then depends critically on the preservation of high-frequency harmonics. As more and more stray shunt capacitance is added to the circuit under test, the shunt (bypass) capacitive reactance decreases. Harmonic frequencies that comprise the pulse's edge will now be shorted to ground by the lower shunt-capacitive reactance.

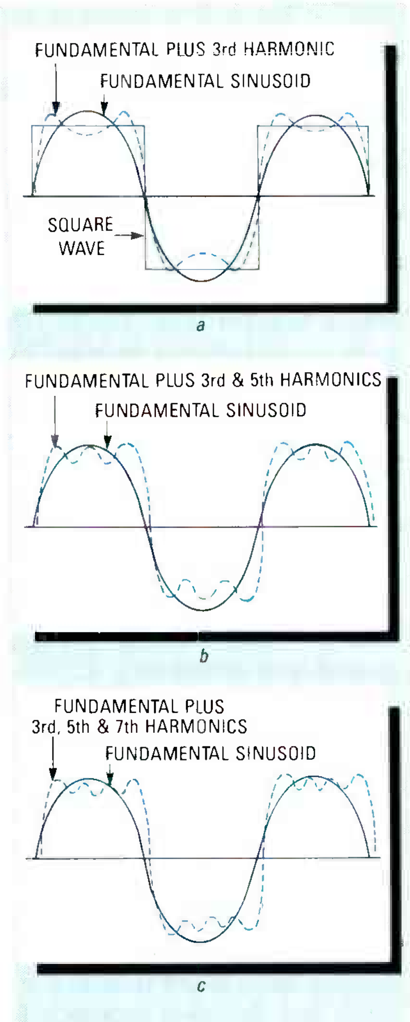
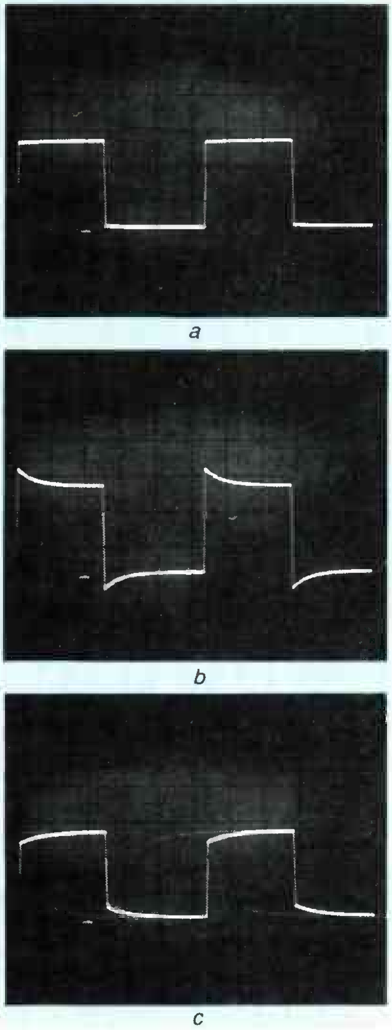


FIG. 7—ALL PULSE WAVEFORMS are built up from sinusoidal harmonic components. As shown in *a*, the fundamental (1st harmonic) plus the 3rd harmonic create a rather distorted square wave. In *b*, the 5th harmonic is added, thus creating a less distorted square wave. In *c*, the 7th harmonic is added, thus minimizing distortion even more.



8—A PROPERLY COMPENSATED probe will display a 1-kHz calibration signal as a perfect square wave, as shown in *a*. However, in *b*, when the probe is over compensated, the same 1-kHz signal shows low-frequency attenuation and phase shifting as indicated in the drooping effect. As shown in *c*, when the probe is under compensated, the high-frequency components are lost (as indicated by the rounded leading edge).

Assume, for example, that a computer circuit is working just fine, and that you want to observe the 20-MHz master clock. So you connect your 1X scope probe—and the whole system crashes. The clock's waveform displayed on the scope looks a little distorted. You then remove the probe from the circuit and the system immediately comes up. What happened? One possible cause is the added shunt capacitance of the probe degraded the clock's rise time, which threw off the system timing. As shown in Fig. 9, slower rise time translates into a wider pulse width. Try using a 10X probe instead of a 1X probe because the 10X probe has a lower shunt capacitance.

In general, the greater the resistive-attenuation ratio, the lower the probe-tip shunt capacitance. For example, a 1X, 10X, and 100X probe attenuation might have a 54 pF, 11.2 pF, and 2-pF tip capacitance, respectively.

Continuous wave

When measuring a continuous signal from the output of a sine-wave

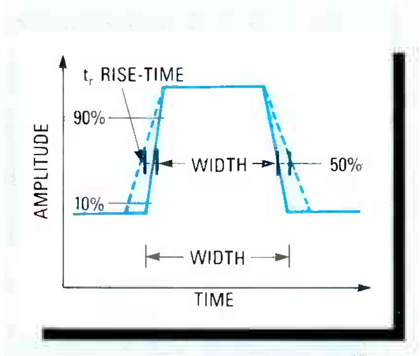


FIG. 9—PULSE WIDTH IS MEASURED at the 50% marks on the waveform. As the circuit's shunt capacitance is increased, the rise-time slows, causing the pulse to become wider.

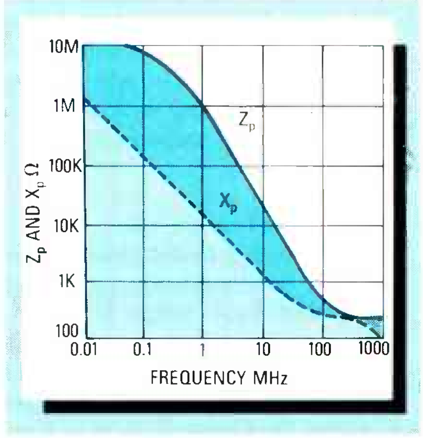


FIG. 10—WHEN MEASURING SINE waves, it's important to know how the probe's input impedance (Z_P) changes with regard to frequency.

oscillator, the probe-tip's capacitive reactance (X_P) at the operating frequency should be taken into account. In Fig. 10, the total probe-tip impedance designated Z_P, includes the probe's resistive, capacitive and inductive elements. The capacitive and resistive elements make up most of the probe's impedance. However, some probes also include additional inductive elements that are designed into the probe itself to offset the capacitive loading. For worst case analysis, use the probe's capacitive reactance formula:

$$X_P = 1/2\pi FC$$

where C is the probe-tip capacitance which is often marked somewhere on the body of the probe.

For example, the Tektronix model *P6105A* passive probe has a 10-megohm input resistance with a tip capacitance of 11.2 pF. The X_P will equal 290 ohms at 50 MHz. Depending on the impedance of the source, the probe's loading could have a major effect on the signal amplitude and possibly interfere with the operation of the circuit under test. The typical curves for probe *impedance* vs. *frequency* vary for each probe type—so consult your probe's specifications. For sine-wave amplitude measurements, a probe should have the highest possible impedance at the frequency of interest.

Voltage derating

The maximum voltage (DC and AC) that can be safely handled by a probe varies with frequency. Figure 11 shows the voltage derating curve for a Tektronix model *P6105A* passive probe. The curve may be summarized by saying that the maximum voltage handling capability is inversely proportional to frequency. Most scope probes are supplied with their own voltage-derating specification.

Bandwidth

Scope probes are often rated for bandwidth. It's best to use a probe that has a bandwidth equal to or higher than that of your scope. However, if the probe's bandwidth is less then that of the scope's, then the input frequency will be limited by the probe. Figure 12 shows the response curve of a probe having a 100-MHz bandwidth. By definition, bandwidth is the upper frequency where the scope's displayed voltage is down 3 dB from the reference frequency voltage. The formula to calculate decibels is:

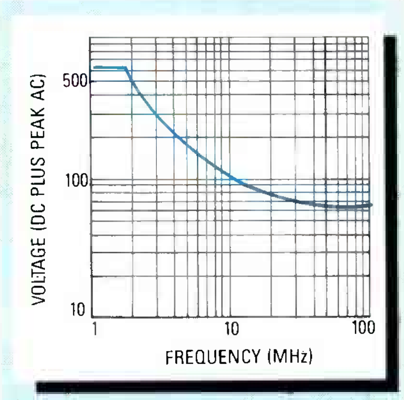


FIG. 11—THE MAXIMUM VOLTAGE that a probe can handle becomes less as the frequency increases.

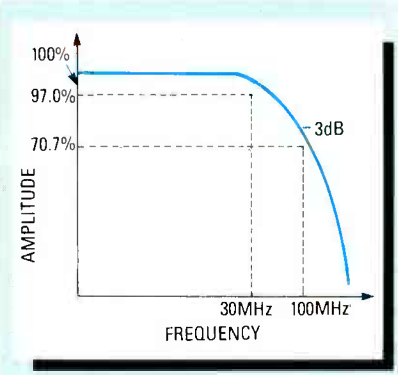


FIG. 12—PROBE BANDWIDTH is the point where the voltage amplitude is down 3 dB from a starting reference level.

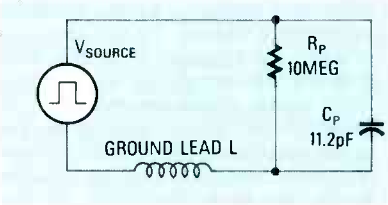


FIG. 13—GROUND-LEAD INDUCTANCE will reduce the high-frequency response through its series-inductive reactance.

$$dB = 20 \log V_{OUT}/V_{IN}$$

For example, if your input is a 1-volt p-p 100-MHz sine wave, then at −3 dB the scope's waveform will show an amplitude of only .707-volts p-p (which is an amplitude accuracy of 70.7%). For an amplitude accuracy of 97% or better, you must limit the input frequency to about 30 MHz. Another useful equation shows how bandwidth is related to rise-time (t_r):

$$\text{Bandwidth} = .35/t_r$$

That equation shows the relation that the faster the rise time, the greater the bandwidth.

For low-frequency applications (audio frequencies), choose a 1X passive probe because it costs the least and will do the job. Be aware that the 1X probe has a limited bandwidth—less than 40 MHz. Use the 10X probe for general digital, analog, and RF frequency measurements because that probe has low capacitance and a bandwidth upwards to 400 MHz depending on the model and the cable length. Although not discussed in this article, for frequencies higher than 400 MHz, choose one of the active probes (FET) with a 1X sensitivity. Those will provide high sensitivity, low shunt capacitance, and a bandwidth greater than 900 MHz.

Grounding

How often have you touched the probe tip to an IC pin only to see a waveform you know from experience isn't right. After moving the probe's grounding clip from the chassis to the IC's grounding pin, the scope's trace immediately shaped up and became recognizable as the waveform you've seen a hundred times before. That leads us to an obvious question: How does the probe's grounding lead effect the circuit measurement? The obvious answer is that improper grounding will generally distort the waveform by allowing excess noise to be picked up. That's true, but it's only part of the reason.

Figure 13 shows an equivalent circuit of a passive probe connected to a voltage source. Notice the series ground-lead inductance, L, which represents the ground return path. R_P and C_P represent the equivalent impedance as seen at the compensated probe's tip. When measuring any signal, the series inductive reactance will be proportional to both frequency and inductance by the formula:

$$X_L = 2\pi fL$$

The higher-frequency harmonics will therefore see a larger inductive reactance than the lower-frequency harmonics. The pulse waveform displayed on the oscilloscope will show distortion and aberrations because the p-p voltage of the higher-frequency harmonics have been attenuated and phase shifted across the ground-lead inductive reactance.

Getting back to the original problem. If you move the probe's grounding clip from the chassis to the IC itself, then the ground-loop inductance will be reduced. That allows the high-frequency harmonics to reach the scope's input, so the trace shapes up. As a rule of thumb, when making any kind of precise measurement—such as amplitude, rise time and pulse width—you should use the shortest grounding path possible.

As shown in Fig. 14, loop inductance may also manifest itself as ringing on the leading and trailing edge of the electrical pulse. The grounding-lead inductance and probe-tip capacitance form a series-resonant circuit with only a 10-megohm resistor for damping. When shock excited by a pulse, the resonant circuit will ring with a predictable damped oscillation. For example, a 11.2-pF passive probe having a 6-inch ground lead will ring at about 140 MHz when hit by a fast rise-time pulse. As the ringing frequency increases, it tends to fall outside the scope's passband and is highly attenuated. It's therefore desirable to try and increase the ringing

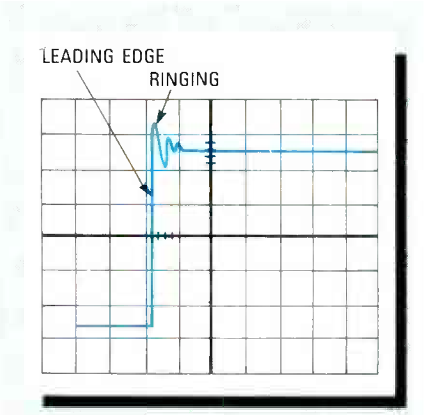


FIG. 14—PULSE RINGING occurs when the grounding-loop inductance and probe-tip capacitance form a series-resonant circuit that is shock excited by a very fast rise-time pulse.

frequency. To do that, use the shortest possible ground lead, and the probe with the lowest shunt capacitance. It's ironic, but for the reasons just mentioned, you're more likely to see unwanted ringing on an expensive high passband 300-MHz scope than a low passband 20-MHz scope.

Mechanical properties

Often, while touching or rearranging a probe or lead wire, unpredictable, confusing, and non-repeatable effects are produced on the observed waveform. That kind of problem may have more to do with the mechanical nature of the probe than anything else.

If the probe's inner signal-carrying conductor is poorly shielded, then the probe's cabling will be susceptible to external electric fields. (The shielding could become frayed due to constant flexing of the cabling over many months or years of use.) A poorly shielded probe wire can act as an antenna and pick up all types of interference, such as electrical noise from fluorescent lamps, radio stations, and signals generated by nearby equipment. To virtually eliminate any external-field pick up, always use a probe with coaxial shielding of the center conductor.

As a final note, the probe tip should be clean or a poor circuit connection will result. Be sure to check printed circuit boards for a conformal coating used for humidity and static guard, which can easily prevent an electrical connection between the probe tip and the circuit. It may be necessary to scrape off some of that coating. **R-E**

LOW-CAPACITANCE SCOPE PROBE

Even audio-frequency scope measurements are more accurate with this easy-to-build low-capacitance probe.

HERB FRIEDMAN

EVEN IF YOU'RE MEASURING WELL DOWN into the bass audio frequencies, an oscilloscope's display of a complex waveform—such as a square wave—will not be accurate unless the input to the scope is made through a low-capacitance test probe.

Elsewhere in this issue of **Radio-Electronics** there is an in-depth discussion on the why's and wherefore's of low-capacitance oscilloscope probes, so there's no sense in repeating what's been said. Suffice to say that, as a general rule, all AC scope measurements should be made using a low-capacitance 10X test probe.

Also as a general rule, you're probably best off with a low-C 10X scope probe that's specifically designed for your scope. But what if you can't afford to buy one? Simple! You build it using readily available, budget-priced parts. From input to output, the prototype low-C 10X probe shown can cost as little as $15. And by building your own, you get the extra advantage of precisely matching your scope's vertical-input connector: anything from a modern BNC connector to a somewhat older banana plug, to an ancient microphone-type connector. Whatever your scope needs, just hang it on the end of the probe's cable.

The circuit of a low-capacitance probe, shown in Fig. 1, is certainly simple enough because it essentially consists of three components: R1, C1, and PL1. R1 can be any kind of ¼- or ½-watt resistor rated about 9 megohms. The actual value really isn't all that critical; it can be 9.2 megohms, or 8.8 megohms; just use the tightest affordable tolerance (1%, 5%, or 10%) that keeps the final value near 9 megohms. Trimmer capacitor C1 can be anything that physically fits inside the handle: The unit specified in the parts list is cheap and an ideal size. PL1 is whatever connector matches your scope's vertical input.

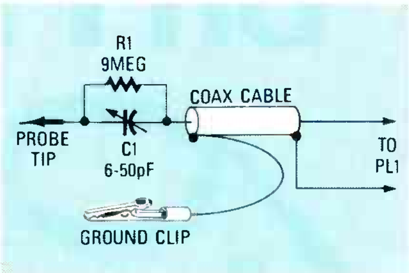


FIG. 1—ALTHOUGH A LOW-CAPACITANCE probe is a simple device, it plays a vital part in obtaining accurate oscilloscope traces.

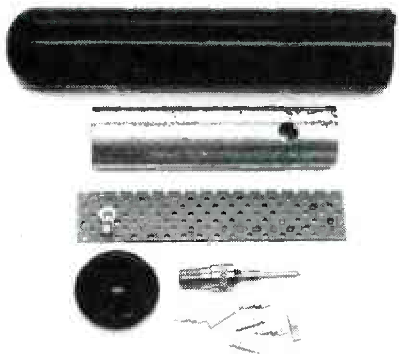


FIG. 2—THE PROBE-HANDLE KIT contains an internal shield and flea-clip mounting terminals. If the pre-drilled version of the kit isn't used, the builder must drill the holes in the handle and the shield that provide access to C1.

The problem is, however, to assemble R1 and C1 in a shielded probe; one that does not pick up extraneous hum and noise because of capacitance-coupling to the user's hand. On the other hand, for the user's safety, even though the probe is shielded it should be insulated from the user's hand. So you will need some form of plastic handle, a probe tip for the handle, an internal shield, and a perforated wiring board having a lug that can be used as a common ground.

The necessary parts are available in a Keystone *1810* probe handle kit, but the *1810* is not modified for use as a low-capacitance probe. Holes must be drilled in both the handle and the shield to allow access to C1. Take extreme care when drilling the holes in the handle and the shield because they are prone to snag on the drill bit. You *must* create some kind of safe drilling jig when working with the handle and the shield.

Figure 2 shows the probe-assembly components after the handle and the shield are drilled. A pre-drilled kit is available from the source given in the parts list.

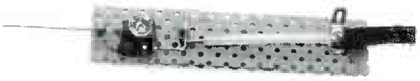


FIG. 3—THE RESISTOR SHOULD be placed to the side of C1. Do not span the resistor across the top of the capacitor.

FIG. 4—THE POINTER INDICATES where the wiring board's solder lug is tack-soldered to the inside of the shield tube.

Construction

Bend the ground lug on the probe's wiring board 90° upward so that the board can slide through the metal shield. Position the lug so that it is inside the tube and exactly flush with one end. Mark the opposite end of the board at the end of the metal tube and cut the board exactly on the line. If you are not using the *CC-5* handle kit, drill a ¼-inch hole in the metal tube exactly 5⁄16 inch from the non-lug end of the tube. Drill a matching hole exactly ¾ inch from the front of the plastic handle.

Install C1 on the board so that it is centered 5⁄16 inch from the cut edge. Enlarge existing board holes so that the trimmer's lugs just barely squeeze through. Pass C1's lugs through the holes and then fold the lugs outward against the board. That's all the support that's needed.

Using Fig. 3 as a guide, install a flea clip on each side of C1; then install R1 between the clips, positioning the resistor so that it is adjacent to the side of C1. Do not position R1 across the top of C1. Notice from Fig. 3 that one of R1's leads passes through the front flea clip full length. The extra length will pass into the probe's tip during final assembly.

Connect C1 to the two flea clips on the bottom of the board using the shortest, most direct lengths of wire.

The connecting cable is three to six feet of conventional coax. To prevent constant flexing from snapping the center conductor, use one of the cable types having a stranded center conductor, such as RG-58A/U or RG-58C/U. Avoid RG-59 cable because its center conductor is solid.

The probe's ground is the solder lug on the wiring board. Unbraid the cable's shield, twist the strands tightly into a pigtail, pass the pigtail through the hole in the solder lug, and solder the pigtail to the lug on the underside of the board. (Avoid letting excess soldering heat flow through the pigtail; that would melt the center conductor's insulation.) Then connect the cable's center conductor to the nearest flea clip that supports R1. Finally, slip the shield tube over the board until the back end is exactly flush with the solder lug. Force or bend the lug against the inside of the shield, rotate the shield so that its hole is exactly opposite C1, and, as shown in Fig. 4, tack-solder the lug to the inside of the shield.

Using a knife, or an ⅛ drill bit as a router, cut a slot for the *grounding* test

PARTS LIST

R1—As close to 9-Megohms as is possible, see text
C1—6–50-pF trimmer capacitor (Radio Shack 272-1310A)
PL1—Connector to match scope (see text)
Misc.: Probe-handle kit, coaxial cable, solder, ground clip, etc.
Note: The pre-drilled test probe kit is available for $10 plus $3 postage and handling per total order from: Custom Components, Box 153, Malverne, NY 11565. NY State residents must add appropriate sales tax.

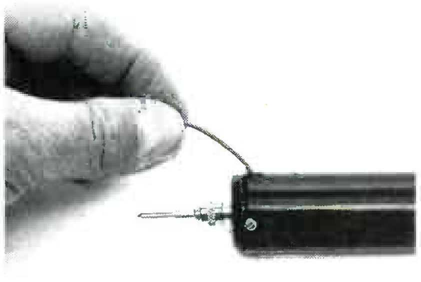


FIG. 5—YOU MUST CUT A NOTCH in the plastic handle so that the ground test lead from the shield tube can exit from the front of the probe.

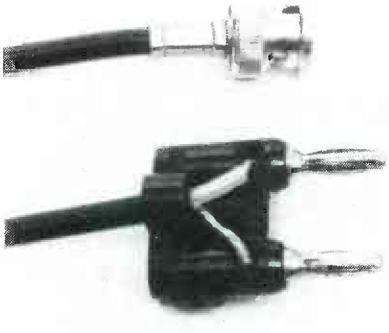


FIG. 6—THE BNC CONNECTOR at the top provides shielding all the way into the scope. On the other hand, a banana plug causes a break in the shield, which exposes the inner conductor to possible hum and noise pickup.

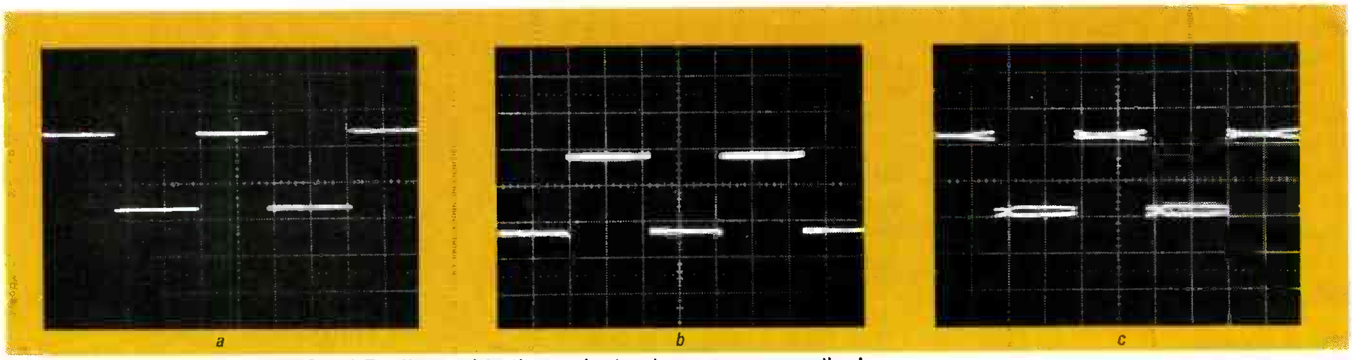


FIG. 7—A FULLY SHIELDED CABLE will provide the rock-steady square wave display shown in *a*. A break in the shield, such as caused by a banana plug, can cause the trace smearing shown in *b*. Close examination of the smear in *c* shows a 60-Hz noise signal superimposed on the desired signal.

FIG. 8—ADJUST C1 USING an insulated tool for an optimum square-wave scope display.

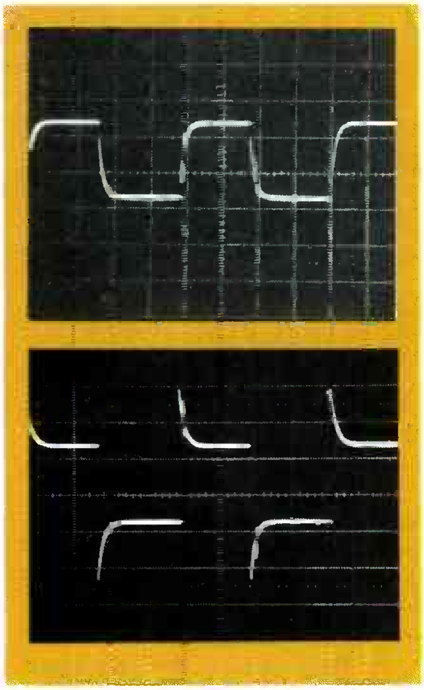


FIG. 9—IMPROPER ADJUSTMENT OF C1 will produce the rounded leading edge shown in *a*, or overshoot of the leading edge, as shown in *b*.

lead in the front of the plastic handle, 180° opposite to the ¼-inch hole.

Slide the assembly into the handle, rotate the assembly so that the holes in the handle and shield correspond, and then mark the slot's location on the metal shield. Remove the assembly and tack-solder a 6-inch length of stranded No. 22 or No. 24 insulated wire to the shield at the mark. As shown in Fig. 5, position the wire so that it will flow naturally from the slot in the handle.

Final assembly

Slide the assembly into the handle, taking care that the holes for C1 are in alignment and that the ground test wire flows out of the slot. Assemble the probe tip and slide the tip over the free resistor lead. Seat the tip into the handle, secure the tip assembly with the two supplied screws, and, using long-nose pliers, pull the lead through the tip so the front of the shield and the board are snug against the front of the probe. Then secure the locking collar on the probe's tip.

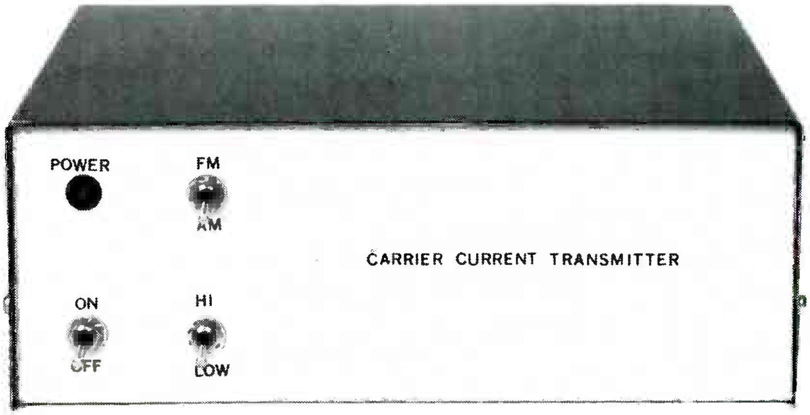
If you want, run a small grommet down the connecting cable to fill the opening in the back of the handle.

PL1 is any connector that matches your scope's vertical input. It might be a BNC connector, a banana plug, or whatever. Bear in mind that, as shown in Fig. 6, a BNC connector provides full shielding all the way from the probe to the scope's input, while a banana plug actually breaks the shield at the connector, and will allow some kind of noise pickup. For example, using the same scope, as shown in Fig. 7-*a*, a BNC connector resulted in a rock-steady trace. In Fig. 7-*b*, PL1 was a banana plug that was connected to a BNC-banana adapter. Notice that noise (hum) pickup causes the trace to "smear." Figure 7-*c* is the same trace as Fig. 7-*b*, but a faster camera shutter was used to show that the "smear" is actually another signal (60 Hz leaking through the broken shield at the banana plug) that is superimposed on the square wave. If possible, maintain shielding throughout the entire assembly and connection. Of course, if your scope has only banana jacks for the vertical-input connections then PL1 must be a banana plug.

Adjustment

To adjust the probe, set the scope's vertical input for DC. Then, using any square wave as the signal source—1 kHz is almost a universal "standard—as shown in Fig. 8, use an insulated (non-metallic) alignment tool to adjust C1 for the precise square wave shown in Fig. 7-*a*. Improper adjustment of C1 will result in a rounding of the signal's leading edge (Fig. 9-*a*), or overshoot of the signal's leading edge (Fig. 9-*b*). See the scope probe article elsewhere in this issue to learn why C1's adjustment does what it does.

Be sure you allow for the 10X factor when using the low-C 10X probe. For example, if the scope indicates that a signal is 1.1 volts p-p, then the actual value is 11 volts. R-E



CARRIER CURRENT AUDIO TRANSMITTER

WILLIAM SHEETS and RUDOLF F. GRAF

Now you can set up your stereo speakers anywhere in your home, as long as there's an electrical outlet nearby!

THERE HAVE PROBABLY BEEN TIMES WHEN you wished you could send audio from one place to another without having to run any wires or cable. Well, now you can stop wishing, because such a method called *carrier current* does exist. It uses the existing AC lines in your home as the transmission medium, in which RF carriers in the range of 100–500 kHz are modulated with the information to be transmitted. (Simple AM, FM, or related modulation methods can be used to place the information on the carrier.)

Carrier-current techniques are also useful for coverage throughout a large building, or perhaps a complex of buildings. Some of the possible applications for carrier-current are wireless extension speakers, headphones, and wireless intercom and loudspeaker paging systems.

Obstacles

There are several problems that must first be taken into account before we can apply the carrier-current technique to practical use. The AC power system in the average home can often vary in its construction. But what is more important than that is that, because there can be any number of appliances operating at any given moment, the load on the power system is constantly varying.

Additionally, if the AC power lines are to be used as an RF transmission medium, the power line's indefinite impedance must be accounted for.

Complicating that fact is that certain loads may be a near short circuit to RF, especially if those loads have built-in RF bypassing.

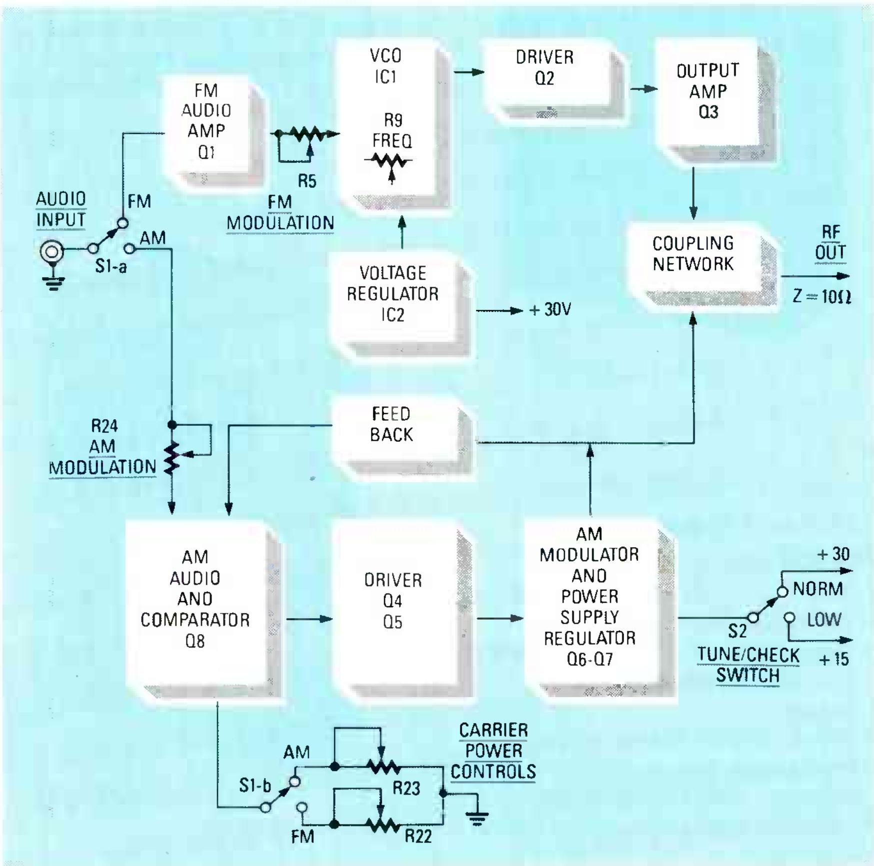


FIG. 1—BLOCK DIAGRAM of the carrier-current transmitter. It can transmit AM and FM.

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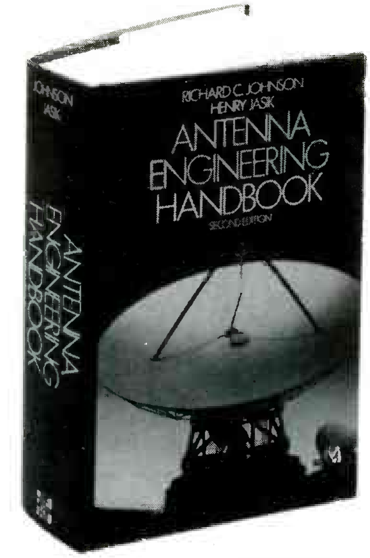

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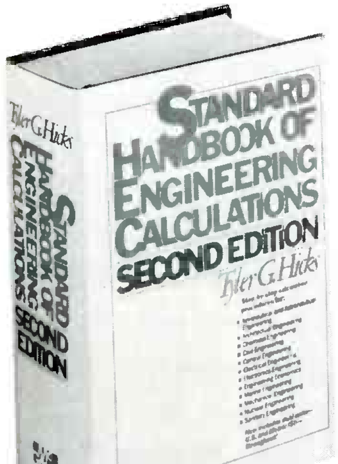

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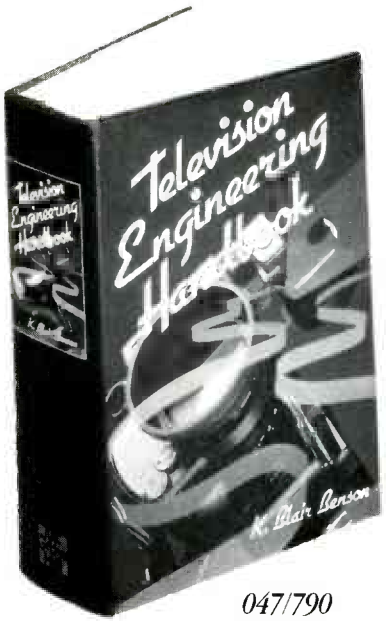

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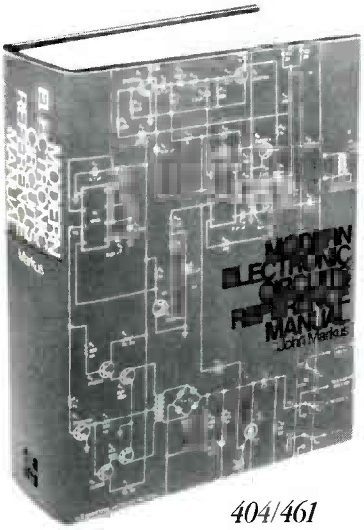

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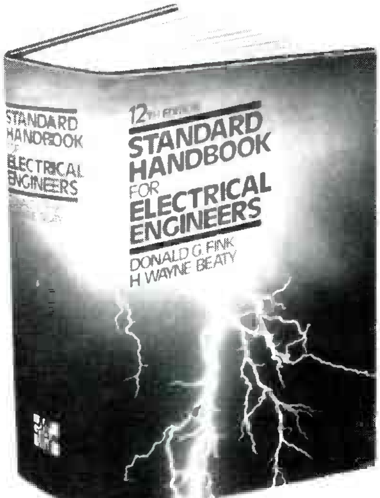

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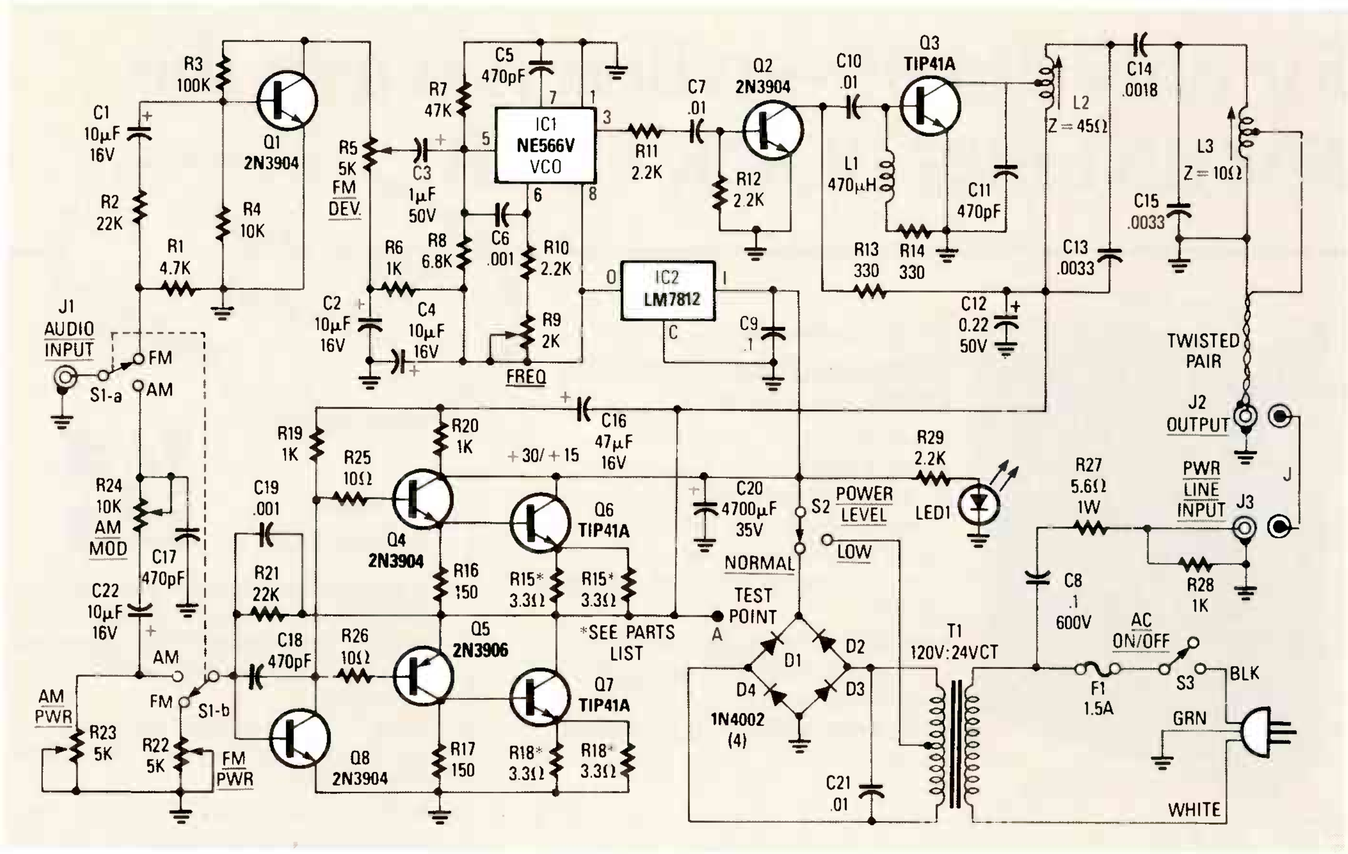


FIG. 2—THE COMPLETE SCHEMATIC of the carrier-current transmitter. Everything except the power-supply components, the switches, and the power-line coupling components are installed on the PC board.

Another problem is the presence of noise voltages generated by appliances that are connected to the power lines. Unfortunately, those noise voltages are within the frequency band of 100–500kHz, which can cause interference with carrier-current transmissions. Offenders are motors, fluorescent lamps, neon signs, relay contacts, triacs and SCR's, rectifier diodes, etc. In short, the AC powerline in the modern home is a hotbed of noise and interference.

However, the situation is not hopeless as it appears. The problems *can* be overcome, and this article will describe an effective carrier transmitter and receiver that can be used for many applications.

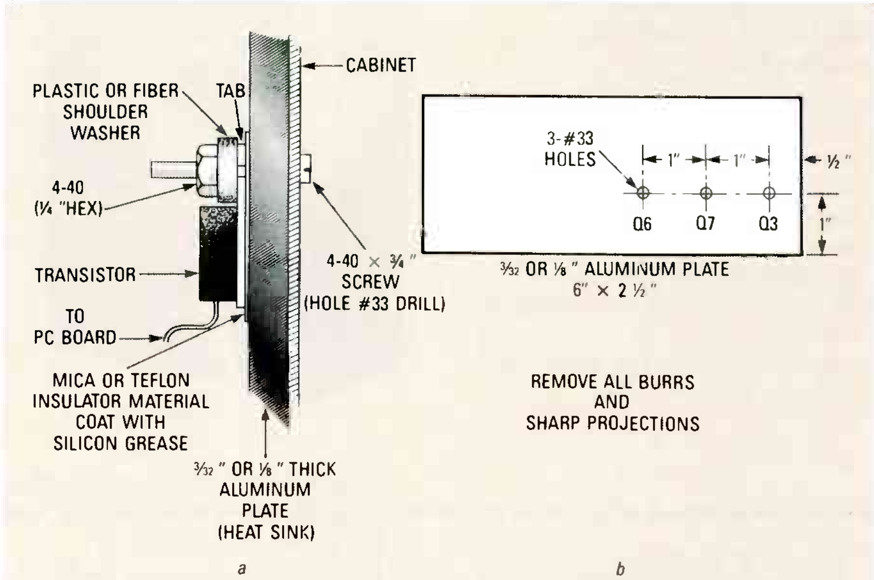


FIG. 3—THE TRANSISTORS SHOULD BE ATTACHED to the heat sink and cabinet as shown in *a*, and a drill guide for the heat sink is shown in *b*.

Carrier-current transmitter

The decision to use either AM, narrowband FM (less than 15 kHz), or wideband FM (greater than 30 kHz) depends on the application. For the transmission of music, FM is better because it has greater noise immunity. For speech or other noncritical applications, AM may be satisfactory. Our transmitter permits either mode by switch selection.

Looking at the block diagram in Fig. 1, audio is fed from switch S1-a to either the FM or AM circuitry. Starting with the FM section, amplifier Q1 accepts an audio signal in the 10-Hz to 20-kHz range of about 0.5 volts peak-to-peak. The audio gain is adjusted via R5 to provide up to 60-kHz deviation of the voltage-controlled oscillator, IC1, which is set to nominally 280 kHz. IC1 and Q1 are supplied with a regulated 12 volts from IC2. A square-wave signal from IC1 pin-3 drives Q2, and Q2 drives the output amplifier Q3. A coupling network is used to match the nominal 45-ohm

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—4700 ohms
R2, R21—22,000 ohms
R3—100,000 ohms
R4—10,000 ohms
R5, R22, R23—5000 ohms, potentiometer
R6, R19, R20, R28—1000 ohms
R7—47,000 ohms
R8—6800 ohms
R9—2000 ohms, potentiometer
R10–R12, R29—2200 ohms
R13, R14—330 ohms
R15, R18—1.65 ohms (use two 3.3-ohm resistors in parallel for both)
R16, R17—150 ohms
R24—10,000 ohms, potentiometer
R25, R26—10 ohms
R27—5.6 ohms, 1 watt

Capacitors
C1, C2, C4, C22—10 µF, 16 volts, electrolytic
C3—1 µF, 50 volts, electrolytic
C5—470 pF, silver mica, 5%
C6, C19—0.001 µF, Mylar
C8—0.1 µF, 600 volts DC
C9—0.1 µF, 50 volts, Mylar
C7, C10, C21—0.01 µF, 50 volts, ceramic disc
C11, C17, C18—470 pF, ceramic disc
C12—0.22 µF, 50 volts, tantalum
C13, C15—0.0033 µF, 250 volts, 10% Mylar
C14—0.0018 µF, 250 volts, 10% Mylar
C16—47 µF, 16 volts, electrolytic
C20—4700 µF, 35 volts, electrolytic

Coils
L1—470 µH choke
L2—100–160 µH, 33% tap (see Fig. 4)
L3—100–160 µH, 14% tap (see Fig. 4)

Semiconductors
IC1—NE566, voltage-controlled oscillator
IC2—LM7812 or LM78L12, 12-volt regulator
Q1, Q2, Q4, Q8—2N3904, NPN transistor
Q3, Q6, Q7—TIP41A, NPN transistor
Q5—2N3906, PNP transistor
D1–D4—1N4002 rectifier diode
LED1—light-emitting diode, any color

Other components
J1–J3—RCA jack
F1—1.5- or 2-amp fast-blow fuse
S1—DPST switch
S2, S3—SPST switch
T1—117 VAC primary, 24-volt 1.5 amp secondary, center tapped

Miscellaneous: 3-wire line cord, PC board, cabinet, two RCA plugs, terminal strips, hardware, etc.

Note: The following items are available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804. A kit of parts containing a PC board and everything that is installed on it is available for $54.50, and a single PC board is available for $13.00. Add $2.50 to either order for postage and handling. NY residents must include sales tax.

output impedance of Q3 to the 10-ohm AC line impedance.

In the AM mode, audio is coupled to Q8 via R24 and then amplified again by transistors Q4 to Q7. The normally stable DC voltage at test point A is thereby varied at an audio rate. Because Q2 and Q3 obtain their DC V_{CC} from test point A, the VCO carrier input to Q2 is amplitude modulated by the varying V_{CC} amplitude. That produces an amplitude-modulated output from the transmitter. Careful setting of R23 (carrier level) and R24 (audio level) provides up to 100% modulation.

Circuitry

Referring to the schematic in Fig. 2, an audio input signal of nominally 0.5 volt peak-to-peak is fed into J1. Switch S1-a selects either FM or AM modulation. For FM modulation, audio appears across R1, which serves as a termination for a 5K audio source impedance. The input signal is applied to the base of Q1. The output of Q1, from the wiper of R5, is fed to IC1. An audio signal between 0.5 and 1.0 volt peak-to-peak appears at pin 5 of that VCO, as the modulation for a carrier of 200–350 kHz; the carrier frequency depends on the setting of R9. The AC component is coupled to the base of driver Q2 via R11 and C7.

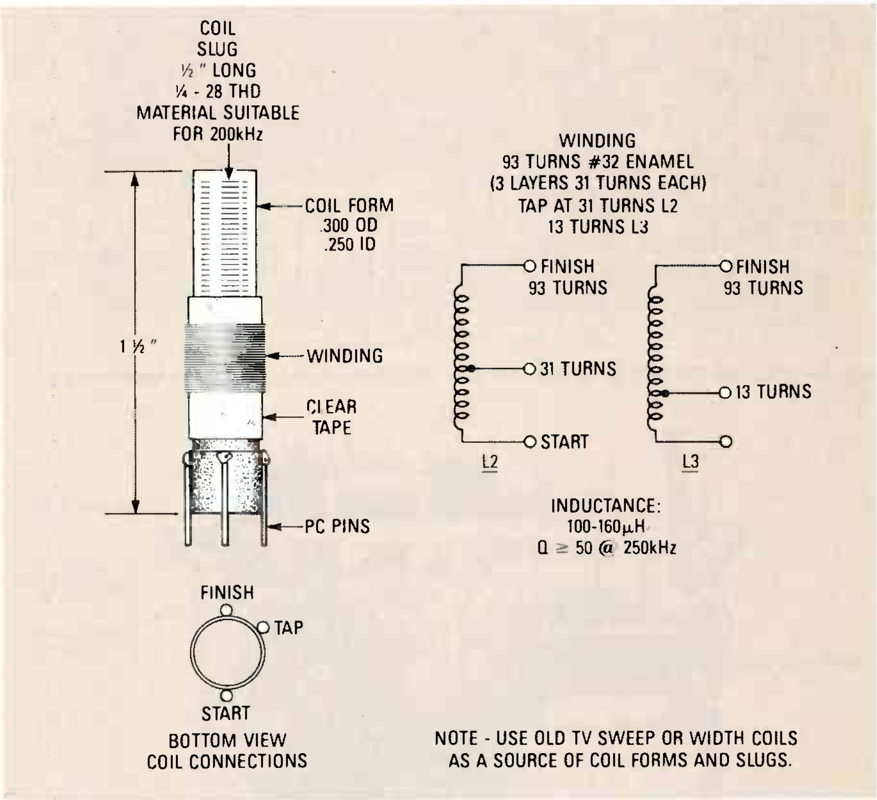


FIG. 4—YOU CAN MAKE COILS L1 AND L2 yourself. First you have to get some old coil forms and slugs with the specifications as shown. Then wind three layers of 31 turns each, wrapping a piece of clear tape around each layer. Remove the enamel coating from each end, as well as the tap point, and solder each point to the appropriate PC pin.

R12 provides a DC path to ground for the base of Q2 and allows Q2 to generate its own base bias. A square wave of about 8 volts peak-to-peak appears at the collector of Q2, and C10 couples that waveform to the base of Q3.

Transistor Q3 provides power amplification of the nominal 280-kHz signal from Q2. The collector of Q3 connects to a tap on L2 at about a 45-ohm impedance level. L2, C13, C14, C15 and L3 form a bandpass filter for the 200–350-kHz range, and also match the impedance of the collector circuit of Q3 to a nominal 10-ohm powerline load impedance. Q3 *must* be heat sinked, and the collector (which is also the tab) must be insulated from ground. A mica washer, with a light coating of silicone grease to aid in heat transfer is used for that purpose.

In the FM mode, Q6 and Q7 function as pass transistors, supplying V_{CC} for Q2 and Q3. A negative feedback circuit keeps the DC V_{CC} voltage at test point A stable during FM operation. Here's how it works. Transistor Q8 is connected as a common-emitter amplifier, receiving its bias from R21, which connects to the emitter of Q6 and collector of Q7, which is also the DC V_{CC} supply for Q2 and Q3. If the voltage at test point A rises, it will tend to turn on Q8 even more; Q8 will draw more current from R20 and R19, lessening the drive current to Q4 and increasing it to Q5. That makes Q6 conduct less and Q7 conduct more, lowering the voltage at point A. A similar but opposite effect occurs if the voltage at point A starts to fall. In that case Q8 tends to conduct less, Q4 and Q6 more, and Q5 and Q7 less, raising the voltage at point A. The exact voltage at point A depends on the ratio of R21 to either R23 for AM or R24 for FM, and the base-emitter turn-on voltage of Q8 (about 0.6 volt). Therefore, R23 and R24 can set the DC level at point A: 10–20 volts for FM and 12–14 volts for AM.

When AM modulation is used, audio is fed to R24 and C17, and coupled to the base of Q8 through C22 and S1-b. R23 determines the quiescent point of Q6 and Q7 and the no-signal resting (static) voltage to Q2 and Q3. Now, Q8, Q4, Q5, Q6, and Q7 function as an audio amplifier, producing a clamped DC voltage at test point A with a superimposed AC voltage that varies at an audio rate. The audio component can cause the voltage at test point A to vary from 0 volts to 27 volts. Remember, it's that voltage that amplitude modulates the VCO carrier at Q2 and Q3.

Components R29 and LED1 are used as a power indicator and may be omitted if desired. A small incandescent lamp rated for 30 or 36 volts can also be used.

To prevent excess radiation, the transmitter's output is connected to J2 via a twisted pair of insulated hookup wire about 6 inches long. RF from J2 is then fed into J3 via a short jumper wire (J) that has RCA plugs at both ends (the jumper uses only the center conductors of the plugs). RCA jack J3 is connected to the hot side of the AC power line via R27, R28, and C8, *after* the fuse, F1. Resistor R28 limits AC voltage on C8 to about five volts. Otherwise a mild but uncomfortable shock would be gotten from J3 if the center pin were touched. The 5.6-ohm 1-watt resistor, R27, provides a stabilizing effect on the impedance seen by the transmitter. It also limits AC line current in case C8 shorts; F1 will blow instantly in that case. C8 *must* be rated at least 600-volts DC or better.

Note: Never plug the unit into an ungrounded outlet (2-wire system), because the transmitter case must be grounded to either an earth ground, a cold-water pipe, or the electrical-system ground (conduit, metal boxes, etc.).

Switch S2 is used to select either the full transformer voltage or half of it. Normally, the full voltage is used. During testing, use the low position, because it reduces the chance of

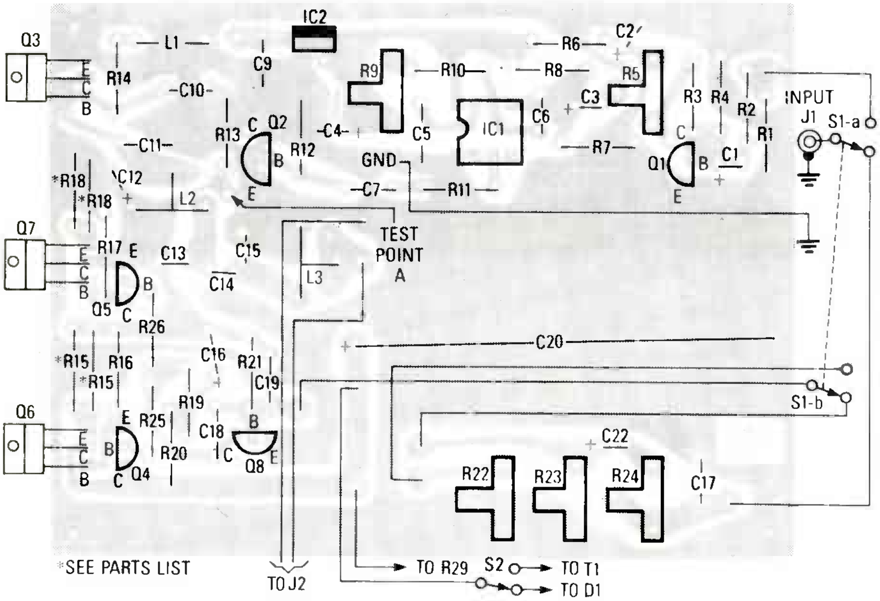


FIG. 5—FOLLOW THIS PARTS-PLACEMENT diagram when building the transmitter.

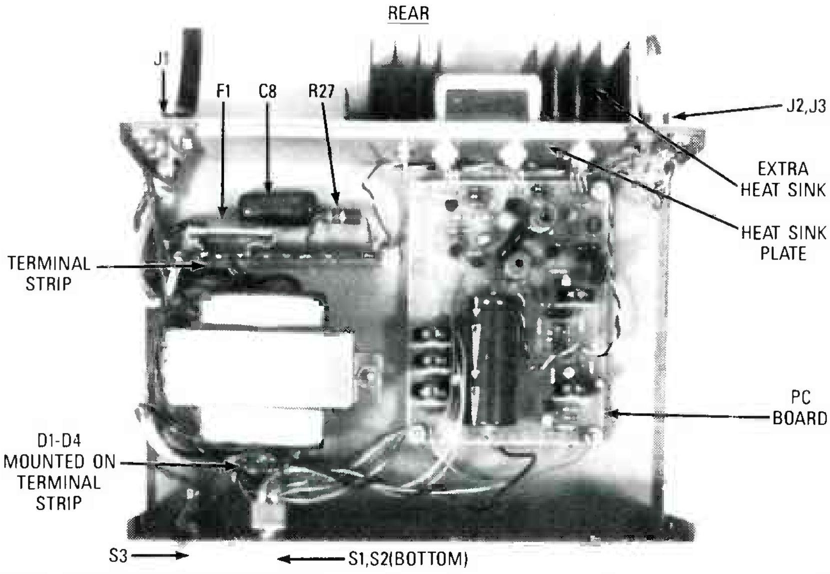


FIG. 6—THE INSIDE OF THE UNIT should be laid out as shown here. Just make sure that the transistors are insulated from the heat sink and cabinet.

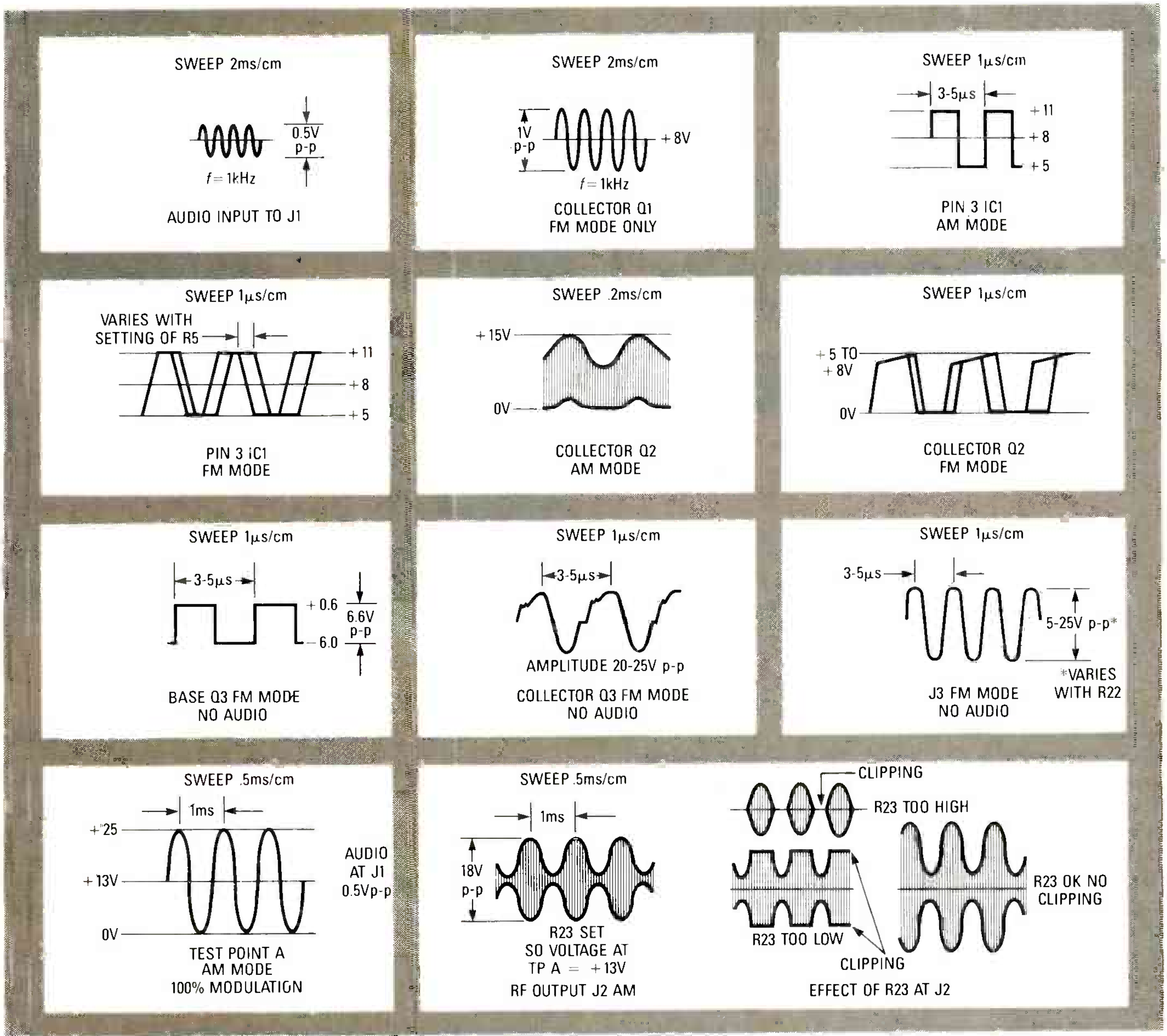


FIG. 7—EXPECT TO SEE THESE WAVEFORMS at the various points in the circuit that are mentioned below each diagram.

damaging something. Also, depending on R22's setting, the low position can be used (in the FM mode only) to reduce the transmitter's output.

Construction

The transmitter is built inside a metal case that is 8-¼ × 6-⅛ × 3 inches. Transistors Q3, Q6, and Q7 are heat-sinked to a piece of ⅛- or $\frac{3}{32}$-inch aluminum that is mounted flat against the rear of the case. Except for the power supply, the switches, and the AC line-coupling components, all of the transmitter circuitry is contained on the PC board. A foil pattern for the PC board is given in PC Service, and it is also available with or without a parts kit, from the source given in the Parts List.

The leads to and from J1, J2 and J3 should be either twisted pairs or shielded cables. Mount all components that are not on the PC board on terminal strips or standoff insulators. Be sure to use the unit only with a grounded outlet—if you live in an older home with two-prong outlets, make sure that the chassis is grounded to the outlet box (and that the outlet box is properly grounded), or run a ground wire to a cold-water pipe. Q3, Q6, and Q7 must be heat-sinked and electrically insulated from the metal chassis.

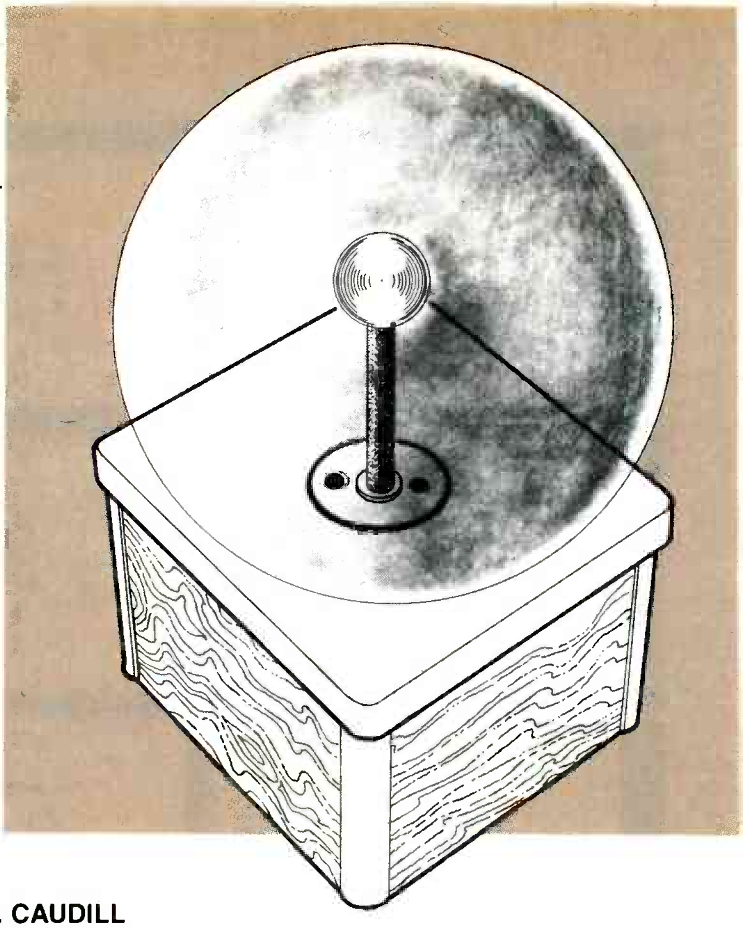
The mounting details for the transistors and a drill guide for the heat sink are shown in Figs. 3-*a* and 3-*b* respectively. Use sheet mica cut to fit (with a light coating of silicon grease) and plastic bushings to insulate the transistor tabs. 4-40 steel hardware should be used to mount the transistors; nylon screws can be used but they tend to loosen over time.

Coils L2 and L3 can be made by hand (see Fig. 4), but they, too, can also be purchased. If you decide to make them yourself, you can use old TV sweep or width coils as a source of coil forms and slugs. Follow the parts placement as shown in Fig. 5. The cabinet layout is shown in Fig. 6. As you can see from that photo, the prototype has an additional heat sink attached to the back of the cabinet. It may be required if the back of the cabinet seems to get excessively hot during operation.

continued on page 64

BUILD THIS

PLASMA DISPLAY GLOBE



You can save really big bucks by home-brewing your plasma display globes. Here's how you do it.

JEFFERY C. CAUDILL

ALTHOUGH THE PLASMA-DISPLAY POWER supply featured in the March 1988 issue of **Radio-Electronics** is relatively inexpensive, the globe itself—which, depending on size, can cost well over $200—often proves to be beyond the budget of many experimenters. But if plasma displays fire your enthusiasm, you can get them at a relatively low cost by making the plasma globes yourself.

Yes, you read correctly: We did say make the globes yourself. You can do it even if you know next to nothing about glass-blowing because our prototype—which costs about $45—is made from a conventional glass lighting globe.

Although making your own plasma globe sounds like a complex project, in reality it is rather easy to do, and it can be a lot of fun. So follow our instructions in the context of fun, rather than as a chore.

Construction

The globe itself is a 14-incher, the kind used for outdoor yard-post lighting fixtures; it can be obtained from a local lighting-equipment supply house for about $20.00. Typical of lighting globes, it has an opening with a curled lip that allows the globe to be held in place by three thumbscrews. As you'll see, we will use the globe's curled lip to ensure an airtight assembly.

The globe's base is made from a 12 × 10 inch piece of ¾-inch Corian—a material that's used for cabinet tops. (It can be purchased at local kitchen-cabinet shops; it's usually the scrap from the sink cut-out.) As shown in Fig. 1, use a router to cut a ⅜ inchW × ⅜ inchD circular groove that matches the diameter of the curled lip; the groove should be centered.

Drill a 5/16-inch hole in the center of the grooved circle. Then, as shown in Fig. 1, drill a ⅛-inch hole that is offset as far as possible from the center hole. The ⅛-inch hole will be needed for pulling a vacuum on the completed globe.

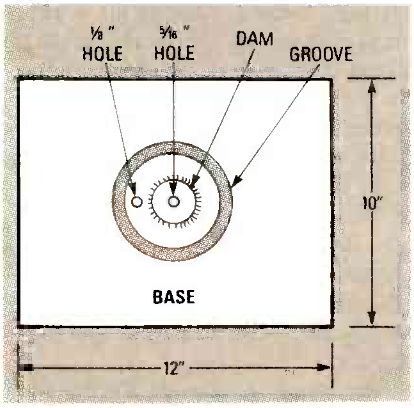


FIG. 1—PREPARE THE BASE by drilling two holes, routing a mounting groove, and building an epoxy dam between the two holes.

Figure 2 shows the dimensions for the globe's discharge assembly. The 1¾-inch discharge ball used in the prototype is aluminum; it has a 1-inch deep 5/16-inch threaded hole for its support rod. (The ball was made by a local machine shop for $12.)

The support is a 5/16-inch threaded brass rod that is 8¼-inches long. It is a standard electrical part that is used to repair table lamps.

Assembling the globe

Screw the rod into the aluminum and then cover the rod with at least four layers of heat-shrink tubing or plastic electrical tape. (Try for eight layers of insulation, if possible.) Leave the bottom threads uncovered for 1¼ inches so that the rod can be fastened through the base.

Apply a nut and a washer to the exposed end of the brass rod, insert the rod through the center hole in the base, and using another washer and another nut, fasten the rod securely. Then sandwich a solderless wire connector between the bottom mounting nut and a third nut. (If you can get the appropriate size lockwasher, use one on each side of the connector.)

To ensure an airtight seal, both the top and the bottom of the rod—as well

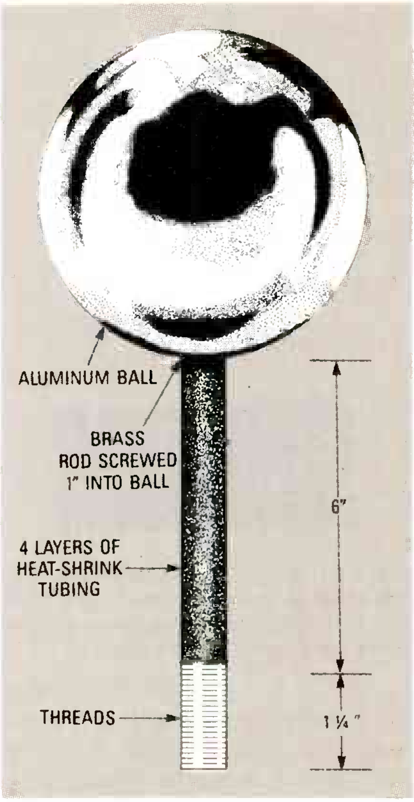


FIG. 2—THE DISPLAY ASSEMBLY consists of an aluminum ball that is mounted on a brass rod that is threaded on both ends.

as where the rod passes through the base—*must* be sealed with epoxy cement. And not just a *smear* of epoxy; really pile it on—the thicker the better. Try for a ¼-inch thickness of epoxy, and make certain the epoxy covers everything: the washers, the nuts, the end of the rod, etc.

Next, install a 1¼-inch length of ⅛-inch steel automotive brake-line tubing (from an auto parts store) into the base's ⅛-inch hole. Do not allow the tubing to protrude into the globe as that will cause the center rod to arc to the tube. In fact, you should manage to install the tubing so that it is about ⅛–¼-inch below the top of the base. (Leaving at least ⅞-inch of the tubing below the Corian will ensure that the tubing is positioned properly.)

The tubing's joint also *must* be sealed at the top and the bottom with epoxy cement, but use extra care not to get any epoxy into the tube.

Since the tubing will be relatively close to the discharge-assembly's rod, there is the possibility that most of the display arc will travel from the bottom of the rod straight across the Corian to the metal tube. To prevent that from happening, it is necessary to increase the length of the path between the rod and the tube. That is done by building a small epoxy dam—made from *epoxy putty*—around the discharge assembly's rod. Epoxy putty comes in stick form; it can molded and shaped much like children's *Play Dough*. Work the putty with your fingers until it's soft, then roll it between your palms until it forms a string having a diameter of about one-half to three-quarters of an inch.

As shown in Fig. 1, use the epoxy string to form a dam on the base between the tube and the discharge rod. Press the dam against the base and then pull it upward so that it looks like a mountain ridge. The higher you stretch the "ridge" the greater the discharge path between the rod and the tube. Try for a height of at least 1-inch, keeping in mind that only the height of the dam is important—not its thickness.

Next, carefully clean the inside of the globe, because once the globe is mounted, there is no way to get inside the globe. Then, fill the routed-groove approximately half-full with epoxy cement and place the globe's lip into the groove. Make certain that the lip is completely submerged—all the way around—in the cement. Set the assembly aside for at least 24-hours to ensure complete curing of the epoxy cement.

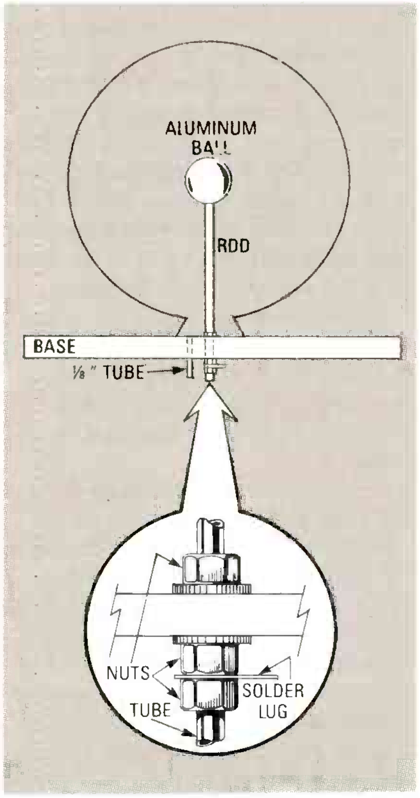


FIG. 3—ASSEMBLY DETAILS for mounting the globe on the Corian base. Take extra care to ensure that the epoxy cement seals the rod and the tubing to the base.

PARTS LIST

- 14-inch round globe
- 1¾-inch aluminum ball
- 8¼-inch length of 5⁄16-inch threaded brass rod
- 10 × 12-inch Corian
- Heat-shrinkable tubing or plastic tape
- Epoxy cement
- Plumber's epoxy
- 1¼-inches of ⅛-inch steel automotive brake tubing
- 5⁄16-inch solderless wire connector
- 5⁄16-inch nuts to match threaded brass rod
- 6-inch length of rubber automotive vacuum line
- ⅛-inch vacuum-line plug

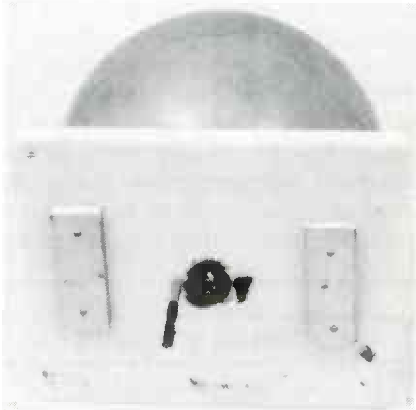


FIG. 4—THIS IS HOW THE BASE of the prototype looks. The second tubing was added to simplify inserting of the gases that change the display's color. Notice the heavy application of the epoxy that is used to seal the tubes and the rod.

The completed globe assembly is shown in Fig. 3. Figure 4 shows the underside of the prototype. The two wood strips that are screwed to the base allow the base to be secured to its cabinet

The vacuum

To vacuum the air from the globe, slide a 6-inch piece of rubber automotive vacuum-hose over the metal tube sticking out from the bottom of the base. Connect a vacuum pump—borrowed from the local college, or rented from a neon-sign vendor, an air-conditioning repairman, or a tool shop—to the rubber hose and pull a vacuum in the globe.

FIG. 5—THE PROTOTYPE'S BASE is made of wood. Holes are drilled in the front and rear for ventilation. Air movement is generated by the small fan mounted in the upper left corner.

With the pump running, connect your power supply to the solderless wire-connector on the base of the threaded rod and power up the supply while the pressure in the globe is being lowered. If you have, or can borrow a vacuum pressure gauge, the final pressure should be between one and three torrs. Otherwise, when the display appears the way you want it (different pressures make different displays), clamp off the rubber hose and seal it with a ⅛-inch plug.

The normal display is blue-white streamers. If desired, various display colors can be attained by releasing different inert gases into the globe through the hose. Helium makes yellow streamers, argon makes dark blue, and neon a reddish-orange.

Power modifications

Although the power supply shown in March 1988 issue works well as is, a brighter and more active display can be attained through two minor changes in the power-supply circuit. First, change capacitor C6 from 0.005 µF to 0.004 µF at 1600 VDC. Second, change resistor R1 to 10 ohms at 5 watts, because that display will overheat a 10 ohm 3-watt resistor.

The cabinet

Figure 5 shows the cabinet that houses the power supply and a small fan that is used to provide air circulation. The cabinet is a 9- × 11-inch wood box that was made from scrap wood. The plasma globe display unit sits directly on the box. If you intend to move the display frequently, secure the Corian base to the cabinet using the wood strips as shown in Fig. 4.

FIG. 6—THE FINISHED PLASMA DISPLAY. The streamers that emanate from the central ball will follow your fingers if you move your hand over the globe.

The completed plasma display is shown in Fig. 6. R-E

CARRIER CURRENT

continued from page 61

Alignment

After construction, make sure everything is properly positioned and assembled, and check for poor connections and solder bridges. Also, make sure that the tabs of Q3, Q6, and Q7 are not shorted to the case or to the heat sink. The V_{CC} line should read at least 200 ohms to ground.

Place S1 in the FM position, S2 in LOW, and S3 OFF. Plug in the unit, connect a DC voltmeter to the junction of D1 and D2, and turn on S3—you should read 25 volts DC. If you don't, quickly turn off S3 and correct the problem. If the voltage reading is okay, check for 15 volts across C20. Then turn off S3, connect the voltmeter to test point A, set R22, R23, and R24 to maximum resistance, and set R5 and R9 to their center positions. Connect a 6-volt flashlight bulb to J2, and set the slugs in L2 and L3 half-way into the windings (a plastic TV alignment tool will prevent damage to the slugs). Remove the jumper between J2 and J3 and short J3's center conductor to ground, and then apply power; the voltage at point A should be less than 5 volts. Then adjust R22 (S1 must be in the FM position) for about 8 volts at point A, and check for 12 volts at pin 8 of IC1.

Note: Do not operate this unit with J3 open. Always short J3 to ground when not used during testing, so that F1 will open in the event that C8 should short circuit.

Then make the following checks:

- Collector of Q1: about +8 volts.
- Collector of Q2: 4 to 10 volts.
- Collector of Q3: about 8 volts.
- Collector of Q5: between 0 and 0.5 volts
- Collector of Q4: between 1.0 and 1.5 volts higher than test point A.

If everything checks out, connect a frequency counter to the collector of Q2 and verify that R9 can adjust the frequency from approximately 200 to 350 kHz. Set R9 for 280 kHz—or a period of 3.57 µs on an oscilloscope. Figure 7 shows the various waveforms that are expected at different points in the circuit. Connect an oscilloscope to J2 (across a 10-ohm 2-watt resistor) and adjust L2 and L3 for a maximum output. Next, vary R9 to produce frequencies from 200 to 350 kHz; you should have a nearly constant output level from 220 to 340 kHz.

The 6-volt bulb connected to J2 should glow dimly; it can be used as an output indicator if an oscilloscope is not available. A 10-ohm 2-watt resistor can be used as a dummy load.

Next, place S2 in the NORMAL position and adjust R22 for 30 volts at point A; the lamp should glow brightly. Then set S1 to the AM position and adjust R23 for 14 volts at point A; the lamp should still glow brightly.

Apply a 0.5-volt pp 1-kHz sine wave to J1 and adjust R24 until 100% modulation is obtained (see Fig. 7). The bulb will brighten with modulation. Adjust R23 for the best possible modulation symmetry.

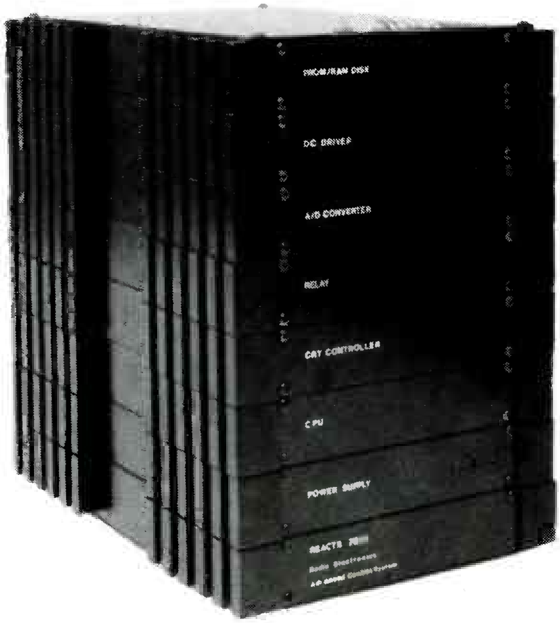
Switch S1 back to FM and re-check the waveforms shown in Fig. 7; adjust R5 if required. Finally, run the transmitter into either the light bulb or the 10-ohm, 2-watt resistor for an hour or so to check for overheating; Q3, Q6, and Q7 should not get too to touch them.

That completes the construction, alignment, and testing of the transmitter. In our next installment, we will show you how to build AM and FM line-carrier receivers. R-E

Build REACTS:

THE RADIO-ELECTRONICS ADVANCED CONTROL SYSTEM

This month we build a battery-backup power supply for the REACTS system.



JIM BYBEE

BATTERY-BACKUP POWER IS REquired when there is no AC power available, in the event of a power failure, or when RAM disks are used in a computer without a magnetic disk for permanent storage. In this article we'll show you how to build a sophisticated battery-backup power-supply module. And, while it is specifically designed for the REACTS system, it can be used with any computer or other project with similar power requirements.

Features

The module can operate from 117-volts AC, 12–15 volts AC, its internal Ni-Cd batteries, or an external 12.6-volts DC. The module automatically charges the 100-milliamp/hour internal Ni-Cd battery pack, and the external 5-amp/hour gel cell, and its circuitry includes two independent chargers for those batteries.

The low-voltage sense circuit, included inside the power-supply, is quite useful when used with the REACTS computer. That circuit lights an LED on the front panel when the voltage at the regulator's input drops to 10 volts or less. The output of that circuit can be used to trigger the system interrupts, such as NMI (*N*on *M*askable *I*nterrupt). In some applications, you might supply the signal to the system BREQ (*B*us *REQ*uest) input which will quickly halt the execution of any program.

The power supply was designed to allow future system expansion without concern for the power-supply output. That is achieved by cutting pins on the power supply in such a way as to only power the modules that are stacked above the power supply.

Three outputs are provided by the module: +5-volts DC at 1 amp, +12-volts DC at 500 mA, and −12-volts DC at 100 mA. The system can actually supply almost double those output currents, but the lower numbers provide a safety margin. By simply substituting larger pass transistors, you can increase the output current to several amps. You should note that each regulator has a bank of current-sense resistors that allows active control of the output current.

Two independent, two-stage charging circuits supply 20 mA for charging the Ni-Cd's and 50 mA for charging the gel cells. (In the low-current mode, approximately 0.2 mA is supplied to the Ni-Cds and 10 mA

Five LED indicators are included in the circuit: One for each of the three voltages (+12, −12, and +5), one to indicate the presence of an external charge voltage, and one to indicate that the batteries are getting low.

Operation

Figure 1 shows the complete schematic for the system. Normally, charging power is supplied by the 14-volt AC, 1.6-amp wall supply. The incoming AC voltage is rectified and filtered before being sent to the rest of the system. Part of the signal is fed to the three switching regulators while the rest is sent to the automatic recharging circuits for the internal Ni-Cd's and the external gel cell.

The circuit contains three independent switching regulators, each one built around a uA78S40 switching-regulator IC. The 5-volt regulator is a step-down circuit. The +12-volt regulator is a step-up circuit that derives its input from the output of the 5-volt regulator. The −12-volt regulator is similar, except for the external PNP transistor which produces the voltage inversion.

The charging circuits operate in a two-step mode. The first step recharges the Ni-Cd's and/or the gel cells at their maximum rate. Once the batteries are charged, the system switches to a low-current trickle charge. That maintains the charge without damaging the batteries. Full charge is detected by operational amplifiers in the uA78S40. The life-time of a standard gel cell when trickle charged is approximately 7–8 years.

To use the supply with other than the normal wall supply, simply connect the AC or DC input to the normal AC-input jack. The system will operate properly with inputs from 12 to 15 volts, AC or DC. If desired, an external battery other than the recommended gel cell may be connected to the gel-cell input. Just be careful to observe polarity when connecting other batteries to that input. Figure 2 shows one of the recommended gel cells, available from the source mentioned at the end of the article.

FIG. 2—ONE OF THE GEL CELLS that can be used with the power-supply module.

BASIC design program

The BASIC program that was used in designing the power supply is available on the RE-BBS (516-293-2283). It is useful if wish to design your own custom power supply, but in any case, you'll find it interesting to see how it's done.

The use of the program is self-explanatory when combined with the data sheet for the uA78S40. Data sheets are available from both Fairchild and Motorola as well as other sources. The program will run on a standard REACTS with a BASIC interpreter or any standard PC BASIC.

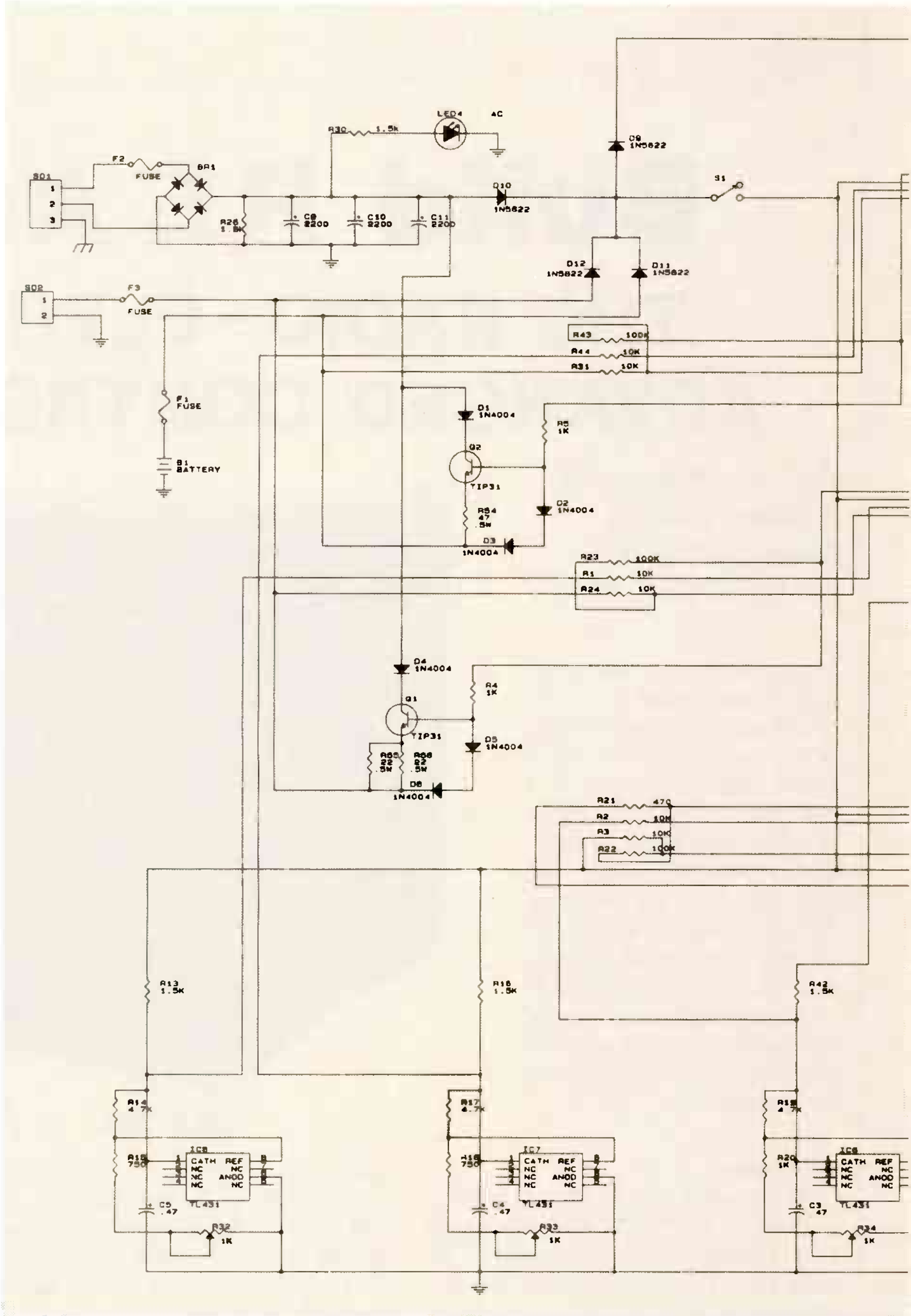


FIG. 1—BATTERY-BACKUP POWER SUPPLY. It will keep your REACTS system up and running in the event of a power failure.

PARTS LIST

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

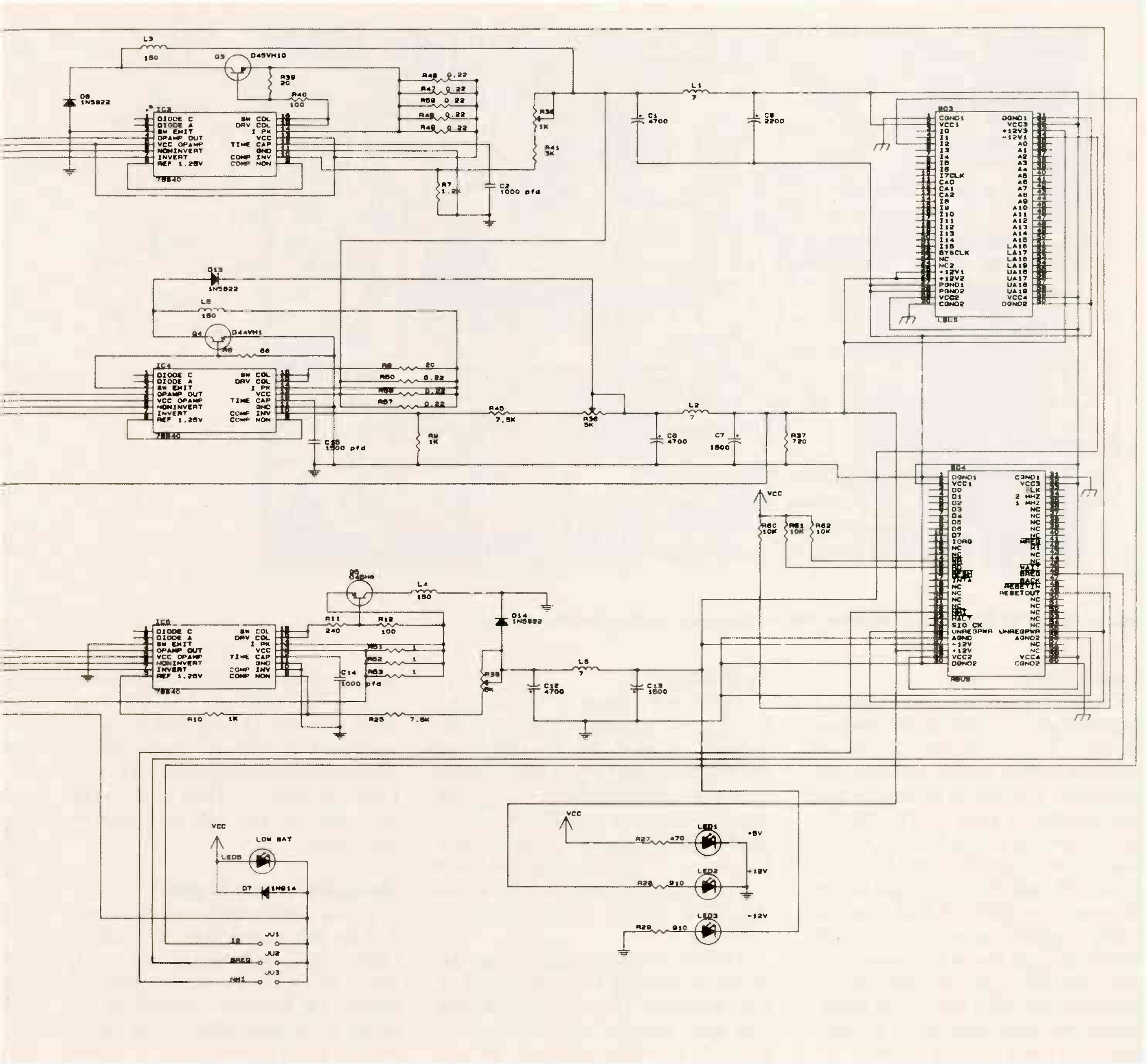
R1–R3, R24, R31, R44, R60–R62—10,000 ohms
R4, R5, R9, R10, R20—1000 ohms
R6—68 ohms
R7—1200 ohms
R8, R39—20 ohms
R11—240 ohms
R12, R40—100 ohms
R13, R16, R30, R42—1500 ohms
R14, R17, R19—4700 ohms
R15, R18—750 ohms
R21, R27—470 ohms
R22, R23, R43—100,000 ohms
R25, R45—7500 ohms
R26—820 ohms, ½ watt
R28, R29—910 ohms
R32–R34, R38—1000 ohms, potentiometer
R35, R36—5000 ohms, potentiometer
R37—720 ohms
R41—3000 ohms
R46–R50, R57–R59—0.22 ohms, 1 watt
R51–R53—1 ohm
R54—47 ohms, ½ watt
R55, R56—22 ohms, ½ watt

Capacitors

C1—4700 µF, 6 volts, electrolytic
C2, C14—1000 pF, 35 volts, ceramic disc
C3–C5—0.47 µF, 35 volts, ceramic disc
C6, C12—4700 µF, 16 volts, electrolytic
C7, C13—1500 µF, 16 volts, electrolytic
C8—2200 µF, 6 volts, electrolytic
C9–C11—2200 µF, 35 volts, electrolytic
C15—1500 pF, 35 volts, ceramic disc

Semiconductors

IC3–IC5—uA78S40 switching



regulator IC
IC6–IC8—precision voltage reference
Q1, Q2—TIP31 NPN transistor
Q3—D45H10 PNP power transistor
Q4—D44VH1 NPN power transistor
Q5—D45H8 PNP power transistor
D1–D6—1N4004 general purpose diode
D7—1N914 switching diode
D8–D14—1N5822 3-amp diode
BR1—3-amp bridge rectifier
LED1–LED5—right angle, PC-mount LED

Other components

L1, L2, L6—7-µH inductor
L3–L5—150-µH inductor
F1–F3—3-amp slow-blow solder-in fuse
S1—right-angle PC-mount SPST rocker switch
SO1—right-angle 3-pin power connector
SO2—right-angle 2-pin power connector
B1—12-volt Ni-Cd battery pack
RBUS, LBUS—60-pin male and female bus connector set
Miscellaneous: PC board, 2-56 × ⅜-inch pan-head screw, 2-56 nut, 2-56 lockwasher

The following items can be ordered from DataBlocks, Inc. PO BOX 579, Glenwood, GA 30428. (800) 652-1336 or in Georgia call (912) 568-7101. PC board: $37.00; A kit of all parts except for batteries and the external wall power supply: $198.00; Wall mounted power supply (10 VAC at 1.6 amps): For prices on other parts, including batteries, please contact DataBlocks, Inc.

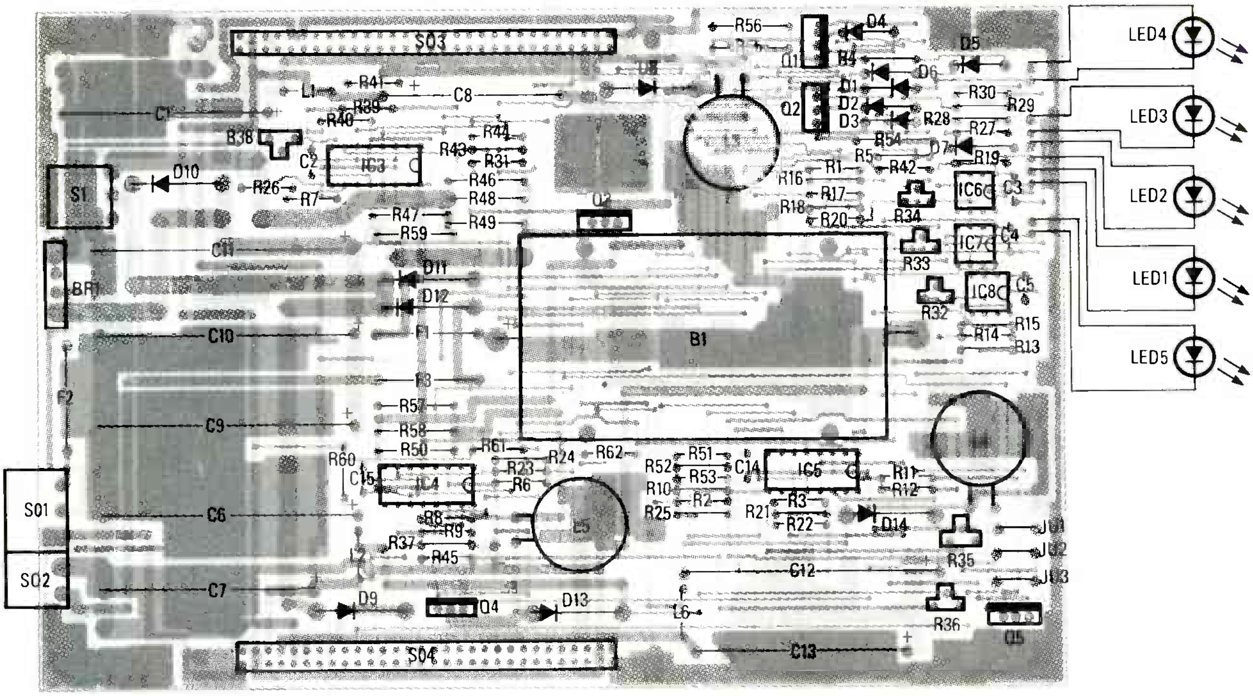


FIG. 3—PARTS PLACEMENT DIAGRAM. Follow this when constructing the PC board.

Construction

Construction of the power supply is quite simple. Just install the parts as shown in Fig. 3, and the Ni-Cd's are soldered to the board. In some applications, it is useful to cut the bottom portion of pins 2, 25, 26, 29, 32–34, and 59 on the left 60-pin bus connector (LBUS), and pins 2, 27–29, 32, and 59 on the right 60-pin bus connector (RBUS). That automatically supplies power to only the boards stacked above the power supply. That way, you use the battery-backup power only for critical items. Remember that once you cut those pins, you can't reconnect them.

Calibration

The 5-volt output is adjusted by turning potentiometer R41 until the voltage at pins 2, 29, 32, and 59 on the left and right system buses equals +5 volts. Resistor R39 is adjusted until the voltage at pins 25, 26, and 33 on the left bus and pin 28 on the right bus equals +12 volts. Adjust R38 for −12 volts at pin 34 on the left bus and that same voltage on pin 27 of the right bus.

The two reference supplies are adjusted by turning R35 until pin 1 of IC8 measures 14 volts, and turning R38 until pin 1 of IC7 measures 14 volts. In a similar manner, the low-power indicator circuit is adjusted by turning R37 until pin 1 of IC6 measures 10 volts. The two reference adjustments should be made with a precision voltmeter capable of at least 1 percent accuracy. Most of the popular 3-digit DVM's will meet that requirement.

Using the power supply

To use your supply, simply connect it to the bottom location on the stack. Connect the wall supply and you're ready to go. The power supply will charge the batteries whether or not power is being supplied to the rest of the REACTS system. **R-E**

IDTV

continued from page 45

mat video programming can be upgraded without resorting to a complete overhaul of the NTSC system was demonstrated by the Mitsubishi Electric Company. Unlike conventional NTSC TV, the Mitsubishi IDTV picture was free of both dot-crawl, and line-crawl (that is normally associated with alternate-scan fields and interlaced TV scanning).

Mitsubishi's IDTV system also eliminates another NTSC artifact that is commonly referred to as cross-color, which is especially obvious in conventional TV sets when the picture contains diagonal lines or edges.

One of the outstanding characteristics of Mitsubishi's IDTV system is its ability to properly reproduce scenes in which there is fast motion. That is accomplished by the use of an 11-megabit memory and microprocessors that vary the action of the signal processing depending on the content of the video signal. For example, in the case of a still picture, field interpolation, or even storage-and-repeat of the identical field to "fill in" between scanning lines cause no problems. However, during fast-motion scenes, it is more appropriate and more effective to use line storage and interpolation, rather than field storage and interpolation.

Unfortunately, the Mitsubishi system—which is a joint effort with Hitachi—is still in its experimental stage. At the moment, as shown in Fig. 3, their prototype hardware fills a cabinet that is considerably larger

continued on page 76

COMPOUND OP-AMPS

Standard op-amp circuits can easily be modified for applications requiring very high slew rates, high output currents, or output swings up to hundreds of volts! Here's how.

RAY MARSTON

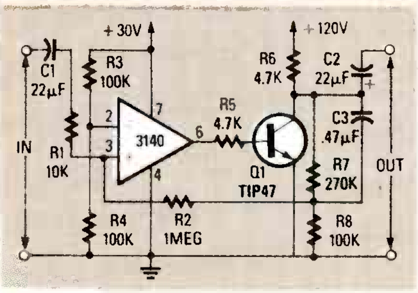


FIG. 1—A COMPOUND OP-AMP with boosted output current can typically source output currents up 50 mA.

THE PERFORMANCE OF A STANDARD OP-amp can be greatly enhanced or modified by connecting one or more bipolar transistors to its output-feedback loop, to make a "compound" or hybrid op-amp. Compound op-amps are inexpensive and quite easy to design. They are specifically intended to have output characteristics that are not economically available from conventional op-amps.

The output current of an inexpensive op-amp, such as the CA3140, is limited to only a few milliamps, but can be boosted to several amps by compounding it with a couple of common-collector transistors. Also, the output voltage can only swing to within a few volts of the supply voltage—thus it is limited to a maximum swing of about 32 volts, and its slew rate is limited to about 9 volts/μs. However, when the output of the 3140 is compounded with a single common-emitter transistor, it can have a swing of up to several hundred volts, and the slew rate is increased to about 100 volts/μs.

With the possible hundreds of op-amp/transistor combinations, the subject of compound op-amps is fairly large. Therefore, for the sake of simplicity, we'll stick to compound designs intended for use in single-ended supply applications using the 3140 op-amp. However, the principles that we are going to explain are easy to adapt for use with other types of op-amps and different power-supply configurations.

High-current circuits

One of the best applications for the compound op-amp is as a boosted-current voltage follower. If a 3140 op-amp were to be wired as a standard DC voltage follower with a single-ended supply, its output current would be limited to only a few mA. That shortcoming can be overcome by compounding the op-amp with a common-collector transistor, as shown in Fig. 1. Note that because Q1's base-emitter junction is wired into the negative-feedback loop of the op-amp, and that there is no phase inversion between Q1's base and emitter, the output of the circuit follows the input signal. The output current is limited to about 50 mA by the power rating of Q1.

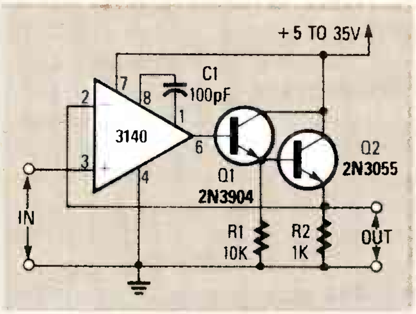


FIG. 2—THIS IMPROVED VERSION of the voltage follower can source output currents up to 1 amp.

The available output current for the circuit in Fig. 1 can be boosted to an amp or so by replacing Q1 with a Darlington pair of transistors, as shown in Fig. 2 (Q2 is a high-power device). The base-emitter junctions of the transistors are again wired into the feedback loop of the circuit.

The circuits in Figs. 1 and 2 provide unidirectional current boosting, which means that they can source high currents but can sink only relatively low ones. They are therefore not suitable for use with low-impedance AC-coupled loads. That problem is solved by using a complementary emitter-follower as the "compounding" device, as shown in Fig. 3. Diodes D1 and D2 provide offset biasing for the two output transistors, which can supply output currents of up to 50 mA each.

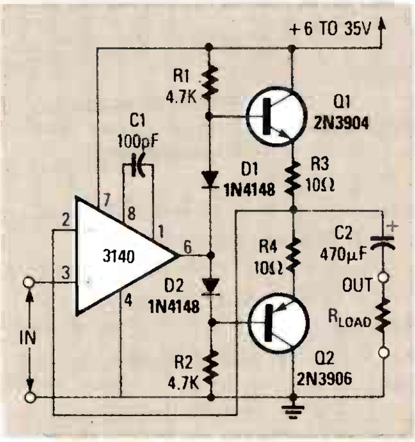


FIG. 3—A COMPOUND OP-AMP with boosted bidirectional output current can both source and sink up to 50 mA.

Voltage followers

Figure 4 shows the circuit of a compound voltage follower or unity-gain non-inverting amplifier, in which a common-emitter transistor (Q1) is wired to the op-amp's output and the collector of Q1 is wired into the negative-feedback loop of the circuit. Because an additional inverting stage (Q1) has been added to the op-amp, the input terminal notations of the 3140 must be mentally transposed to understand the circuit's operation. Therefore, the input signal is applied to the terminal marked *inverting* (pin 2), which now acts as the non-inverting terminal, and the feedback connection from the output (Q1's collector) goes to the terminal marked

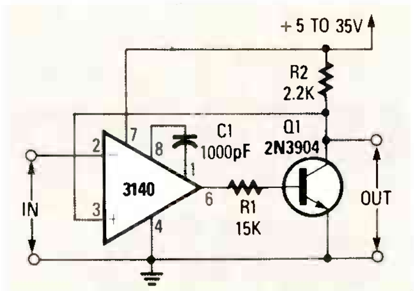


FIG. 4—A BASIC COMPOUND-FOLLOWER circuit has an improved slew rate that is about ten times faster than a non-compound follower.

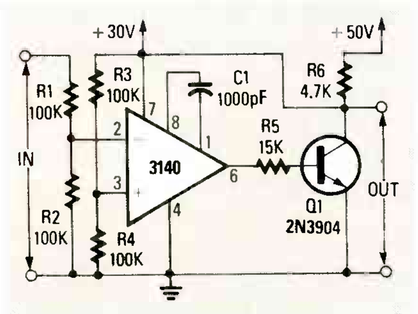


FIG. 5—BY USING SEPARATE power supplies, this version of the circuit can follow input signals up to 50 volts peak.

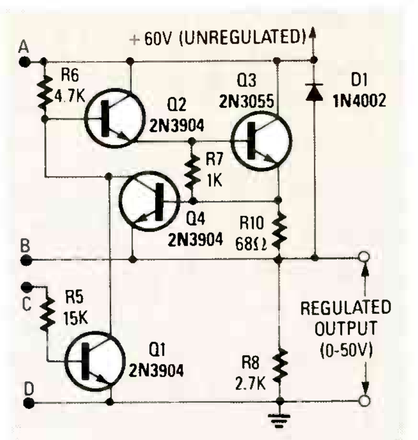


FIG. 7—A MODIFIED OUTPUT stage provides 1-amp current limiting to the circuit in Fig. 6.

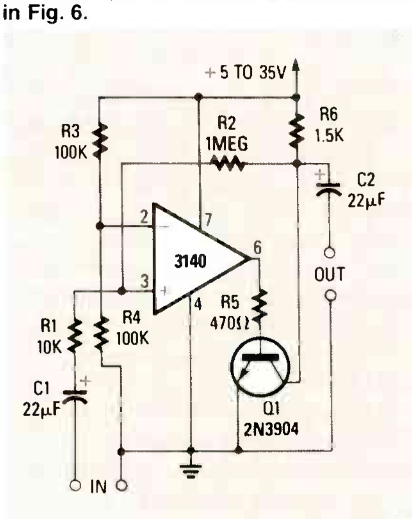


FIG. 8—A ×100 INVERTING compound amplifier has a full-power bandwidth of several hundred kHz. Its output can swing to within 50 mV of both the positive supply and ground.

non-inverting (pin 3), which now acts as the inverting terminal.

When the input to the circuit in Fig. 4 is at zero volts, the 3140 turns Q1 on, which pulls its collector into saturation (typically within 50 mV of zero volts). When the input is above zero but a couple of volts below the supply voltage, the 3140 forces Q1's collector to take on a voltage identical to the input signal. The follower characteristics of the circuit in Fig. 4 are identical to those of a basic 3140, except that it can't quite follow input signals down to zero volts. However, the signals appearing at Q1's collector are amplified and phase-inverted versions of those appearing at the output of the 3140, so the slew rate of the compound follower is typically ten times faster (100 V/μs) than a basic 3140 op-amp. Care must be taken in the layout though, because that high slew rate can cause instability. That problem can be compensated for by increasing C1 from 100 pF to 1000 pF as shown.

The circuit in Fig. 5 has been given a gain of 2 via R3/R4, and the input signal is attenuated by a factor of two via R1/R2, so the circuit is still a unity-gain voltage follower (overall). Also, the 3140 is powered from a 30-volt supply and Q1 is powered from a 50-volt supply. Therefore, it can accurately follow input signals with peak values of up to 50 volts, and can follow them to within 50 mV of both the supply voltage and ground, and also has a high slew rate. That circuit is therefore greatly superior to a basic 3140.

Figure 6 shows how to make a 0–50 volt, 1-amp, regulated DC supply. In that case, the output of Q1 is buffered via Darlington emitter-follower, Q2/Q3, which can supply output currents of an amp or so. Also, the feedback loop for the 3140 is taken from Q3's emitter, rather than from Q1's collector. Q1–Q3 are powered from an unregulated 60-volt supply, and the 3140 is powered from a Zener-regulated 33-volt supply. The compound op-amp is configured as a ×2 non-inverting amplifier, with its input derived from the center tap of R9, whose potential can be varied from 0 to 25 volts. The regulated output of the circuit is fully variable from 0 to 50 volts via R9, and output currents of up to an amp or so are available.

Finally, Fig. 7 shows how the output stage of the circuit in Fig. 6 can be modified to provide 1-amp overload protection (current limiting). Points A, B, C, and D in Fig. 7 connect to the corresponding points in Fig. 6. When the circuit's output current exceeds 1 amp, the resulting voltage drop across R10 turns Q4 on, which in turn "steals" the base current from Q2, thereby limiting the output current. Note that the feedback connection to R3 is taken from the R8/R10 junction.

Inverting amplifiers

Figure 8 is a compound inverting amplifier, with a gain of 100 set by the R1/R2 ratio. The output of the op-amp is biased at half of the supply voltage (for a maximum undistorted output swing) via voltage-divider R3/R4. The output swing of the compound circuit is limited by Q1 rather than by the 3140 op-amp itself. Therefore, the output of the compound circuit can swing to within 50 mV of both ground

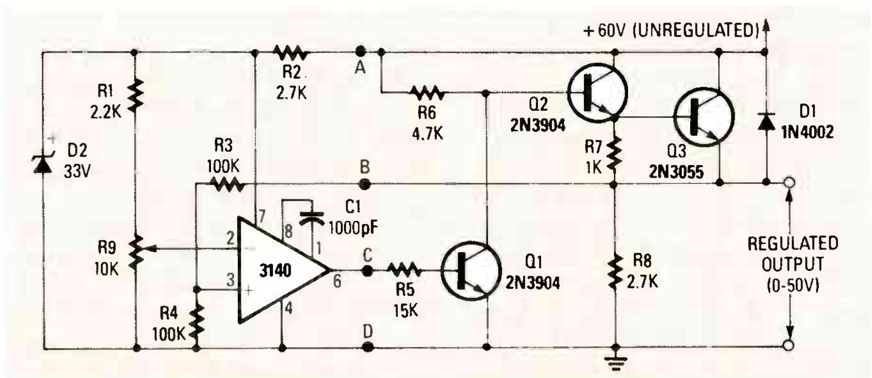


FIG. 6—A COMPOUND OP-AMP can be used to make a 0–50 volt, 1-amp, regulated DC supply.

and the positive supply before clipping starts to occur. (The output signals of a basic 3140 amplifier can only swing within a few tens of mV of ground and within a few volts of the positive supply.) The slew rate and full-power bandwidth of the circuit in Fig. 8 is about ten times higher than in a basic 3140-amplifier circuit. All things considered, the compound-amplifier circuit is quite superior to the basic 3140. Because of its high slew rate, the compound circuit tends to become unstable if the input signal is disconnected or has a source impedance greater than about 2.2K.

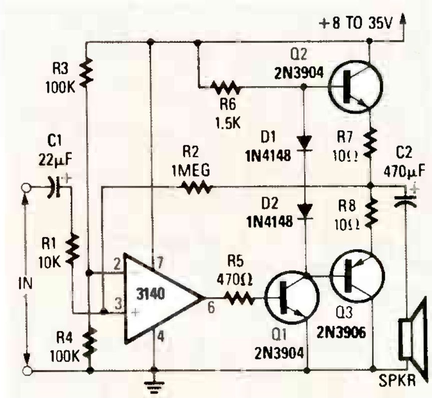


FIG. 9—A COMPOUND CIRCUIT with ×100 voltage gain using hi-fi output components is well suited for use in audio applications.

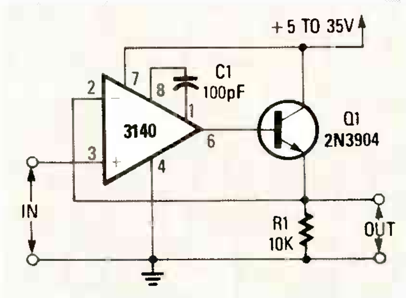


FIG. 10—THIS COMPOUND ×100 inverting amplifier can provide an output of 120 volts peak to peak.

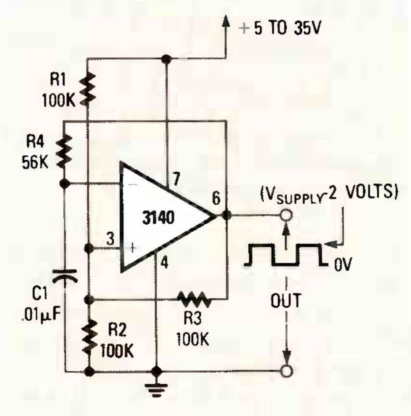


FIG. 11—THIS RELAXATION OSCILLATOR has a period is 6 ms, a rise time 12 µs, and a fall time of 7 µs.

The available output current of the circuit in Fig. 8 is limited to a few tens of mA by R6, but can easily be increased by adding a power-amplifier stage to Q1 and incorporating it in the amplifier's feedback loop, as shown in Fig. 9. In practice, the simple amplifier consisting of D1, D2, Q2, Q3, R7, and R8 can be replaced by any standard hi-fi output components, making the circuit suitable for use in audio power-amplifier systems.

The maximum output swing of the circuits in Figs. 8 and 9 is restricted (by the supply voltage limitations of the 3140 op-amp) to 35 volts. Figure 10 shows how the output swing can be increased to 120 volts (or any other desired value) by powering the 3140 from a 30-volt supply and powering Q1 from a 120-volt supply.

Some thought must be given to the biasing of the circuit in Fig. 10, because the 3140 must be biased (for maximum output swing) to half of its 30-volt supply, while Q1 must be biased to half of its 120-volt supply. That is achieved by biasing pin 2 of the 3140 to 15 volts via R3/R4 and by using a 4:1 voltage divider (R7/R8) between the output of Q1 and the input to the feedback resistor R2. That way, 15 volts appears on pin 3 of the 3140 when Q1's collector is at a quiescent (half-supply) value of 60 volts. Note that R7 is decoupled by C3, so that the R7/R8 divider has no significant effect on the AC voltage gain (determined by R1/R2).

Relaxation oscillators

Figure 11 shows a relaxation oscillator or square-wave generator for use with a single-ended supply. The circuit operates as follows: The output of the circuit is a rectangular waveform which, at any given moment, is either at zero volts or at a positive value that is typically three volts below the supply voltage. Suppose that the output has just switched high. R3 is then effectively switched in parallel with R1. Therefore, approximately two-thirds of the supply voltage is applied to pin 3, and C1 charges towards the supply-voltage value (via R4) until it reaches the pin-3 voltage. The op-amp's output then starts to switch low, at which point a regenerative switching action is initiated, and the op-amp's output abruptly switches to zero volts. R3 is then effectively switched in parallel with R2, so only

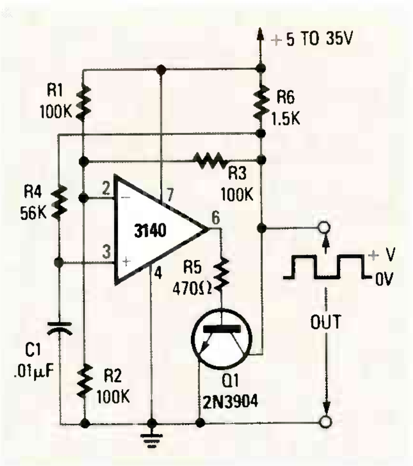


FIG. 12—A COMPOUND VERSION of the relaxation oscillator has a period of 6 ms, a rise time of 1 µs, and a fall time of 0.7 µs.

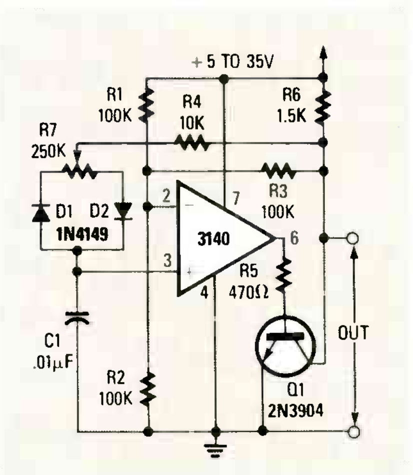


FIG. 13—THE DUTY-CYCLE RATIO of this fixed-frequency compound oscillator is variable from 25:1 to 1:25.

one-third of the supply voltage is applied to pin 3. C1 then starts to discharge towards zero (via R4) until C1's voltage reaches the new pin-3 value and another regenerative switching cycle is initiated and the output abruptly switches high again. The process then repeats over and over again.

The circuit in Fig. 11 generates a rectangular waveform with a period that is determined by the values of R3, R4, and C1, and it is *almost* independent of the supply-voltage value. With the component values shown, the circuit has a period of about 6 ms, but can be increased (or reduced) by increasing (or reducing) the values of C1 and/or R4. R4 can have any value from 10K to 10 megohms, and C1 can have any value from 33 pF to 1000 µF. The circuit is quite useful, although it suffers from a number of defects. First of all, since the output does not

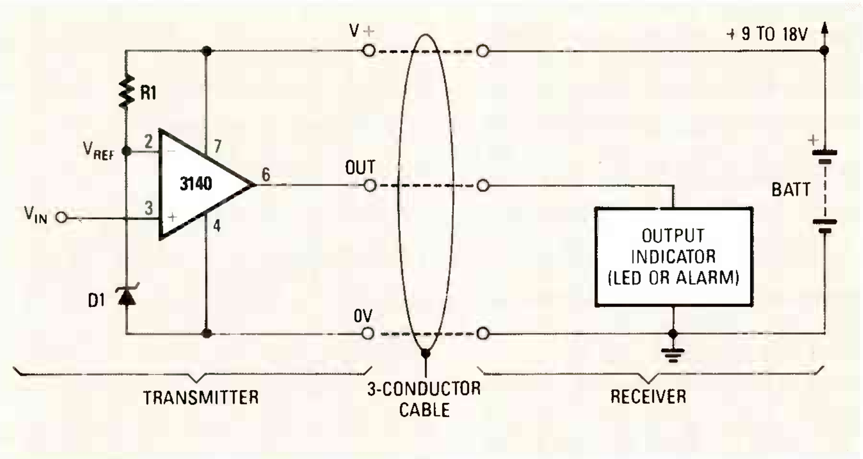


FIG. 14—A CONVENTIONAL OP-AMP comparator requires 3 wires to connect the two halves of the circuit together.

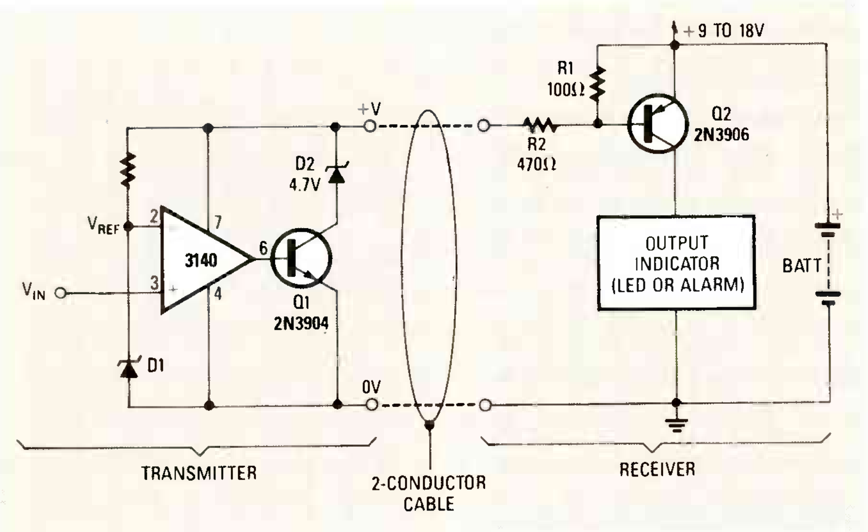


FIG. 15—THIS COMPOUND COMPARATOR requires only 2 wires to send information from one half of the circuit to the other.

switch to the full supply voltage when in the "high" state, the output waveform is not quite symmetrical, and also the period and symmetry vary slightly with the supply-voltage value. Also, the rise and fall times of the output waveform are restricted by the characteristics of the op-amp; when used with a 15-volt supply and a 50-pF load, the output takes 12 μs to rise up to 12 volts, and 7 μs to fall back down to zero volts.

Figure 12 shows a compound version of the circuit in Fig. 11, in which all the defects mentioned have been done away with. The output waveform is perfectly symmetrical, switches fully between the supply voltage and ground, has a period that is totally independent of the supply-voltage value, and has rise and fall times of 1 μs and 0.7 μs respectively.

The circuit in Fig. 12 can be modified (as shown in Fig. 13) so that it generates a fixed-frequency rectangular waveform in which the duty-cycle ratio is fully variable from 25:1 to 1:25 via R7. The circuit operates similarly to that in Fig. 12, except that on high-output portion of the cycle, C1 charges via R4/D2 and the right half of R7, and on the low-output portion of the cycle, C1 discharges via R4/D1 and the left half of R7.

2-wire detectors

To help understand what a 2-wire detector is, compare the circuits in Figs. 14 and 15. Figure 14 shows the circuit of a conventional op-amp voltage comparator. The op-amp's output is normally low, but it switches high when V_{IN} rises above V_{REF}. An LED, a buzzer, or any other type of signaling device is connected to the op-amp's output, to indicate the relative state of V_{IN}. In many applications, the power supply and output-state indicator (known as the receiver) and the actual op-amp and its associated circuitry (known as the transmitter) are located far apart from each other. Figure 14 requires three interconnecting wires; but because it uses a compound comparator, the circuit in Fig. 15 only requires two wires. In

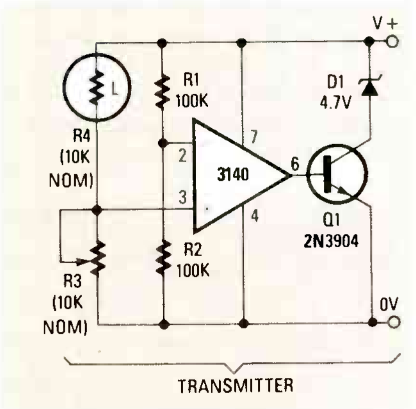


FIG. 16—THIS LIGHT-SENSITIVE circuit can easily be modified to operate as an over-temperature monitor.

either case, a length of cable (indicated in Figs. 14 and 15 by the dotted lines) is needed to connect the two halves (transmitter and receiver) of the circuit together. The cost of the 3-wire interconnecting cable alone may exceed the total cost of all the electronic circuitry, so clearly, the two-wire system is more economical.

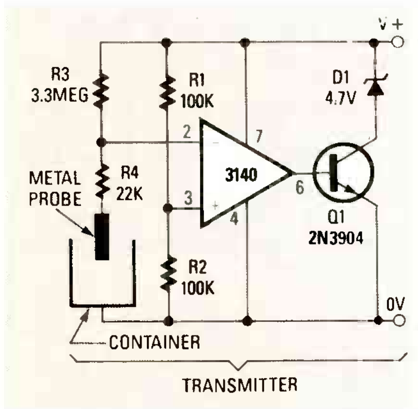


FIG. 17—THIS LIQUID-LEVEL monitor has a high output when the liquid in the container rises above a pre-set level.

The compound-comparator circuit in Fig. 15 operates as follows: When V_{IN} is below V_{REF}, the output of the 3140 is at zero volts, so Q1 is off. In that state the op-amp circuit only consumes about 2 or 3 mA, and the voltage drop across R1 is not enough to turn Q2 on. When V_{IN} is above V_{REF}, however, the output of the 3140

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IDTV

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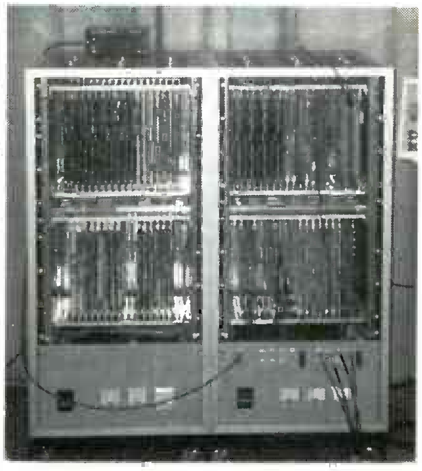

FIG. 3—ALTHOUGH MITSUBISHI'S IDTV SYSTEM presently requires two relatively large cabinets, it can be reduced to the handful of LSI chips shown by the technician.

than the cubic volume occupied by the two 35-inch TV sets Mitsubishi uses for demonstrations. Although Mitsubishi's engineers claim that all of the signal-processing circuitry could be provided by seven LSI IC's that could be held in the palm of one hand, it would most likely increase the price of a TV set 20–25%, and Mitsubishi's management seems hesitant to make the substantial investment needed to turn those two cabinets full of circuitry into the required LSI's. The reason for their hesitation is the lengthening shadow of HDTV. With so many HDTV systems being considered, and with the subject of high-definition TV getting increased coverage in the general media, Mitsubishi is fearful that the huge investment in their IDTV system might not be able to be fully amortized if, indeed, HDTV is suddenly standardized and people begin to discard their NTSC sets (IDTV augmented, or not) in favor of HDTV receivers.

In a future article we will discuss the technology of some of the current proposals for HDTV, some of which are fully compatible with present-day sets, while others are backwards compatible—meaning that the HDTV transmissions could be received on older sets, albeit in the old 4:3 aspect ratio and without the improvement in definition. **R-E**

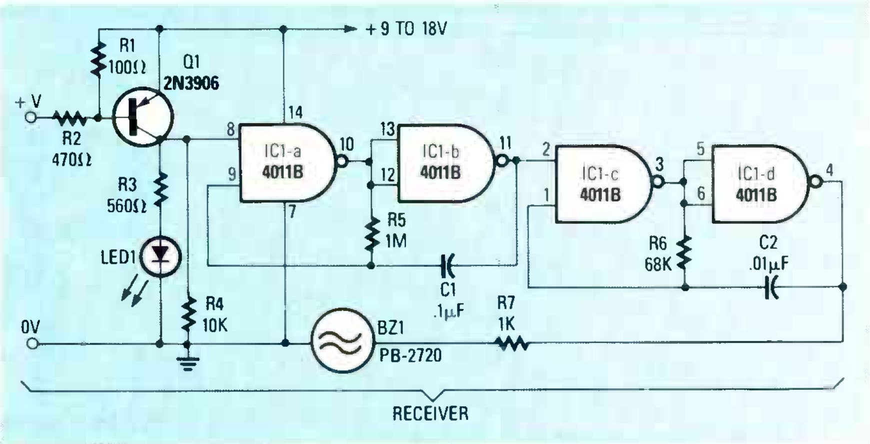

FIG. 18—AN AUDIO-VISUAL output indicator that turns on an LED and sounds a buzzer can be connected directly to any one of the circuits in Figs. 15 to 18.

switches high turning Q1 on. At that point, the circuit draws enough current to activate D2, which pulls the 3140's supply voltage down to 4.7 volts. The supply current then rises to between 8 and 25 mA (depending on Q2's supply-voltage value), and the resulting drop across R1 turns Q2 on, which activates the output indicator. It can now be seen how the positive supply line of the 2-wire system also carries the "state" information. Note that, in order for the circuit to operate properly, the minimum supply voltage must be at least 2 volts greater than V_{REF}.

In most applications for the type of circuit in Fig. 15, a half-supply reference voltage is applied to one input of the comparator, and a variable voltage is applied to the other input. That variable input is usually obtained from a Wheatstone-bridge network in which one of the elements is a resistive transducer that is sensitive to light, heat, pressure, etc. Because the variable input is bridge-derived, the "trigger point" of the circuit is independent of the supply-voltage value and is determined only by the resistance ratio of the input bridge.

In figures 16 and 17, only the transmitter portion of the circuit is shown. That is because all of the circuits can use the receiver in Fig. 15.

Figure 16 is a light-sensitive transmitter circuit in which a cadmium-sulphide photocell or *L*ight-*S*ensitive *R*esistor (LSR) is used as the sensing element. The potentiometer (R3) and the LSR (R4) should have nominal values of at least 10K. In Fig. 16, the LSR is wired above R3. Consequently, the voltage at pin 3 rises as the light intensity increases and the LSR's resistance falls; that circuit can be referred to as a light-sensitive transmitter. If the LSR were to be wired below R3, the voltage at pin 3 would rise as the light intensity decreases and the LSR's resistance would increase; the circuit would then be referred to as a dark-sensitive transmitter. In both configurations, the light level at which the circuits become active can be preset via R3.

The circuit in Figure 16 can easily be modified to be sensitive to temperature rather than light. By replacing the light-sensitive resistor with a *N*egative-*T*emperature-*C*oefficient (NTC) thermistor (nominal value 10K), the first configuration would become an over-temperature transmitter, and the second configuration would become an under-temperature transmitter. Of course, the temperature at which the circuits would become active could be preset via R3.

Figure 17 shows a circuit that has a high output when the level of a liquid exceeds a pre-set level. When the liquid level is below the probe's tip, pin 2 of the op-amp is pulled above pin 3, and the op-amp's output is low. When the liquid reaches the probe, the liquid's resistance pulls pin 2 below pin 3 and the op-amp's output switches high. With R3's value as shown, the liquid's resistance between the probe and the container must be less than 3.3 megohms for correct operation.

Finally, Fig. 18 is an audio-visual output indicator that can be used with any of the circuits that are in Figs. 15–17. When a high output is detected from the transmitter, transistor Q1 turns on and its collector is pulled high, simultaneously driving LED1 on via R3 and activating IC1, which produces a pulsed tone in the buzzer BZ1. **R-E**

AUDIO UPDATE

Amplifier damping factor: How important is it?

LARRY KLEIN,
AUDIO EDITOR

THE MAIN TOPIC THIS MONTH CONcerns audio-damping factors. But before we get into that, let's finish our discussion from last month. I had said that many audio professionals work with unusually high audio levels when monitoring mixes. My explanation for that was hearing loss, and an AES survey examines that possibility.

More than two hundred members of the AES participated in an audiometric survey at a 1986 meeting in Los Angeles. The object was to determine what degrees of hearing loss—if any—were experienced by those engaged in the recording professions. It has long been known that prolonged exposure to high-intensity sound causes hearing loss. In fact, Occupational Safety and Health Administration (OSHA) regulations limit workers' noise exposure to no more than 90-dB average during an 8-hour workday.

The elevation of hearing thresholds (which is a technical way of stating that sounds have to be louder before they are audible) usually first occur in the 3,000- to 6,000-Hz range. That is true regardless of the spectral content of the impinging sound. There are two main reasons for that: The 3- to 6-kHz range is handled by the first hair-cell transducers encountered in the inner ear, and the external ear canal acts as an acoustic resonator in the same general range. Those two factors are also responsible for the normal ear's increased sensitivity in the 4-kHz area.

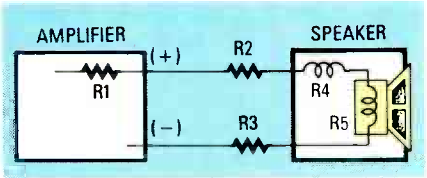

FIG. 1

In any case, the audiometric survey revealed a small, but consistent hearing loss among those tested that cannot be attributed to the normal aging process. Although the loss averaged less than 15 dB after age correction, a wide variation in hearing thresholds was measured, particularly in the 3- to 6-kHz range. More than 10 percent of those tested had significant hearing loss at 4 kHz.

It's long been known that, for unknown reasons, some individuals are far more susceptible to sound-induced hearing damage than others. The 10 percent of those tested—particularly the younger subjects—who had a significant 4-kHz notch in their hearing should be aware that such a loss can be an early warning of greater trouble to come. The only way to avoid further loss (and over a wider frequency range) is to take precautions when exposed to loud noise or music.

It seems to me that anyone professionally involved in audio would want to safeguard the vital tools of his trade (his ears) with an annual hearing test that pays particular attention to the 4-kHz area. There's an unfortunate paradox at work here; for many of us, prolonged critical listening at high sonic levels will ultimately disqualify us as critical listeners. Be warned: Unlike diamonds, golden ears are *not* forever!

Damping factors

There is an audio-amplifier specification that manufacturers always feature in their product sheets, that magazine test labs always report on, and that hi-fi buyers are nearly always totally confused about—it is known as the *D*amping *F*actor, or DF. During the late 1950's or early 1960's, there was a brief period when a few amplifiers appeared that had rear-panel variable damping controls. Those controls purported to allow the adjustment of the amplifier's output impedance to the specific requirements of the speaker that was being used with it.

I was doing hi-fi service work at the time, and the way I handled problems with the variable damping control—which were frequent—was to disconnect it. To my ears, varying the control had no audible effect until you hit a setting that caused the amplifier to oscillate—and *that* I heard. After one selling season the manufacturers wisely decided that DF controls caused more problems than they cured, and they haven't been found in amplifiers since.

Measuring DF

The damping-factor number that appears on amplifier specifications sheets expresses the ratio of the load at the amplifier's output terminals (the speaker) to the amplifier's internal output impedance. (An amplifier's output impedance is practically never specified, and has nothing to do with matching speaker impedance.) For example, with the *E*lectronic *I*ndustries *A*ssociation (EIA) standard 8-ohm reference load as specified in RS-490, an amplifier with an output impedance of, say, 0.08 ohm would have a DF of 100. A 0.04-ohm output impedance would yield a DF of 200, and so forth. Damping factors have ranged from a low of under 20 to a high of about 1,000.

The EIA Amplifier Standard includes a Wideband-Damping-Factor rating that calls for a listing of an amplifier's lowest DF value within the audio range, but I've never seen it listed on any specifications sheet in that way. The point of the rating is that some amplifiers have a high midrange DF that falls to a very low value at low frequencies. That is a possible problem faced mostly by tube amplifiers whose output transformers make it difficult to maintain a very low-source impedance at low frequencies. Unless information to the contrary is given, you can assume that an amplifier's specified DF was measured at a midrange frequency with a standard 8-ohm load.

Damping is usually assumed to be a good thing, implying tight control of high- and low-frequency speaker-cone motion in much the same way that a car's shock absorbers damp its tendency to bounce after hitting a pothole. And it would also seem to follow that the higher the DF, the better. A DF of 100 is assumed to be better than 10, and 1,000 is better than 100. However, the truth of the matter is not so simple. Let's take a closer look at the electrical and mechanical aspects of damping.

A speaker cone and voice-coil assembly have three separate damping elements acting on them: mechanical, acoustical, and electromagnetic. The mechanical damping element is easy to understand; it results from internal frictions in the cone's suspension. Acoustic damping is produced by the loading effects of the air on both sides of the speaker cone.

Electromagnetic damping

You can demonstrate the effect of electromagnetic damping for yourself with any unhoused 10- or 12-inch speaker. Gently push on the speaker cone and it will move readily with a slight springy quality provided by its suspension. Now short out the speaker terminals with a clip lead or a length of wire. You'll notice that there is an entirely different feel to the cone movement, almost as though the voice-coil gap was filled with molasses. Shorting the speaker terminals increases the electromagnetic resistance to movement. The damping factor of an amplifier is supposed to affect voice-coil movement in the same way, except that it does not in any way impede voice-coil movement in response to an amplifier signal.

Up to now, the virtues of high DF may seem self evident, but unfortunately the situation changes when dealing with real-world speaker systems in normal operation. The beneficial effect of a high amplifier DF can occur only if there's little or no resistance in the circuit loop that starts and ends at the output terminals of the amplifier. In real life we have the sum of the series resistances that are shown in Fig. 1, where R1 is the amplifier's internal impedance, R2 and R3 is the resistance of the speaker cable, R4 is the crossover inductor, and R5 is the voice coil.

There is perhaps, 0.05 ohms in each of the two conductors of the cable going to the speaker system, 0.5 ohms in the crossover inductor in series with the woofer, and another 5 ohms or so in the woofer voice coil. And we should not forget the 0.008 ohms at the speaker terminals of our amplifier with the DF of 1,000. That means that the woofer within the speaker system sees a total 5.608 ohms—a far cry from the promised 0.008! That translates into a real-world damping factor of 1.42! If our amplifier had a "low" DF of 20 rather than 1,000, the effective DF at the speaker voice coil would be 1.33—not a great deal of difference.

Practical tests

More than 10 years ago Dr. Floyd Toole of the National Research Council of Canada ran a series of tests with an amplifier that was modified so as to be able to switch its damping factor from 9.5 to 200. He used the amplifier in various DF settings with a variety of speakers. Some of the speakers were deliberately chosen for their resonant, undamped qualities; others were among the best available at the time. The speakers were subjected to a series of tone-burst and frequency-response tests with a variety of damping factor settings. In no case was there a significant change, for better or worse, in performance.

Dr. Toole's test did not pretend to be totally comprehensive, covering all possible types of speaker systems, but it certainly indicates that high or low damping factors don't do much to alter the performance of today's conventional speakers. Speaker designers are well aware of that fact and they don't rely on amplifier DF's to enhance the performance of their products.

If an extra-high damping factor is of no consequence in respect to controlling or enhancing speaker sound, then why have so many manufacturers gone out of their way to achieve it? Well, they really haven't—gone out of their way, that is. Heavy feedback is used in most output circuits to stabilize and enhance performance. That feedback also causes a lowering of the amplifier's output impedance, which means a high DF. **R-E**

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DRAWING BOARD

"Custom" EPROM decoders

ROBERT GROSSBLATT,
CIRCUITS EDITOR

NO MATTER HOW MANY WAYS YOU look at a circuit problem, there's always a couple of ways of getting around it. The brain damage you go through to find a solution usually disappears soon after the problem's solved but it's nice to have a way to avoid the whole thing from the beginning.

Now don't get me wrong. I'm not going to show you how to avoid all design problems altogether—I'm still waiting for someone to show *me* how to do that—but what we're going to start talking about now can go a long way to making bench time a lot easier on the brain.

If you look through a catalog of digital IC's, one of the things you should notice is that there are an awful lot of numbers reserved for things like decoders, demultiplexers, and selectors. That makes perfect sense, because circuits with any degree of complexity spend a lot of time decoding, demultiplexing, and selecting. All IC manufacturers are, if nothing else, responsive to the market.

Once you've got some bench time under your belt, however, you begin to understand why there are so many of those parts available. The more complex the circuit, the more complex the decoding problems that are likely to arise. Computer circuits, for instance, routinely have to work out ways to decode one unique address from as many as thirty two address lines. That's an extreme example but it's common to be faced with the need to deal with 16 address lines—that's what most eight-bit computers have.

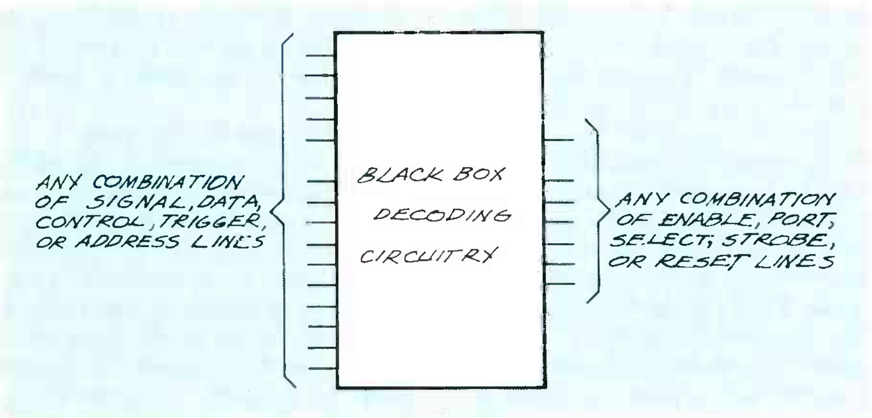

FIG. 1

Problems like that are often real brain benders and the solutions can be a real pain in the something else. They up the parts count and the circuit complexity—sometimes to the point where the cost of PC boards makes the whole product economically impossible.

So what we're going to start talking about here is a way that you can do the same job but cut down the complications. As a matter of fact, any time you find yourself with a circuit that's composed of an inordinate number of gates watching a few common busses, this may be just the thing you're looking for.

The basic job of any decoding circuitry is shown in Fig. 1. A lot of lines go into a magic decoding box with outputs that become active when certain input combinations are met. If you pop the lid off the box, there's no telling what you'll see, because the exact contents are going to depend on the particular characteristics of the circuit being decoded or driven and, ultimately, the skill and imagination of the person who designed it. In most cases, it will be filled with TTL or CMOS parts that manage to get the job done, but also gobble up lots of power, cause timing problems, and if nothing else, helped send the designer to an early grave. All of those are good things to avoid...remember Grossblatt's eighty-seventh law: Keep it simple.

Complex circuits are acceptable, (almost inevitable), for the first solution where the main interest is just putting together something that works; but final engineering solutions have to be neater, and less complex, to be economically feasible.

Most modern circuits that have to deal with decoding problems do away with the mass of decoders found on older boards and replace them with ROM's. You'd be surprised to see how much of a dent even a small ROM will make in the silicon real estate developed to handle multiple-line decoding.

The sure way to tell that that has become a very common technique in circuit designs is that the ROM's used that way have been given names like *mapping ROM's* or, if you want to get really high tech about it, "state machines." Whatever you want to call them, they can save a lot of work and it's worth our time to look at them.

Any permanent memory can be used as a decoding ROM (there's another name for you) as long as it meets the needs of the circuit in terms of power, size, and speed. Let's take those one at a time.

Power requirements can be a major circuit consideration. If you're designing a CMOS circuit and going out of your way to put it together so that it will run on changes in barometric pressure, it would be very silly to use a ROM that's going to draw more power than the rest of the circuit.

Unless, of course, you lived someplace where the weather was very unpredictable.

Modern CMOS technology has produced a number of ROM's (including a wide range of EPROM's) that draw the typically CMOS minimal amount of power and, if that's still too much, there are circuit techniques that can cut down the draw even further. We'll get into that later on when we actually start building stuff.

The more decoding you have to do, the bigger the ROM you're going to need. Unfortunately, off-the-shelf ROM's don't come in the same variety of sizes as off-the-shelf clothing. It's a fact of electronics life that lots of space is usually wasted in mapping ROM's. That, by the way, is what our current contest is all about. (I built a binary to 7-segment decoder using a 2716 EPROM. What can I do with the extra space in the EPROM?) The contest details were spelled out at the end of last month's column.

Small decoding jobs can be handled with a bipolar PROM; that is a solution that shows up in a lot of circuits becuase bipolar PROM's are fast, *really* fast—usually less than 20-nanosecond access time. The problem with those parts is that they're not as convenient to program as EPROM's. It's not particularly difficult to burn a bipolar PROM but they're not popular for development work, as there's no going back once you burn them. Any mistake means that you need another PROM because blowing a bit is done by actually burning a small nichrome fuse.

For most applications, the best all-around choice for a mapping PROM is an EPROM. They're not the fastest or low-powered but they're cheap and reprogrammable; and there are a host of available, inexpensive EPROM burners on the market. They are either stand-alone units or computer peripherals. You'll find both kinds available from several advertisers in the back of **Radio-Electronics** magazine. If you don't have one yet, you should look into getting an EPROM burner, as it is an incredibly useful addition to anyone's bench.

Next month we'll work out some of the design problems, and then design a custom character generator for an LED display using an EPROM. **R-E**

Communications Corner

HERB FRIEDMAN,
COMMUNICATIONS EDITOR

Tunable preselectors

A FAMOUS PHILOSOPHER—ACTUALLY not so famous because I can't recall his name—claimed that there could be no progress without memory. If you think about it for a moment you'll see he was correct. It's the reason why highly successful companies go bankrupt when they're bought out by a youth-oriented conglomerate that fires the old-timers: The old-timers are the ones who know how and why things were manufactured and sold. It's also the reason why many modern engineers and technicians keep reinventing the wheel—they don't know why we use or need certain circuits.

The value of memory came to mind as I sat listening to a 21-year-old teaching-assistant explain the wonders of the RF preselector: how its invention allows us to manufacture a $100 communications receiver that can pick up the whisper of a flea 3000 miles away, and how modern solid-state technology makes it all possible.

After 45 minutes of watching him fill a blackboard with equations on frequency, impedance, noise, and a bagful of DC and AC transistor parameters, my brain had turned to jelly. Why must everything we do be quantified at even an introductory level—particularly when an understanding does not require quantification?

The problem with that instructor is that he is too young to have any memory—or knowledge—of the real progress represented by the preselector; why it is presently used on virtually every kind of communications receiver regardless of its price.

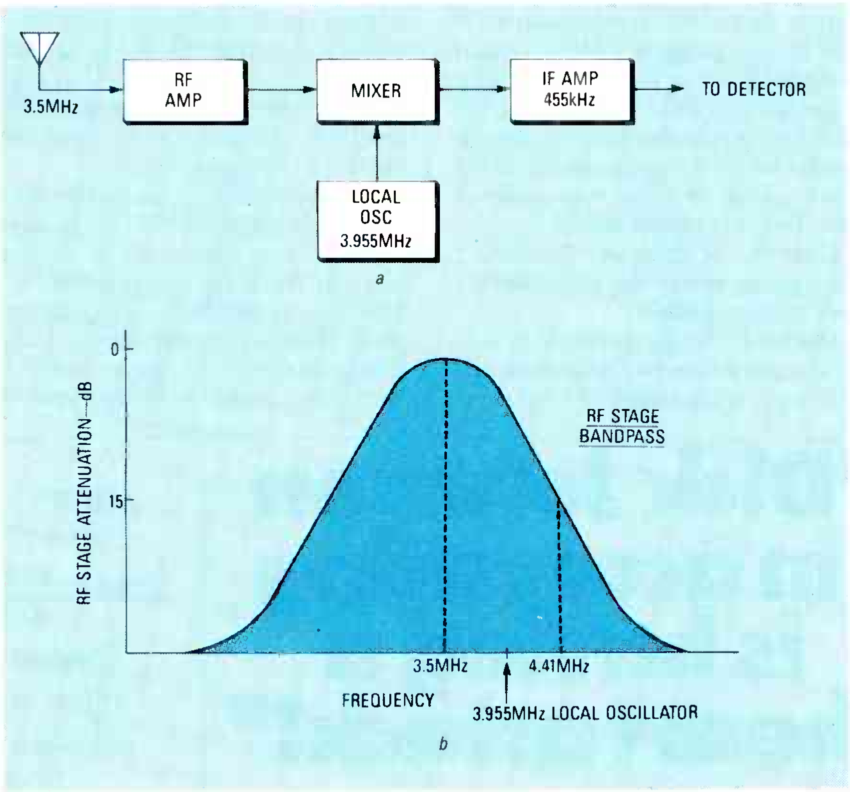

FIG. 1

I first used a preselector back in the late 1940's, long before the transistor was a thought in anyone's mind. It was made by the James Millen Co., and it connected between the antenna and my communications receiver's antenna input. It used small plug-in tuning units for each of the amateur bands. Basically, it was simply an extra stage of optimized RF amplification; optimized because the tuning circuits didn't have to be band-switched or gang-tuned. As I recall, I had to tweak three controls to peak the gain on the desired station.

But the preselector wasn't used just to provide additional RF gain. By peaking the RF-input stage it was hoped that interference from *image* signals would be reduced. In fact, image reduction was the key to better receiver performance, and it is the reason why we can easily incorporate preselectors into the modern receiver.

Image interference

To explain: Moderately priced receivers used a 455-kHz IF amplifier because it was a good compromise between sensitivity and selectivity. It allowed decent frequency response for AM-broadcast and shortwave reception, yet provided sufficient selectivity to reduce interference from signals near in frequency to that of the desired (tuned) station. But that didn't apply to image signals that got past the RF amplifier—the stage of amplification between the receiver's antenna input and the mixer, or the antenna-tuning circuit if the receiver didn't have an RF amplifier. As shown in Fig. 1-*a*, if the desired frequency was 3.5 MHz, the receiver's local oscillator was tuned to 3.955 MHz. The receiver's mixer heterodyned the two signals, and the resulting difference signal of 455 kHz was fed to the IF amplifier.

But, as shown in Fig. 1-*b*, if a 4.410-MHz signal is also received, it would also beat against the 3.955-MHz local oscillator. The resulting difference signal of 455 kHz would also be fed to the IF amplifier—which could not distinguish between the desired and the interfering signals. The undesired signal is called the image signal; the image frequency is one that is separated from the desired signal by two-times the IF frequency.

The selectivity of early RF amplifiers was similar to that of Fig. 1-*b*, so image-frequency rejection was only 10–15 dB. In plain terms, it means that if the image signal is 20-dB stronger than the desired signal, it would actually come through the IF amplifier louder than the desired signal.

Double conversion

It was *inexpensive* double conversion, made possible by the millions of Citizen-Band transceivers being manufactured, that forever changed RF tuning: It actually made possible both the inexpensive communications receiver, and the super-performance "gold-plated special."

Early single-conversion CB transceivers suffered unmercifully from image interference because the Q of the 27-MHz antenna-input circuits was very low—there was effectively no image-frequency suppression when the receiver had but a single IF frequency. So CB manufacturers switched to double conversion, which was still an expensive feature in conventional communications equipment sold at that time.

Double conversion works basically like this: There are two mixers and two local oscillators. The first mixer heterodynes the desired signal (let's assume it's 27 MHz) to 10 MHz. That means that the first local oscillator is running at 17 MHz. (At the higher frequencies we usually—but not always—run the local oscillator below the frequency of the desired signal.) The image frequency is 7 MHz. If the receiver's antenna-input stage is tuned for 27 MHz, very little 7-MHz signal (if any practical amount) will get through the receiver's RF amplifier. Now the 10-MHz IF frequency from the first mixer is beat down in the second mixer to 455 kHz, or to whatever frequency the manufacturer decides to use for the second-IF amplifier. Some have used a second-IF frequency of approximately 262 kHz to attain super-selectivity; others used 1.6 MHz, depending on crystal or ceramic filters to provide acceptable selectivity.

But the receiver's selectivity is not the point. What is the point is that because of double-conversion, virtually no image-signal reception gets through the receiver even if the RF amplifier is broad-tuned, as it is in CB transceivers. We no longer have to worry about either the Q or the precise tuning of the RF-amplifier stage. That means that by using double conversion in communication receivers we can divorce the receiver's RF-amplifier tuning from the station tuning and eliminate the ganged band-switching coils and the ganged tuning capacitors. The user simply sets the "preselector" or "antenna" tuning control to some pre-marked average position, tunes in the desired station, and then tweaks the preselector for maximum overall gain. Because the circuit has been made more compact, and the ganged-tuning's alignment problems and losses have been completely eliminated, the "preselector" now provides higher gain while being less prone to frequency instability. **R-E**

ANTIQUE RADIOS

Condensers and tubes

RICHARD D. FITCH

ONE OF THE FIRST THINGS AN ANTIQUE-radio restorer learns is that almost nothing is readily available in replacement parts. While you can often find a modern substitute for a resistor, and maybe even an audio-output transformer, tubes and "condensers"—the old term for capacitors—are a whole different ball game.

Condensers

Capacitors suitable for use in an antique radio are rarely, if ever, to be found in modern electronics supply stores. While you might be able to match the capacitance value, rarely will you find a unit rated at 600-WVDC (Working Volts DC), and an under-voltage capacitor will usually "pop" or burn up if used. (It's a good idea to wear eye protection when working around old capacitors.) One way to get the correct voltage rating is to connect two capacitors in series so that the DC voltage divides equally (and we hope) across the two units. For example, if your radio needs a 20-µF, 600-WVDC capacitor, you can series-connect two 40-µF, 400-WVDC capacitors. The final rating will be 20-µF at 800-WVDC. (While the voltage ratings are additive, series-connected capacitors behave the same as parallel-connected resistors, while parallel-connected capacitors behave like series-connected resistors.)

Paper capacitors, which are made of wrapped foils, have no polarity, although most are marked on one end with a black band. The band indicates that the foil connected to that end is the outside wrapping of the capacitor.

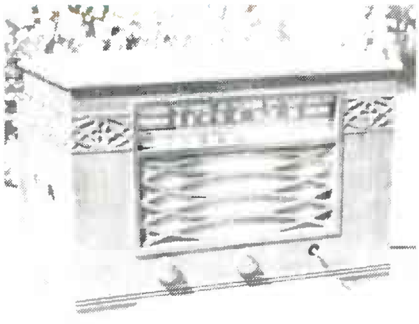

FIG. 1

If a capacitor connects directly to ground, or through a low impedance path to ground, the banded end should go to that connection so that the outside foil will act as a grounded shield to prevent undesirable coupling between the capacitor and other circuits. Other than the remote chance of circuit instability, reversing the connections of a paper capacitor usually has no affect on how well the radio performs.

Electrolytic capacitors do have polarity, and it should always be observed. When replacing electrolytics, its best to use a unit having the same capacitance as the original part (if known). If you can't find out the value of the original part, then assume that the part you're replacing is original—even if it is obviously a replacement—and substitute the same value. If you can't match the original value, a slightly larger value can be used in most applications. However, an input-filter capacitor's value can be critical, and a larger capacitance is not recommended because it might cause damage to the rectifier tube.

The real value

Effective component tolerance is an important point to keep in mind when you're working on antique radios that might be more than 50 years old. It's likely that over the years some components have been replaced many times, and if each serviceman made a 10% variation in a value—which is usually an acceptable tolerance—the part could off 50% or more from the original design value. So, if you don't have a schematic, replace an antique radio component with one having exact value and connections as the unit being replaced, even if there is no physical resemblance.

For example, you might not be able to find an exact physical match for an electrolytic capacitor. In particular, the different sizes and mounting of electrolytic "cans" will be hard to duplicate. As long as you observe the capacitance, working voltage, and polarity, just about any shape or size will work. Although you might have to use two or three capacitors to replace what was originally a single unit, always try to replace all sections in a defective electrolytic, because it's more than likely that if one section is defective, the others are also ready to fail. If you can locate a direct substitute for an chassis-mounting electrolytic "can," pay particular attention to the way it's mounted to the chassis. Although some appear to be mounted directly on the chassis, they are actually insulated from the chassis by rubber or fiber insulators under the mounting screws. Remember, if a can is insulated from the chassis there's usually a good reason for doing it; perhaps the can itself is not at ground potential.

To maintain authenticity in appearance, many antique radio restorers leave a dead (disconnected) electrolytic can in place and install the replacement capacitor under the chassis.

Tubes

Most antique-radio restorers consider tubes to be the most important component because it's usually the only part for which there is absolutely no kind of substitute. Although many different tube types were developed during the halcyon days of radio, one tube type, the 01A, which is synonymous with early radios, is still much in demand by antique-radio restorers. In my limited collection there are three battery-operated sets that use a total of ten 01A's, yet I have been able to get only three. (It would be a great gift if a tube manufacturer would turn out a few thousand 01A's to keep us antique-radio restorers supplied through the years.)

Because of its unusual versatility, the general-purpose 201A tube was another popular type. It was called a general-purpose tube because it could be used as an RF amplifier, as a detector, and as an audio amplifier.

The tube was used extensively in both tuned and untuned RF-amplifier circuits. As an audio-frequency amplifier, the 201A was used in transformer, resistance, and impedance-coupled circuits. It also could be used as a low-power AF power amplifier.

When the 201A was used as a detector, the triode elements were converted to function as a diode by connecting the grid and the plate together to form an anode. Using a similar grid-plate connection, almost any triode tube can be used as a rectifier.

The 201A was considered to be a particularly reliable detector because it was free from tube noises, such as *microphonics*. A tube was considered microphonic when a disturbance of the tube or the chassis would cause a continuous squealing or a "bonk...bonk" sound. To prevent microphonic noise, the sockets were often isolated from chassis vibrations by some form of cushioning.

Although not as popular as the 01A and 201A, there are other collectible tubes. Among them are the WD11 and WX12. Although the two tubes are similar, they are not interchangeable without an adapter. They are also scarce.

There is a considerable difference in design between tubes designed for a DC filament power supply and those that can be powered by either DC or AC. By the 1920's the demand was for tubes that were suitable for AC-powered receivers. Although the 201A didn't qualify, a few types designed for battery power, such as the 12A, were suitable for some kind of AC operation and can be found in radios designed for both battery and AC power.

The 112A, or 12A, had a filament that could be powered by DC or AC, and had operating characteristics similar to that of the 01A. The tube was useful as an RF amplifier, detector, AF amplifier, and power amplifier. It also made a good regenerative detector that oscillated more easily than the 01A. It was also useful as an oscillator in superheterodyne receivers and shortwave converters.

As an audio-frequency amplifier, the 12A was used with any of the standard interstage couplings of the time, giving less distortion than the 01A in the same kind of application. It also could be used for the audio power amplifier. When used for anything other than the audio power output the filament had to be DC-powered.

In external appearance, the 112A was identical to the 201A. It also had the standard UX base, which was able to fit into either the earlier bayonet socket or the newer plug-in socket.

Because of its rugged construction, there was little need to mount the tube in a cushioned socket or take any of the other precautions needed for the 01A. The 12A was used the same way as the 01A in resistance, impedance, and transformer-coupled audio-amplifier circuits. Due to its characteristics, the 12A was especially useful as a driver for push-pull output amplifiers. **R-E**

HARDWARE HACKER

continued from page 37

walking-ring counter that divides by eight...

0000
1000
1100
1110
1111
0111
0011
0001
0000, etc...

At times, all three of the resistors are pulling up, while at other times, all three are pulling down. The output is a four-step approximation to a sine wave. If you use an eight-state walking-ring counter, you divide by sixteen and end up with an eight-level sine wave.

What is really surprising is the harmonic performance. They are both carefully crafted magic waveforms. With perfect resistors, the first harmonics for the four-stage generator are the seventh at 1/7th and the ninth at 1/9th the amplitude of the fundamental.

On your eight-stage generator, your first harmonics are the fifteenth at a minuscule 1/15th and the seventeenth at 1/17th of the fundamental amplitude. Way down there.

Thus, those magic waveforms are extremely easy to filter, even over a wide frequency range. Often a single capacitor is all you need. The counters might be built in either hardware or software. Those are both good high-frequency circuits because the clock only has to be 8 or 16 times that of the sine wave.

Two minor gotchas: Variations in resistor values and circuit strays can introduce a few other low-amplitude harmonics into your output. And, with a hardware counter, you have to be very careful to eliminate any disallowed states by resetting to all zeros before you start. For instance, on the eight-bit counter, you are only using 16 of the possible 256 states; the other 240 can do all sorts of weird things if you inadvertently get into them.

One place where you will see walking-ring sine-wave generators

continued on page 103

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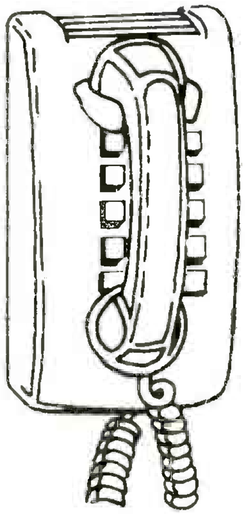

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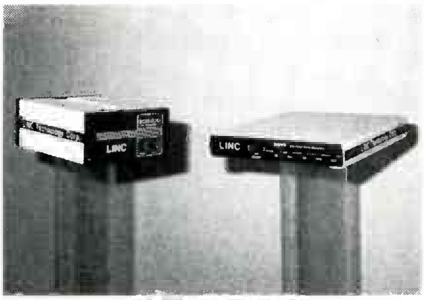

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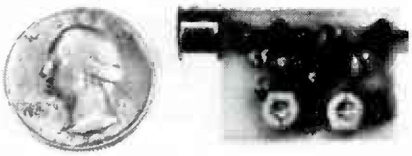

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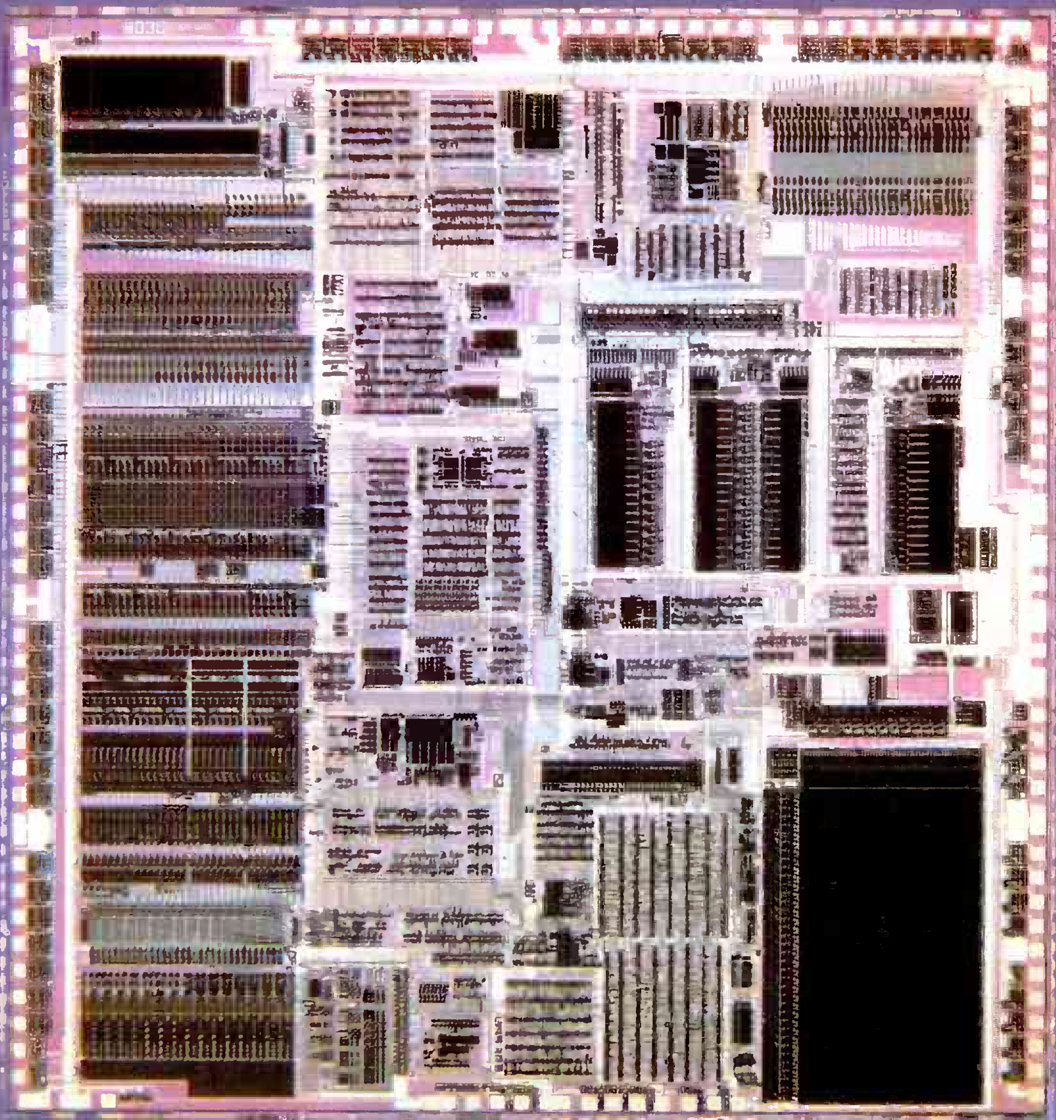
COMPUTER DIGEST

A NEW KIND OF MAGAZINE FOR ELECTRONICS PROFESSIONALS

INSIDE INTEL'S 80386

Speed + Multi-tasking = Power



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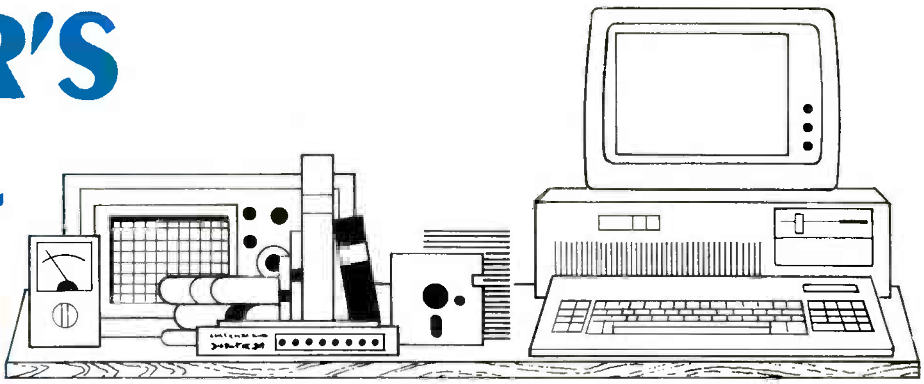

Memorial for Herb

Herb Friedman passed away this past fall, and will be sorely missed. In a career spanning some 30 years, Herb had a profound influence on the electronics industry and on many involved in it.

As a kid, I grew up building his projects and reading his articles in **Popular Electronics, Radio-Electronics,** and many others. Later on I had the privilege of working with him for a period of about a year and a half. During that time, I found out that his interests spanned everything from automobiles to communications to high fidelity to photography to computers. The latter were what drew the two of us together.

When Herb first came to work at our office, I was still a relative newcomer, "green behind the ears." Herb gave of himself unselfishly, teaching me the ropes. If I had a question, the chances were that he had an answer. If he didn't, he would help me find it. In any case, he always had time to help.

Herb came to our office to "retire" from a long career in education. He did more in his "retirement" than many people do in the prime of life.

Herb was a man of great enthusiasm. If a new technology was introduced, he was there badgering manufacturers for details, and badgering editors to cover it.

At bottom, Herb was a great teacher. He influenced thousands of people through his articles. He influenced thousands of students in the New York City schools. And he influenced his colleagues at the office.

If you had the privilege of meeting Herb, you'll never forget him. If you didn't, you missed out.

Herb was an irreplaceable friend. Goodbye, Herb, and good luck.

—Jeff Holtzman

DoubleCOM

Time was, two serial ports were enough. Now, however, a mouse, a modem, a plotter, a laser printer, a printer buffer, an RS-232 link to another PC—all those and more compete for the precious ports.

One solution is simply to switch cables when necessary. But digging around your PC's nether parts grows old fast. It can also be bad for your PC's health.

Another possibility is an RS-232 switchbox, but that can be expensive, inconvenient, and also bad for health.

DG Electronic Developments has a better idea: The DoubleCOM, which combines a serial port and an electronic A/B switch on a single half-length card.

The card provides a single COM port, addressable as either COM1 or COM2, and two nine-pin D connectors. One 9-to-25 pin adapter cable is included.

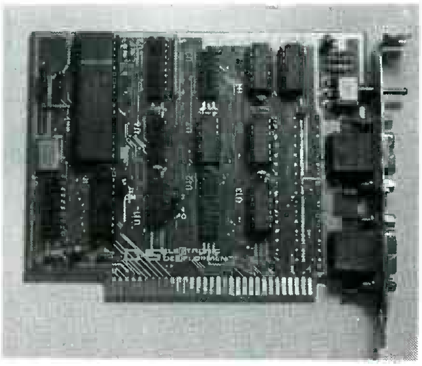

FIG. 1

To use DoubleCOM, connect the two devices you wish to share to the D connectors. You can then switch between them using a toggle switch on the card's mounting bracket. Even better, you can switch between them electronically by installing a small (less than 1K) memory-resident program. Pressing Alt-Shift-A selects the upper port (A), and pressing Alt-Shift-B selects the lower port (B). You can also select the desired port using a stand-alone program; that is useful for batch-file selection. Last, a special selection program works from within Windows.

Installation is as simple as setting the card's port and interrupt jumpers (COM1 uses IRQ4 and COM2 uses IRQ3), and inserting the card in an unused slot. An installation program copies software to your disk, and asks you several questions to configure it for your hardware setup.

Your answers are used to configure the ports when you switch them. For example, you might set up Port A as a Microsoft mouse port, and Port B as a printer port running at 9600 baud, with eight data, one stop, one start, and no parity bits. Then, each time you use the software to change ports, the board's UART is reconfigured with the correct operating parameters.

A three-position toggle switch protrudes through the mounting bracket. In the upper position, Port A is selected; in the lower, Port B is selected. In either of those positions, the port is hard wired and will not respond to software selection. The board responds to software commands when the switch is in the middle position.

Limitations

The software has some minor limitations. First, it can configure the UART for baud rates only as high as 9600 bps.

Versions of DOS beginning with 3.30 allow 19,200 bps transmission, and serial-link programs (Brooklyn Bridge, for example) can go as high as 115K bps.

However, even though the DoubleCOM software can't configure the UART for high-speed baud rates, the hardware will function normally. The catch is that you may not be able to switch out of and back into a session at one of the higher rates. Some programs reset port parameters periodically throughout a communications session; others do it once only at the beginning. The former are the ones that could cause trouble; however, just don't switch ports during a session.

The software supports the Microsoft mouse (and compatibles) directly. You can use another type of serial mouse, but, depending on the program, it may stop responding if you switch ports.

All in all, the DoubleCOM is a highly useful piece of hardware. At $149, it's price-competitive with a stand-alone serial port plus an external A/B switch—and it provides a more elegant and convenient solution. ◆CD◆

ProComm + and Smartcom III

Telecommunications programs have grown in sophistication rapidly during the past few years. Two leaders in the field are Smartcom III from Hayes (the modem company) and Procomm + from Datastorm Technologies. Both are powerful programs with many built-in features including terminal emulation, scroll-back buffering (to see what's happened previously in a session), session logging to disk or printer, background communications, keyboard macros, script languages (that allow you to write programs to automate communications tasks), and more.

Smartcom's strengths include a built-in text editor and multiple simultaneous communications sessions. Procomm's strengths include many file-transfer protocols and terminal emulations. Both have sharp, intuitive user interfaces that are easy and pleasurable to use.

Smartcom III

Smartcom is built around activities and connections. Activity settings govern the basic communications environment: terminal emulation type, communications protocol, script files, keyboard macros, etc. Connection settings govern the physical hook-up: modem or direct, transmission settings (baud rate, etc.), etc.

The program comes with a number of pre-defined activities (Compuserve, MCI Mail, TTY, etc.) and connections (Tymnet, 9600-baud direct connect, etc.). You can use the built-in settings as-is, or you can define your own. A series of menus makes the process easy. After you've defined an activity/connection combination, you can access them one by one via Smartcom's menus, or directly from the DOS command line. For example, suppose you have an activity named RE-BBS, and a connection named BAUD2400. The activity defines the RE-BBS telephone number, terminal type, etc., and BAUD2400 defines a 2400-baud Hayes internal modem. Then, to dial the RE-BBS from the command line you would type:

```
SCOM3 RE-BBS.BAUD2400
```

Because each activity is separate from each connection, you might also dial up with:

```
SCOM3 RE-BBS.BAUD1200
```

After initiating a session, you can return to Smartcom's master menu and start another. In that way, you could simultaneously download a lengthy file from a BBS and exchange files with a local PC. With the appropriate hardware, you could even communicate with a mainframe in one session and a BBS in another!

Smartcom is a little weak when it comes to terminal emulation and file-transfer protocols. It has only three basic emulations: TTY, ANSI.SYS, and DEC VT52/100/102. Likewise, only Kermit and several XMODEM protocols are supported. However, most users need no more than those anyway.

Smartcom also contains a script language (SCOPE) that can automate your telecommunications chores. With SCOPE you could create a system to automatically log on to your favorite telecom service, check your personal mailbox for messages and download them, if any, and then log off. You can even force the whole thing to happen in the middle of the night when telephone rates are lowest! SCOPE is not difficult to master, and examples provided with the program illustrate the basics.

Script programs can be "taped live" by recording your keystrokes as you make them on-line. Or you can create or edit a script file using the built-in editor. Then you compile it and it's ready to run. You can associate a script file with an activity or connection so that it runs automatically every time you choose that activity or connection.

Procomm +

Procomm provides similar capabilities. Lacking is the on-line text editor, but, in compensation, the program provides many file-transfer protocols and terminal emulations. Procomm also includes a script language that is quite similar in capability to Smartcom's.

Procomm is somewhat easier to get started with than Smartcom, because when you load the program, you're immediately placed into a telecommunications screen. To dial a number, press Alt-D; a directory window pops up. You can add and edit directory entries at will, or simply enter a number to dial manually. With Procomm's auto-redial, it's easy to break through a line that's often busy.

Procomm also has extensive customization features and on-line help. Lacking is Smartcom's disk and file maintenance tools, but a DOS "gateway" can take you to DOS from within the program.

Like Smartcom, you can capture the entire contents of a session to a disk file, but Procomm is less intelligent about what it stores—it stores everything. If you're used to editing your work extensively while on-line, you'll end up with many unwanted control characters.

One useful feature is the ability to run Procomm in the "host" mode—i.e., to set up a miniature BBS.

The choice

Choosing between Procomm + and Smartcom III is difficult. Both provide powerful, reliable communications. Smartcom allows for multiple simultaneous sessions, and its user interface is more polished, but the activities/connections orientation takes some getting used to. Procomm, on the other hand, is quite easy to use, although many its choices for keystrokes are odd (e.g., Alt-Z for help). A moving-bar menu approach (a la 1-2-3) alleviates learning those keystrokes.

What tipped the scale to Procomm is its extensive customizability, the intuitive dialing directory, the auto-redial feature, and it costs 1/3 of Smartcom. ◆CD◆

PRODUCTS REVIEWED

- DoubleCOM: ($149), D-G Electronic Developments, Inc., 700 South Armstrong, Denison, TX 75020. (214) 465-7807.
CIRCLE 17 ON FREE INFORMATION CARD

- Smartcom III ($249), Hayes Microcomputer Products, Inc., 705 Westech Drive, Norcross, GA 30092. (800) 241-6492.
CIRCLE 18 ON FREE INFORMATION CARD

- Procomm + ($75 + $3 shipping), Procomm 2.4.2 ($50 + $2 shipping), Datastorm Technologies, Inc., P.O. Box 1471, Columbia, MO 65205. (314) 474-8461.
CIRCLE 19 ON FREE INFORMATION CARD

INSIDE INTEL's 80386

A revolution is occurring, quietly and subtly, and it promises to drastically alter the way we work and the tools we work with. The 80386 microprocessor is the cause of the revolution; it has high speed and the ability to run advanced operating systems and applications programs. Yet it maintains full compatibility with the 8086/88 and 80286 microprocessors, and with the wealth of DOS software that runs on them.

Here is an introduction to the 386 family. In a series of three articles, we'll present basic theory. Then we'll present a really hot construction project showing you how to put a 386 in your PC for about $600. After that, an article by a leading vendor of DOS-compatible multi-tasking operating systems will show you how to put that 386 to work. Stay tuned.—Editor

Speed + Multi-tasking = Power. Try a 386 once, and you'll become addicted to that power. Start learning about the microprocessor of the future in the first of a three-part series.

NEAL MARGULIS, INTEL CORP.

The 80386 microprocessor has drastically changed the course of personal computing. Systems built around the 80386 initially were very costly, but competition among manufacturers and new low-cost versions of the chip are making 386 power available to more and more people every day. In fact, it is estimated that two million 386-based systems will be sold in 1989—not counting 386SX-based systems. That number should triple over the next few years. Meanwhile, the 386SX is sure to acquire a share of the more than seven million 80286 systems estimated to be sold between 1989 and 1991.

The 386 family consists of three microprocessors: the 80386, the 16-bit 386SX, and the 376 embedded processor. Although they have varying external hardware characteristics, all three have 32-bit internal buses, on-chip memory management, protected- and real-mode operation, and software compatibility. Major features are summarized in Table 1.

In the first of this three-part series, we'll discuss the basic features of all three family members, comparing them with the previous generation (the 8088/86 and the 80286) along the way. In the second part, we'll show how to take advantage of the on-chip hardware for developing advanced operating systems. In part three, we'll discuss how to interface the CPU with memory and peripherals, and we'll examine the support IC's, including the 80387 and 80387SX math coprocessors, the 82385 cache controller, and the 82370 and 82380 integrated system peripherals.

Because of space limitations, we assume you have at least a passing familiarity with the Intel family. If not, you may wish to consult one or more of the references listed in the bibliography.

Family basics

The 8086 and 8088 provide 16-bit registers and a one-megabyte address space. The two differ in that the 8086 has a sixteen-bit external data bus, and the 8088 has an eight-bit data bus. Internally, however, they're the same.

The 8088/86's address space is divided into variable-sized segments, each of which may contain up to 64K bytes of memory. The one-megabyte address limit has caused widespread use of complex and slow memory-management techniques: program overlays and expanded (EMS) memory.

Next is the 80286. When first powered up, it operates in *real mode,* a mode that is compatible with the 8088: the same 16-bit registers are present, as are the same 64K-byte segments, and the same one-megabyte address space. Real mode on the 80286 enhances performance through increased clock speed and fewer clock cycles to execute an instruction.

The 80286 can also operate in a new mode, called *protected mode,* that provides a 16-megabyte address space, multitasking, virtual memory, and protection. (When two programs are running in protected mode, one cannot access the other's data or program memory; thus, programs are protected from one another.) MS-DOS runs in real mode; OS/2 and varieties of UNIX run in protected mode.

To increase the amount of memory it can access, the 80286 deals with segments in protected mode in a different way than in real mode. Instead of being associated with a physical area of memory, a segment register is treated as a pointer into a table of *descriptors;* that table shows which areas of memory belong to each stored program.

The 80386 improves on the 80286 in several ways. First, all registers have been extended to 32 bits. That means that data can be shuttled to and from memory more efficiently than with the earlier generation processors. It also means that segments can be larger than 64K bytes. In addition, an on-chip memory-management unit provides better protection facilities. Last, switching between modes (real, protected, and a new virtual mode) is much more efficient than with the 80286.

TABLE 1—INTEL FAMILY MICROPROCESSORS

	8086/88	80286	386SX	386	376
Register Sizes (bits) 8, 16, 32	8, 16	8, 16	8, 16, 32	8, 16, 32	
Operand Sizes (bits) 8, 16, 32	8, 16	8, 16	8, 16, 32	8, 16, 32	
Maximum Segment Size	64KB	64KB	64KB/4GB	64KB/4GB	16MB
Maximum Virtual Memory	1MB	1GB	64TB	64TB	256GB
Maximum Physical Memory	1MB	16MB	16MB	4GB	16MB
Paging Unit	NO	NO	YES	YES	NO
16-bit Real Mode	YES	YES	YES	YES	NO
16-bit Protected Mode	NO	YES	YES	YES	NO
Virtual 8086 Mode	NO	NO	YES	YES	NO
32-bit Protected Mode	NO	NO	YES	YES	YES

Internal architecture

The 386 is built from 275,000 transistors using CMOS technology. The key to the microprocessor's high performance is the pipelined operation of its six internal units, as well as its high-performance 32-bit architecture. Figure 1 shows the basic structure of the 386. Both the 386SX and the 376 have 16-bit data buses and 24-bit address buses.

The bus-interface unit is the microprocessor's path to the outside world. It functions by granting priorities to the code prefetch unit and the execution unit. The scheme gives highest priority to the execution unit. Spare clock cycles are used by the code-prefetch unit.

The code-prefetch unit uses the bus-interface unit to sequentially fetch new instructions from memory. Because execution-unit requests are given a higher priority, prefetch activity seldom slows the execution unit. However, by using cycles that would otherwise be wasted, the prefetch unit reduces the amount of time that the processor spends waiting for the next instruction. The code-prefetch unit stores the fetched instructions in a 12-byte code queue where they await processing.

As its name suggests, the instruction-decode unit decodes machine-language instructions, and then stores them in a FIFO (*F*irst *In* *F*irst *O*ut) buffer. Opcodes are decoded at a rate of one byte per clock cycle. Immediate data and offsets are decoded in one cycle, regardless of length. The decoded-instruction FIFO can hold three instructions; instructions that have been decoded wait in the FIFO for use by the execution unit.

The execution unit contains three sub-units. The control unit contains the microcode and dedicated hardware for address calculations. The data unit contains eight general-purpose registers and a 64-bit barrel shifter. Microcode in the control unit operates on data in the data unit.

The third sub-unit is the protection-test unit; it checks for segment violations (i.e., illegal access by one program of another's allotted memory space). Several 32-bit busses are used internally to tie everything together.

Fifth is the segmentation unit. It contains the segment registers and the segment descriptor caches. The segmentation unit uses on-chip information to translate logical addresses into linear addresses and check them with

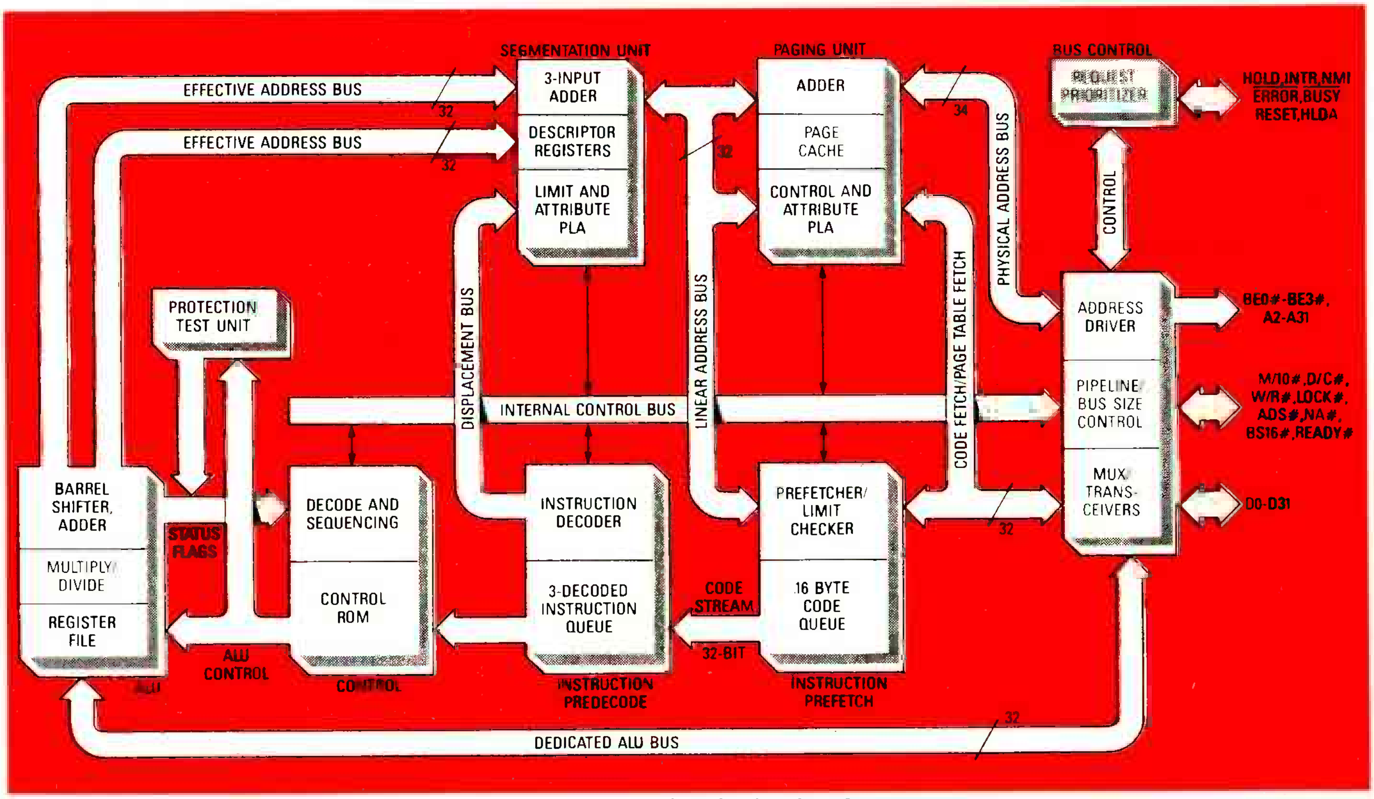

FIG. 1—INTERNAL STRUCTURE OF THE 80386: It's composed of six units: bus interface, prefetch, decode, execution, segmentation, and paging.

the segment limit fields. When paging is not used, the linear addresses are used by the bus unit for accessing external memory.

Sixth and last is the paging unit (which is unavailable on the 376). When paging is enabled, the paging unit translates linear addresses into physical addresses. The paging unit has a 32-entry translation cache, called the *T*ranslation *L*ookaside *B*uffer (TLB), that stores the most recently used page translations.

Register Structure

The 80386 has eight general-purpose registers, each of which is 32 bits wide (see Fig. 2). For compatibility with the 80286 and the 8088/86, each 32-bit register can also be used as a 16-bit register, and four can also be used as eight-bit registers. The eight 80386 registers are highly versatile; for example, in most instructions, any register can be specified as an operand, multiplied with another register, or used as an index into memory.

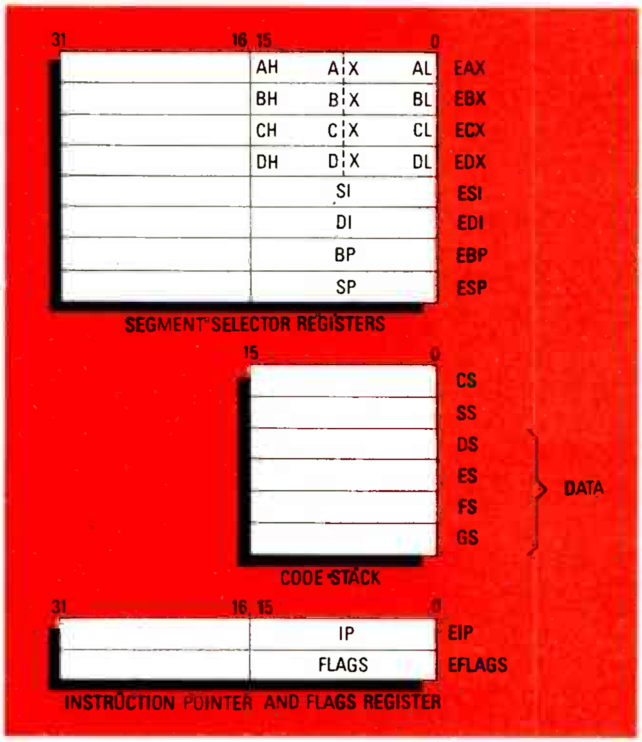

FIG. 2—MAIN REGISTERS include eight general-purpose registers, six segment registers, the instruction pointer, and flags.

Flags

In addition to the status, control, and system flags present in the 80286, two new flags have been added to the 80386 (see Fig. 3). First is the VM (*V*irtual *M*ode) flag. When that flag is set, the 386 treats the segment registers as the 8086 would—i.e., values in the segment registers point to actual memory locations, and not entries in a table. Thus, in virtual mode, real-mode software can run with all the benefits of protected mode. 80386 control programs use virtual mode to provide multiple independent DOS environments. The 376 embedded microprocessor cannot operate in virtual mode.

The VM flag is affected only by the IRET (*I*nterrupt *RET*urn) instruction and by task-switching operations. You cannot alter the VM flag using the POPF instruction.

The second new flag is the RF (*R*esume *F*lag), which is used in conjunction with the new debug registers. The RF flag is used to resume program execution at a breakpoint address without causing another breakpoint to occur on the same instruction.

The flag register also provides a method for distinguishing among microprocessors. In an 8086/88, bit 15 is always a 1, but in an 80286 or 80386, bit 15 is always a 0. In addition, bits 14, 13, and 12 in the 80286 are always zero, but they can be set on the 80386.

Debug registers

The 386 has the same ability to single-step programs and to insert software breakpoints as the 286. For example, the 386 supports the Interrupt 3 breakpoint.

In addition, the 386 has advanced debugging capabilities, including dedicated debug registers that support both code and data breakpoints. Using them, a debugger can regain control after every instruction, after execution of a breakpoint instruction, after a task switch to a specified task, after executing code or accessing data at a specified address, or on an attempt to change a debug register.

As shown in Fig. 4, the debug hardware consists of six registers: four address and two control registers. The linear-address breakpoint registers (DR0–DR3) can be accessed with a special form of the MOV instruction while the microprocessor is running in privilege level zero. Because the addresses specified in those registers are linear addresses, paging has no effect.

A complication occurs when two tasks have different linear-to-physical mappings of a given address. To avoid the complication, control register DR7 has a number of

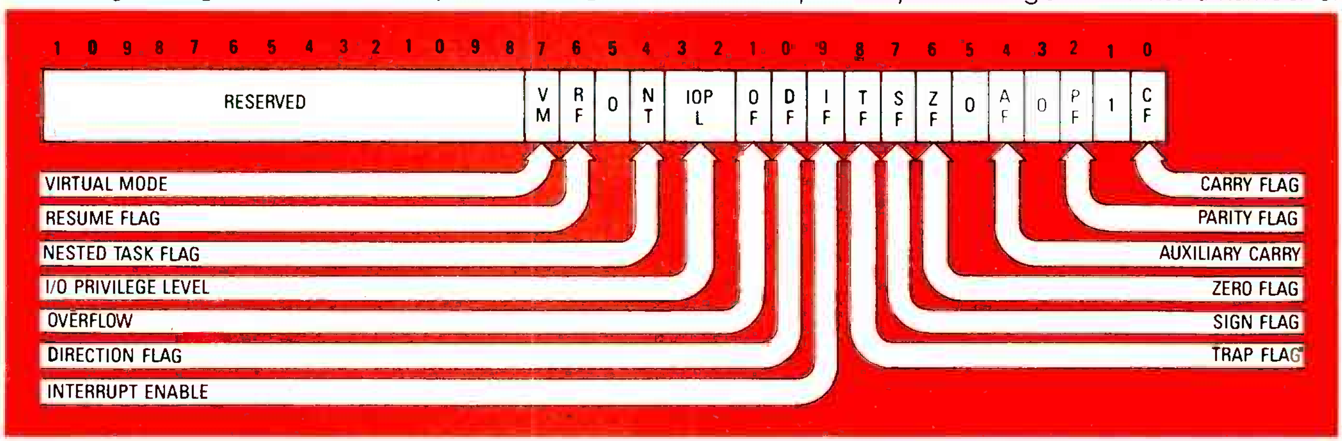

FIG. 3—THE FLAGS REGISTER: The VM flag enables virtual-mode operation, and the RF flag allows execution to resume after a breakpoint has been encountered.

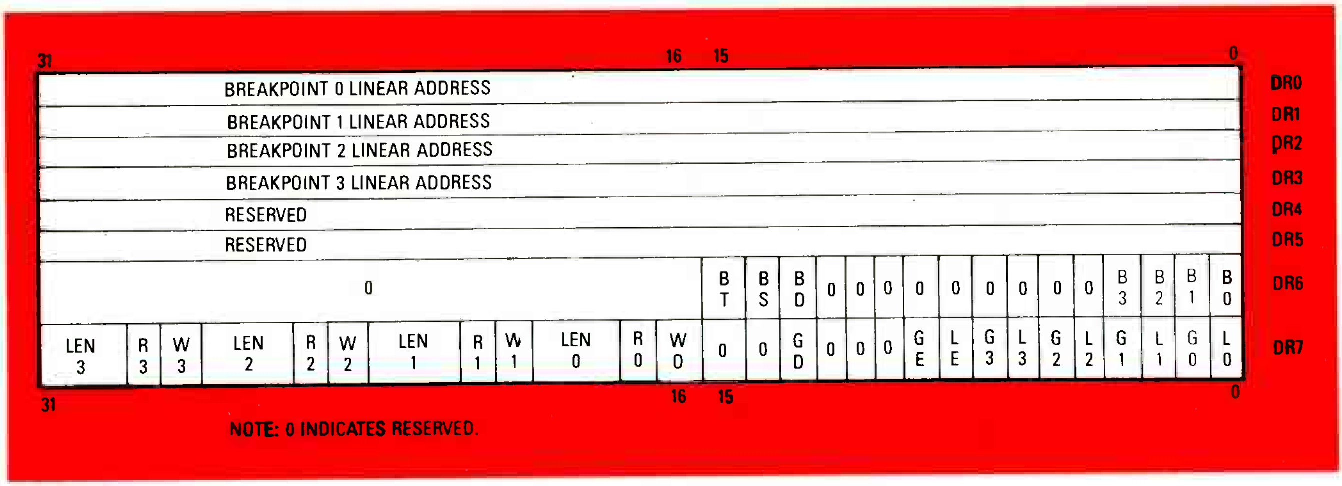

FIG. 4—THE DEBUG REGISTERS: DR0–DR3 hold addresses of as many as four breakpoints; DR6 and DR7 provide status information, and specify whether a breakpoint should occur on code or data access of the specified memory location.

bits (L0–L3 and G0–G3) that indicate whether an address is relevant to the current task only, or to all tasks.

In addition, register DR7 also contains several four-bit groups, each of which corresponds to a debug address register. As shown in Table 2, two of those bits specify the type of memory access that will cause a breakpoint; the other two bits indicate the size of the breakpoint object—byte, word, or double word.

When a debug exception occurs, various bits in the debug status register (DR6) are set, thus allowing a debugger to determine the source of the exception. (An exception is similar to an interrupt, except that interrupts are generated externally, and exceptions are generated internally.) If the breakpoint conditions have not been modified, and program execution is to continue at the breakpoint address, the RF in the flags register must be set to one. That can be done by popping the appropriate value into the flags register with the IRET instruction.

Those features allow real-time debugging support. So a debugger that traps every instruction while checking for data access becomes unnecessary. Rather, a debugger can use built-in features of the 386 to "watch" variables during execution. The debug registers allow near full-speed execution during a variable "watch."

Control Registers

Whereas the 286 has only a single 16-bit Machine Status Word (MSW), the 386 has three 32-bit control registers: CR0, CR2, and CR3. For compatibility, the machine status word has been incorporated as the lower word of CR0. In addition, the 80286 instructions that relate to the MSW operate identically on the 386 Microprocessor, but ignore the upper 16 bits. The new bits in CR0, CR2, and CR3 are used to implement memory paging on the 386.

Real-mode segment addressing

In real mode, a segment register is treated as part of a physical address. A 20-bit address is formed by shifting the segment register left four bits and adding an offset, which is contained in the instruction pointer or one of the general-purpose registers. The result is a 20-bit address ranging from 000000 to 0FFFFFh

Each segment register is independent; the memory

TABLE 2—BREAKPOINTS

Value	Type of Break	Length
00	Break on instruction execution only	Byte
01	Break on data writes only	Word
10	Undefined	Undefined
11	Break on data reads or writes only	Double word

referred to by one can partially or totally overlap that referred to by another, or it can be completely different.

A segmented address space has advantages and disadvantages. On the plus side, small programs need only modify a 16-bit address component for most memory accesses. In addition, it can be easier to manage relocatable segments and to code procedures that work on multiple areas of data without modification. The disadvantages come from having to reload the segment registers to access areas outside the 64K limit.

Protected-mode memory addressing

In protected mode, things are more complicated. The 386 has three distinct address spaces: logical, linear, and physical. Working backward, the physical address corresponds to the arrangement of memory IC's in a computer. When paging is not used, linear addresses correspond one-for-one with physical addresses. However, when paging is used, any given 4K page of linear memory may be treated by the processor as if it were located at a different physical location (on a 4K boundary). That capability is what allows 386 control programs (Windows/386 and VM/386, for example) to set up multiple "simultaneous" DOS environments.

The 8088/86 and 80286 have four segment registers (CS, SS, DS, and ES); the 386 adds two additional ones, FS and GS, that hold *selectors* that identify the currently addressable segments. As on the 80286, in protected mode the value of the selector is an index into a *descriptor table*. There are two descriptor tables: local and global. An operating system stores information relevant to all tasks in the global descriptor table; particular tasks use local descriptor tables.

Figure 5 illustrates a segment register and its use as a descriptor table selector. The lower two bits are the *Requestor Privilege Level* (RPL). Lower values of the RPL have higher priority and greater freedom in accessing particular memory segments. The third bit is the table

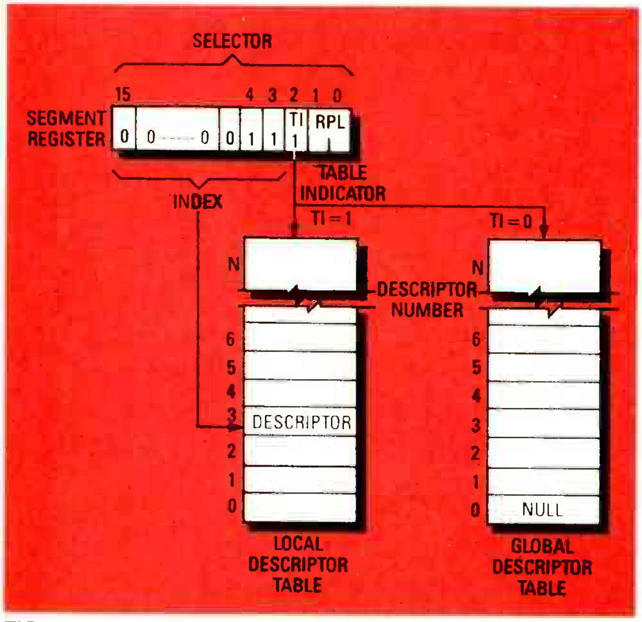

FIG. 5—A SEGMENT REGISTER contains a 16-bit selector that points to one of two tables, each of which contains eight-byte memory descriptors that specify how memory is allocated.

WHO NEEDS 32 BITS?

Using 32-bit registers for data can dramatically increase the performance of many programs. Because a 32-bit register can contain long-integer values, functions that take multiple operations on an 80286 can be performed in a single step on a 386.

For example, multiplying a long-integer value on a 386 can be performed in one operation. On a 286, the same procedure would have to be performed as a series of 16-bit multiplies and adds.

Because a long-integer multiply is simple on a 386, a compiler can directly "in-line" the operation (insert code that performs the multiplication directly, rather than call a library routine). By contrast, a long-integer multiply on a 286 is usually provided as a library function. In addition to the less-efficient multiplication, calling a library function further increases the number of necessary instructions.

The code sample shows a side-by-side comparison of how the same multiplication is performed on a 286 and a 386. The 80286 routine was generated by version 5.1 of the Microsoft C compiler.

indicator (global or local), and the upper 13 bits constitute an index into the table itself.

Each entry in the table is called a descriptor; each descriptor consists of eight bytes of data. When a segment register is loaded in protected mode, the eight bytes of information associated with that selector are automatically loaded into the microprocessor's segment descriptor cache, a set of on-chip memory registers that allow quick access to the desired segment. The 386 has a separate cache for each segment register.

Figure 6 shows a segment descriptor. It is similar to the 80286's descriptor, but the base and limit fields are larger. The 80386's descriptor contains a 32-bit base address that designates the starting point for the segment in the microprocessor's four-gigabyte address range. The 20-bit limit field specifies the maximum size of the segment. Because it's only 20 bits wide, you might expect that segments could have a maximum size of 1MB (2^{20}). The trick is in the G (Granularity) bit. When it is set to one, the limit field is effectively multiplied by 4K, thereby providing access to 4096 megabytes, or 4 gigabytes, of memory.

When the processor loads a segment register, it must determine which segment descriptor to load. To understand the process, let's work through an example. Assume the GDT base is 400h and that AX contains 28h. Which memory location would be loaded in the DS selector's descriptor cache if the following assembly instruction were executed?

```
MOV DS,AX
```

The 28H in AX is 0010 1000 in binary. The lower two bits contain an RPL level of zero, and the zero in bit three indicates that the descriptor is in the GDT. The remaining bits (00101) have a value of 5, so that entry refers to the fifth entry in the GDT. Each entry contains eight bytes, so the descriptor begins at byte 40 (28h). The table begins at 400h, so the desired descriptor is located at 428h.

Address modes

The 386 supports 11 addressing modes consisting of immediate, register, displacement, base, index, scale, and various combinations thereof.

With an immediate operand, the address is specified as part of the instruction itself. With a register operand, one of the eight general-purpose registers points to the desired location. With an index operand, the contents of one of the general-purpose registers (except ESP) is added to the contents of the base register to point to the desired location. In addition, an index register may be

31												0	
SEGMENT BASE 15...0						SEGMENT LIMIT 15...0							0
BASE 31...24	G	D	0	0	LIMIT 19...16	P	DPL	S	TYPE	A	BASE 23...16		+4

BASE	BASE ADDRESS OF THE SEGMENT	DPL	DESCRIPTION PRIVILEGE LEVEL (0-3)
LIMIT	THE LENGTH OF THE SEGMENT	S	SYSTEM DESCRIPTOR (0 = SYSTEM 1 = USER)
P	PRESENT BIT (1 = PRESENT 0 = NOT PRESENT)	TYPE	TYPE OF SEGMENT
A	ACCESSED BIT	G	GRANULARITY BIT (0 = BYTE 1 = PAGE)
D	DEFAULT SIZE (1 = 32 BIT SEGMENT 0 = 16 BIT SEGMENT)	0	BIT MUST BE ZERO

FIG. 6—EACH DESCRIPTOR consists of eight bytes of information, including a 32-bit base address, a 20-bit limit, a granularity bit, and other status information.

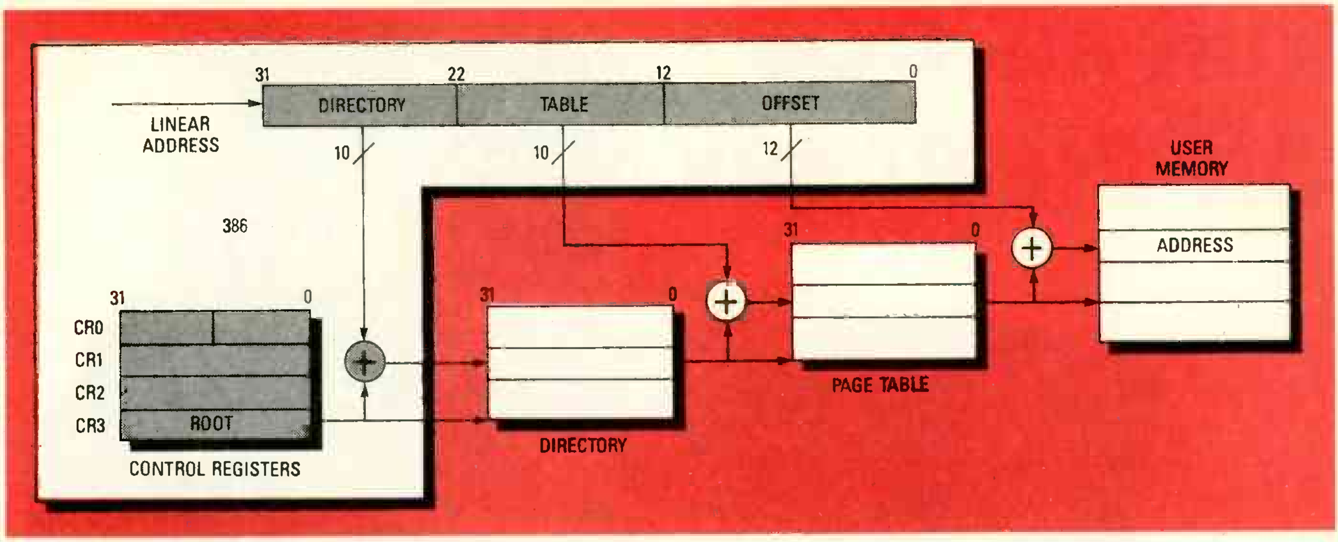

FIG. 8—IF PAGING IS ENABLED, a two-level table structure allows any 4K linear address page to be located at any 4K boundary in physical memory.

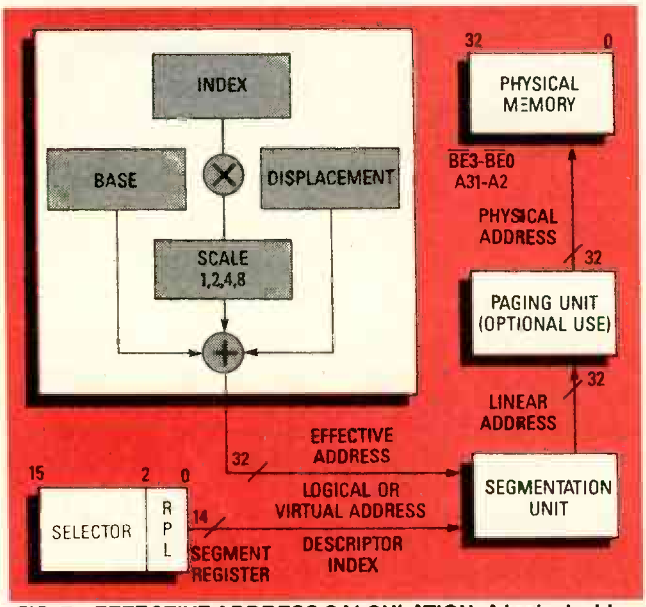

FIG. 7—EFFECTIVE ADDRESS CALCULATION: A logical address is combined with a descriptor index and processed by the segmentation unit to arrive at a linear address. If paging is disabled, the linear address corresponds to the physical address.

scaled by 1, 2, 4, or 8. Last, a displacement may be added to the other values. This is the formula for determining the *Effective Address* (EA) of an instruction:

$$EA = Base + (Index \times Scale) + Displacement$$

Those addressing modes are combined with the segment register and descriptor register addressing described above. The complete mechanism for computing the linear address in protected mode is summarized in Fig. 7.

After a linear address has been calculated, it must be converted to a physical address. That is done via two levels of tables, as shown in Fig. 8.

Instruction set

The 386 instruction set is quite efficient. In order to reduce bus usage by the CPU (thereby leaving the bus free for use by other devices), many commonly used instructions (for example, PUSH, POP, INC, and DEC) are one byte long. Less-common instructions are only two bytes long. In addition, common move instructions (register-register, memory-register and register-memory) are efficiently coded in one to three bytes.

Many simple instruction set computers require all instructions to be the same length. Because the 386 has on-chip microcode, complex instructions are implemented with a simple machine-language encoding, leaving the microcode to sequence the processor through the actual steps of the instruction. The encoded instructions are smaller and may be loaded from memory faster than the sequence of smaller instructions they replace. Instructions of that sort include bit manipulations, loop instructions,

continued on page 102

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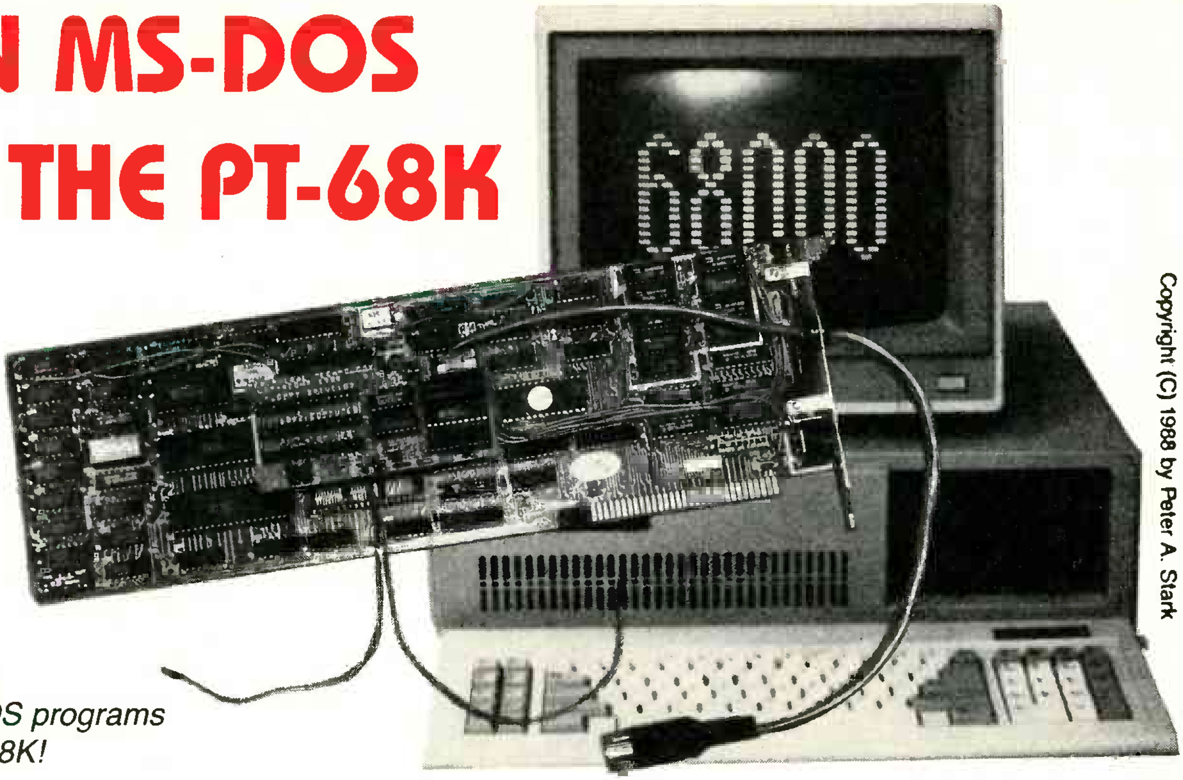
RUN MS-DOS ON THE PT-68K



Run MS-DOS programs in your PT-68K!

MARK HENRY

In case you missed it, beginning in the October 1987 issue, we began a series of articles on building a 68000-based computer from scratch. A basic system can be assembled for about $200; an expanded system with disk drives, etc., is also inexpensive, due to use of IBM PC clone components (case, power supply, video adapters, disk controllers, and keyboard). Many hundreds of readers have already built the PT-68K; many of them and others have been clamoring for an adapter card that would allow them to run IBM software in their 68K machines. Here it is.—Editor.

Let's face it—even 68000 aficionados want to use IBM-compatible software. Even though you own a powerful 68000-based PC, you still want access to the many thousands of MS-DOS programs.

Now you can have the best of both worlds. Your PT-68K already provides a great environment for learning about and experimenting with 68000 hardware and software; now, by adding an inexpensive (less than $400, less RAM) co-processor board, you can tap in on all the great software that's available for IBM's and compatibles.

TABLE 1—ALT88 FEATURES

8088 microprocessor
Standard 4.77 MHz and 8.0 MHz turbo speeds
BIOS by Award Software
256K DRAM on-board, expandable to 640K
DMA controller
Speaker interface
Keyboard interface
Turbo and power LED indicator outputs

System overview

Although software emulators are available, for reasons of performance and compatibility, we prefer a hardware solution with an 8088 microprocessor. Many inexpensive clone motherboards are available, but it is physically impossible to install most in a cabinet that already contains a 68000 motherboard.

However, we have located a special plug-in card that provides all the basics of a turbo (4.77/8 MHz) PC compatible. The card resembles a standard full-length expansion card, but it is designed for a passive-backplane motherboard, one that has no active circuitry on it. The card has on-board BIOS ROM, DMA controller, keyboard connector, and sockets for 256K of RAM. To build a fully functional system, all it needs is RAM, a keyboard, a video adapter, and a monitor.

Because the 8088 board was designed for a passive backplane, and because it has no provision for sharing the bus with another microprocessor, we designed a special adapter card that allows the 8088 and the 68000 to coexist peacefully. The card provides an interface that can disable the bus-driving components of either microprocessor, thereby allowing the other to access I/O ports, video adapters, etc. The card also switches the keyboard and the floppy-disk drive(s) between the two environments. We call the combined coprocessor and adapter card the ALT88.

The ALT88 contains most of the circuitry found on a typical PC clone motherboard. The main difference is that the ALT88 has a maximum of 256K on-board memory, whereas most clones can accommodate 640K. That's not really a limitation, because memory can be expanded to 640K by using a standard PC memory or multi-function

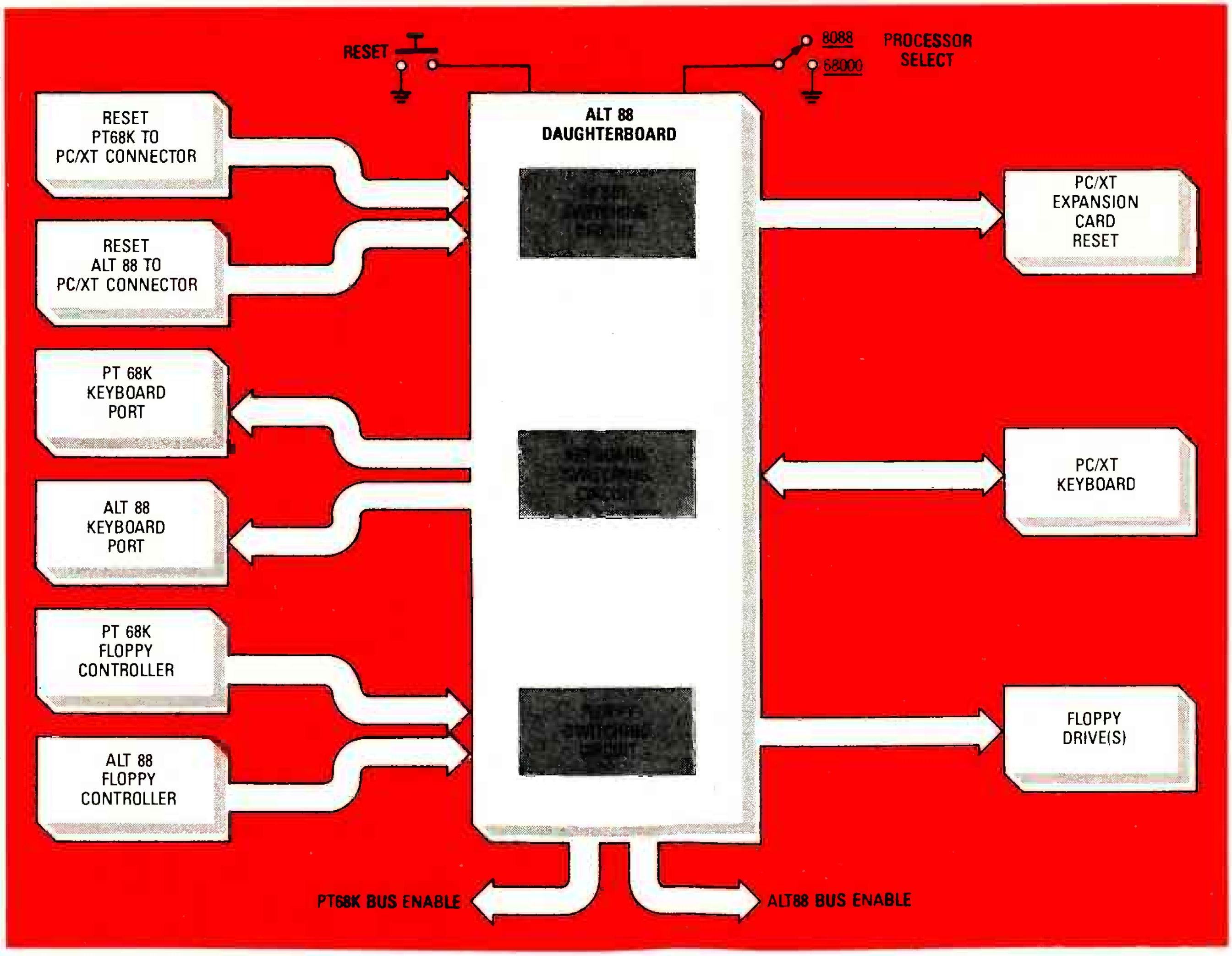


FIG. 1—A SMALL DAUGHTERBOARD is at the core of the 8088/68000 adapter. It provides a system reset, as well as processor, keyboard, and floppy-disk drive selection.

card. The features of the ALT88 are summarized in Table 1.

Ideally, you'd like to plug the ALT88 into the PT-68K and start running IBM programs immediately. Unfortunately, that is not possible; some minor surgery must be performed on the motherboard. Ten traces must be cut, and fifteen jumpers must be added. We'll present complete step-by-step directions for doing so, but if you're nervous about doing the modifications yourself, they can be done for you for a nominal fee (see note in Parts List). Future versions of the PT-68K motherboard will not require those modifications.

Hardware requirements

To run the ALT88 board in a PT-68K, you need a monochrome or color/graphics adapter and appropriate monitor, a PC clone keyboard, a 40-track (360K) floppy-disk drive for booting MS-DOS, and a PC/XT floppy-disk controller. You can use a high-density drive or a 3.5-inch drive, but you must have an appropriate disk controller, as well software in the appropriate disk format.

The ALT88 has only 256K of memory, so you may want to add a memory or multi-function card with 384K, to bring your PC up to the 640K limit. A multi-I/O card with serial, parallel, and game ports, and a clock and floppy-disk controller is highly desirable for purposes of saving expansion slots. The basic kit (the PACK88) includes an unpopulated memory card; a Multi I/O card with serial, parallel, and game ports, and a floppy-disk controller; DOS 3.30, and all required cables. The ALT88 is also available separately, if you prefer to purchase your own memory and I/O adapter.

Although any IBM-compatible hard-disk controller may be used with the ALT88, if you wish to use the controller with both the 8088 and the 68000, a Western Digital model XT-GEN controller must be selected. Even if you do share controllers, however, the hard disk itself may not be shared between the PT-68K and the ALT88. A separate drive is required for use with each processor.

The ALT88 uses the Award BIOS, which has an outstanding reputation for reliability, compatibility, and problem-free operation.

MS-DOS vs. PC-DOS: Many people are unaware of the differences between PC-DOS and MS-DOS. PC-DOS is sold by IBM; MS-DOS is available from other manufacturers. The main difference between the two is the BASIC interpreter supplied with each. Part of IBM's BASIC, called BASICA, is burned in the machine's ROM; the other part is loaded from disk. BASICA will not run on non-IBM PC's, because they don't have the BASIC ROM's.

The BASIC interpreter included with MS-DOS is usually

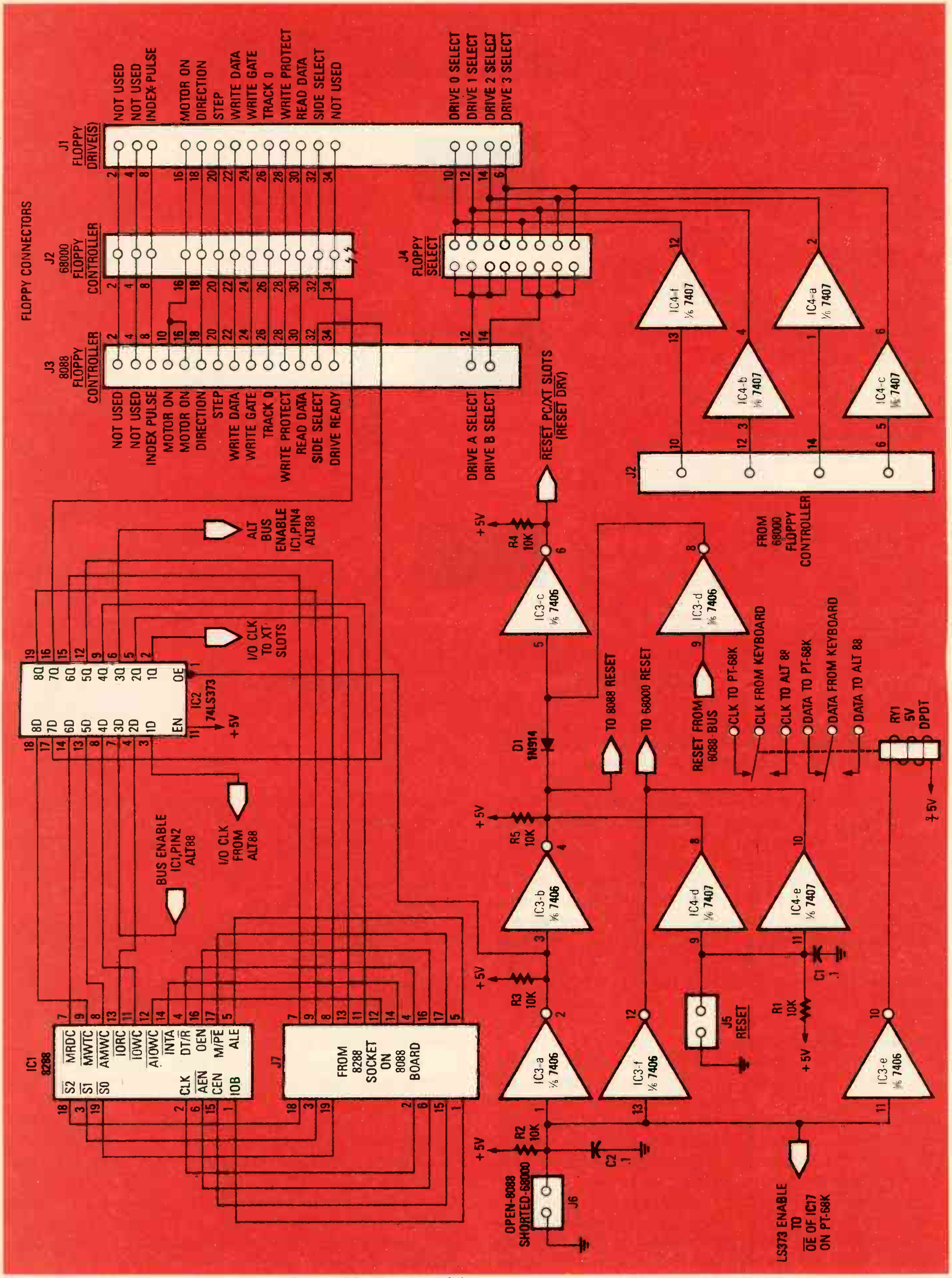


FIG. 2—SCHEMATIC OF THE DAUGHTERBOARD: The 8288 (IC1) is removed from the 8088 card and relocated to the daughterboard, which then plugs into the vacant socket card via J7.

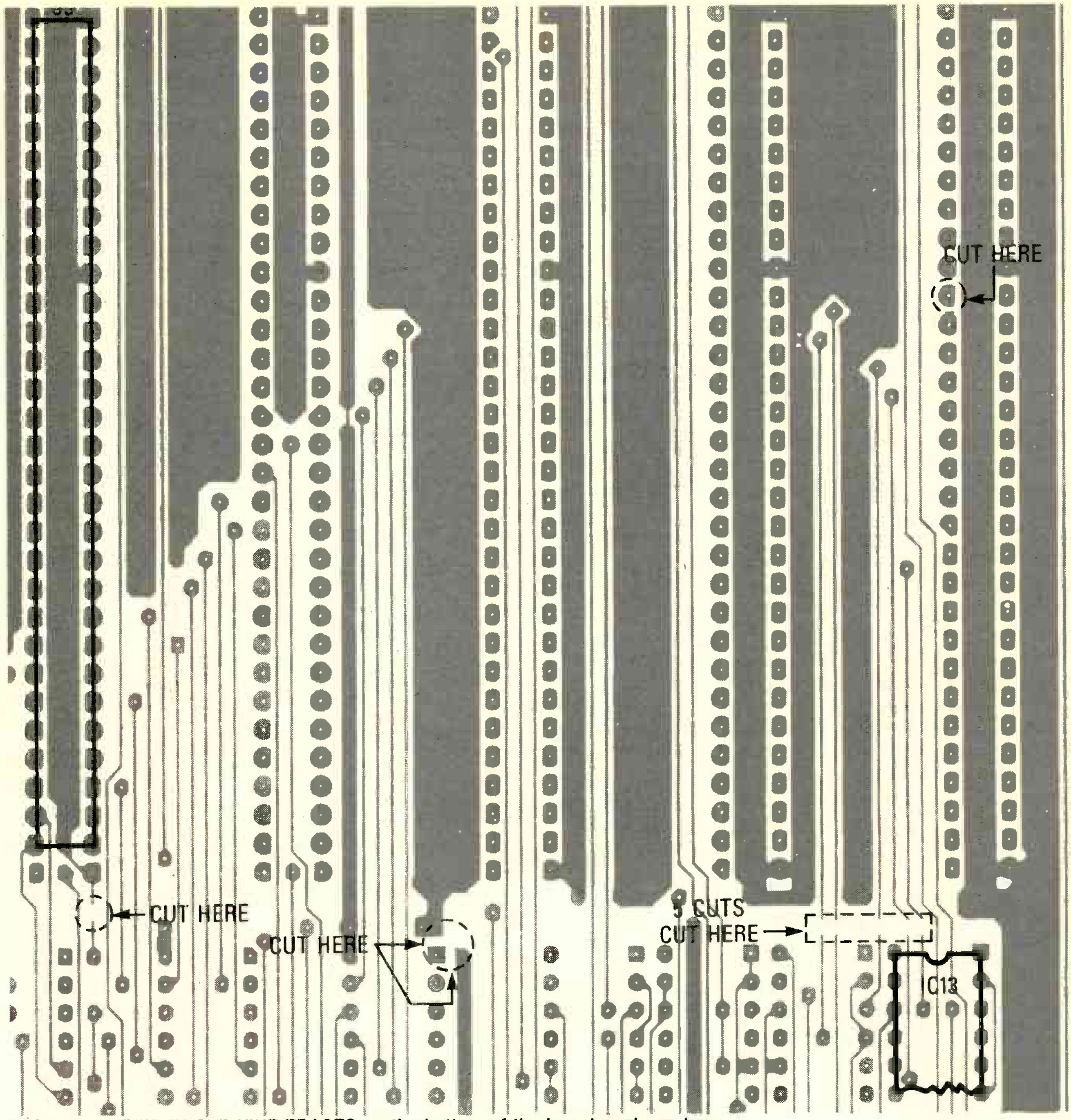


FIG. 3—CAREFULLY CUT NINE TRACES on the bottom of the board as shown here.

called GW-BASIC; it is loaded entirely from disk, so it will run on just about any PC compatible. MS-DOS also includes a manual on the language; the corresponding manual is an extra-cost option from IBM..

The problems

Several problems must be resolved in order for both the 8088 and the 68000 to share the bus and peripherals.

When one microprocessor is active, the address, data, and control lines of the other must be three-stated so they will not interfere with the active processor. In addition, the IBM keyboard must be switched between the two processors. Further, the floppy-disk drives require additional drive-select circuitry so that they may be used in both environments. A small daughterboard attached to the ALT88 allows you to control the appropriate bus signals, keyboard, and floppy-disk drives. Display adapters, hard-disk controllers, and other expansion cards can be shared without modification.

The solutions

To share the bus and peripheral devices between the PT-68K and the ALT88, several circuits must be accounted for. First, we must be able to enable and disable the bus buffers of both environments. Second, we must be able to switch the keyboard between the two. Third, we must provide a means of decoding floppy-disk drive selects for both environments. Fourth, we must provide a master reset circuit. Fifth, we must provide a means of switching environments. Figure 1 summarizes those requirements.

The bus: To allow the PT-68K buffers that drive the XT expansion slots to be three-stated, we must modify the system board. The modifications require buffering several signals through spare latches in IC17, a 74LS373. The relevant portion of the schematic was shown in Fig. 5 of the PT-68K article that ran in the April 1988 issue of Computer Digest.

As shown in that article, latches IC17, IC18, and IC19 have an output-enable signal that is tied to ground. If that enable line can be controlled by the ALT88, the PT-68K bus signals can be disabled, so the ALT88 can have access to the bus and the devices on it.

The daughterboard also switches several signals on the 8088 card to allow it to three-state its lines when the 68000 has control of the bus.

The keyboard: Some keyboard signals (clock and data) are bidirectional, so it is difficult to switch the keyboard electronically. Therefore, as shown in Fig. 2, we use a miniature DPDT relay that can be controlled by a TTL-level signal. It is not necessary to switch the power and ground connections to the keyboard.

You must plug the keyboard into the back of the ALT88 board. The keyboard signals are then routed to either the ALT88 or the PT-68K, depending on which one is selected. An additional cable runs from the daughterboard to the normal keyboard connector on the PT-68K.

Floppy-disk decoding: Because of an anomaly in the way the PC's floppy-disk controller is initialized, additional logic is required to allow floppy drives to be shared. The controller has open-collector outputs, but unfortunately leaves SIDE SELECT low when the card is initialized. Therefore, that signal is routed to an additional buffer on the daughterboard, thereby allowing the signal to be three-stated when the 68000 has control.

On the 68000 side, the drive selects must be converted to open-collector outputs by a 7407. In addition, a jumper block is included so that you can assign the floppy-disk drives in both environments to be whatever you want.

PARTS LIST

R1–R4—10,000 ohms, ¼ watt, 5%
C1, C2—0.1 µF
IC1—8288 bus controller (from 8088 card)
IC2—74LS373 octal three-state latch
IC3—7406 hex inverter
IC4—7404 hex buffer
J1–J3—34-pin dual-row header strip
J4—12-pin triple-row header strip
J5, J6—2-pin header strip
J7—20-pin wirewrap socket
RY1—5-volt miniature DPDT relay

Note: The following items are available from Peripheral Technology, 1480 Terrell Mill Rd., Suite 870, Marietta, GA 30067 (404) 984-0742. Due to unstable market conditions, RAM is not included in any prices below; please contact us for current pricing. PACK88 (8088 coprocessor, DOS 3.3, Multi-I/O board, unpopulated 576K RAM board, all cables, assembled and tested): $399. PACK88-KIT (same as PACK88, but unassembled): $379. ALT88 (8088 card, floppy-disk controller card, all cables): $250. MS-DOS 3.30 with GW-BASIC: $95. Motherboard modification: $25. Other accessories (disk drives, monitors, etc.) are available; write or call for more information. All orders add $5.00 shipping per item; Georgia residents add appropriate sales tax.

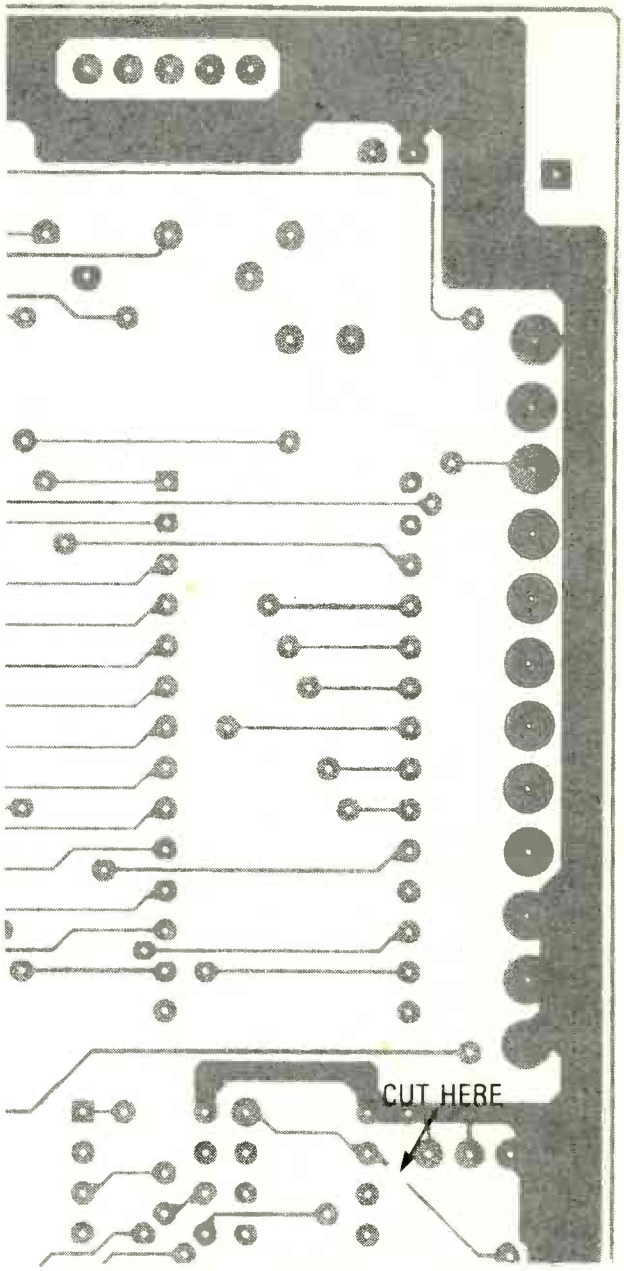


FIG. 4—CAREFULLY CUT ONE TRACE on the top of the board as shown here.

The PC disk controller will select only one of two drives at a time. However, the jumper block allows you to connect any of the PT-68K's four drive-select lines to either controller-select line. That would allow, for example, a PT-68K to have two 80-track drives configured as drives 0 and 1. A 40-track drive could then be configured as drive-2 to the PT-68K, but, via the jumper blocks, as Drive-A (the first drive) to the PC controller.

Reset: The reset circuit on the daughterboard will reset whichever microprocessor happens to be active. Meanwhile, the inactive processor is held in the reset state to prevent interference with expansion-bus signals.

Environment: Last, let's discuss the circuit that selects the active microprocessor. When the pins at J6 are open, the ALT88 processor is selected, the ALT88 I/O drivers are enabled, the keyboard is connected via RY1 to the ALT88, and the floppy-disk drive is connected to the ALT88. In

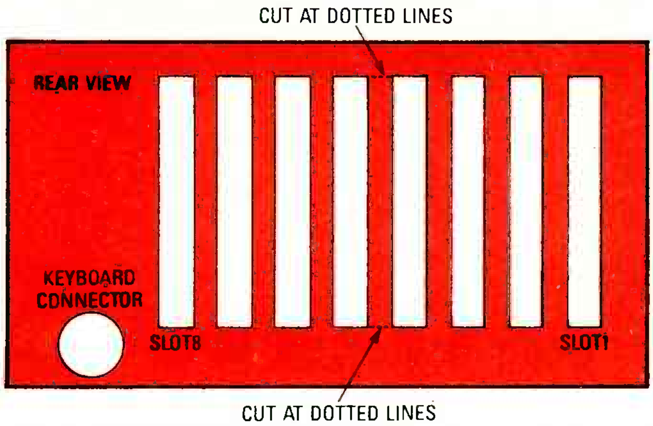


FIG. 5—CUT THE REAR CHASSIS PANEL between slots four and five as shown here to provide clearance for the ALT88.

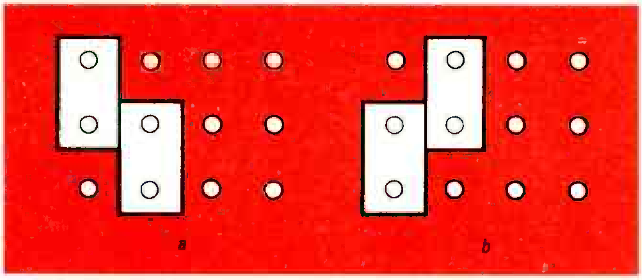


FIG. 6—FLOPPY-DISK DRIVE CONFIGURATION: Use the setup at (*a*) for two 40-track drives, and the setup at (*b*) for one 80-track drive and one 40-track drive. The 80-track drive will respond as drive 0 to the PT-68K and as drive B to the ALT88. The 40-track drive will respond as drive A to the ALT88 and as drive 1 to the PT-68K.

addition, the PT-68K's expansion I/O drivers are disabled, and the 68000 is held in reset.

On the other hand, when the pins at J6 are shorted, the ALT88 is held in reset, and its I/O drivers are disabled. In addition, the 68000's reset line is cleared, its I/O drivers are enabled, and the keyboard and floppy-disk drives are switched to it.

Modifying the PT-68K

A total of ten traces must be cut on the PT-68K's motherboard: Nine on the back, and one on the front. It is recommended that a sharp hobby knife be used to make the incisions. Refer to Fig. 3 for the locations of the nine cuts to be made on the back of the board.

1—Cut the five traces near IC13.

2—Cut J1 (AEN) free from the ground plane.

3—Cut pin 1 of IC17 free from the trace that passes through it. Doing so requires two cuts that should be made close to pin 1 of the IC.

4—Cut the trace shown near J5.

The next trace is cut on the top side of the board, as shown in Fig. 4.

TABLE 2—ALT88 BOOT ERROR MESSAGES

101	ALT88 system board error
201	Memory error during initial test
301	Keyboard error
601	Floppy controller error
Parity check	Indicates memory failure

5—Cut the trace between pin 15 of IC7 and C6.

Wire jumpers must now be installed between several points on the PT-68K system board. 30-gauge wire-wrap wire should be used to make the modifications. The wires should be soldered securely to the connection points. The PC expansion connectors are numbered from 1 to 31 from the back of the chassis to the front. The left row (facing from the front) comprises the "B" connectors; the right row, the "A."

1—Connect pin 8 of IC13 to pin 10 of IC7.

2—Connect pin 3 of IC14 to pin 7 of IC17.

3—Connect pin 6 of IC14 to pin 4 of IC17.

4—Connect pin 8 of IC14 to pin 3 of IC17.

5—Connect pin 11 of IC14 to pin 14 of IC7.

6—Connect pin 10 of IC17 to the grounded pin of J3.

7—Connect pin 6 of IC17 to pin B13 ($\overline{\text{IOW}}$) of J4.

8—Connect pin 5 of IC17 to pin B14 ($\overline{\text{IOR}}$) of J3.

9—Connect pin 2 of IC17 to pin B11 ($\overline{\text{MEMW}}$) of J3.

10—Connect pin 1 of IC18 to pin 1 of IC19.

11—Insert and solder a one-pin header in the top side of the board through the feed-through closest to pin 1 of IC19.

12—Connect pin 1 of IC19 to pin 1 of IC7.

13—Connect pin 9 of IC7 to pin B20 ($\overline{\text{I/O-CLK}}$) of J6.

14—Connect pin 11 of IC7 to pin A11 (AEN) of J6.

15—Connect pin 12 of IC7 to pin 8 of IC7.

16—Connect pin 13 of IC7 to pin B12 ($\overline{\text{MEMR}}$) of J6.

The 8088 board must also be modified; however, we will not discuss the details here. The price of PACK88 includes the cost of making all modifications. If you insist on modifying the board yourself, the PACK88-KIT includes the appropriate instructions.

Initial testing

Important note: The header pin near IC19 must be grounded if you wish to use the PT-68K without the ALT88 installed. You can wrap a piece of wire-wrap wire around the pin and attach the other end to a convenient ground.

Turn the PT-68K on and check for proper operation. No discernible difference should be noted in the operation of the keyboard and video system. If the PT-68K system board fails to work properly, recheck the cuts and jumpers. A common mistake is improperly connecting the jumpers on the back side of the board. When everything works as normal, the ALT88 board can be installed.

Installing the ALT88

1—Install nine 256K DRAM's in the sockets (IC9, IC10, IC18–IC21, IC27, IC28 and IC35) on the 8088 card.

2—Set the DIP switches on the ALT88 board according to the type of video system you have. With a C/GA, switch-5 should be on and switch-6 should be off. With a monochrome adapter, both should be off. You can install an EGA adapter in the system, but it will only work in the 8088 environment, not the 68000 environment, which requires a C/GA or monochrome video adapter, or an RS-232 ASCII terminal.

3—Connect the signal called "LS373 Enable" from the ALT88 board to the header pin near IC19 on the PT-68K system board.

4—Connect the signal called "68000 Reset" to pin 1 of J23 on the PT-68K system board. Pin 1 of J23 is located near IC61.

5—To provide room for the ALT88, remove the metal support bracket between I/O slots four and five on the rear of the cabinet, as shown in Fig. 5. (Slots are numbered one through eight from left to right, facing the front of the machine.)

6—Plug the ALT88 into slot four, and the floppy-disk controller card into slot three. If you use a multi-I/O card rather than a separate floppy controller, it should be plugged into slot three.

7—Unplug your PC keyboard from the PT-68K system board, and plug it into the back of the ALT88 board. Then insert the plug from the ALT88's daughterboard into the connector on the PT-68K system board.

8—Unplug the floppy-disk data cable from J7 on the PT-68K system board, and plug it into J1 on the ALT88 daughterboard. Observe pin 1 orientation.

9—Plug a short 34-pin cable from J2 on the ALT88 to J7 on the PT-68K. Observe pin 1 orientation.

10—Plug a card-to-socket cable between the PC floppy-disk controller and J3 of the ALT88. That cable is included with the ALT88.

11—Connect the pins at jumper block J6 on the ALT88 to an SPST switch. That switch selects the active processor. If you're using a baby AT case, we suggest using either the Turbo switch or the key switch on the computer's front panel for that purpose.

12—Connect the RST line on the ALT88 board to a reset switch. That switch will reset either processor, depending on which is active.

13—Configure the jumper block to assign drive selects. Figure 6-*a* shows the setup for two 40-track drives that will respond as drives 0 and 1 to the PT-68K and as drives A and B to ALT88. Figure 6-*b* shows the setup for one 80-track drive and one 40-track drive. That way, the 80-track drive will respond as drive 0 to the PT-68K and as drive B to the ALT88. The 40-track drive will respond as drive A to the ALT88 and as drive 1 to the PT-68K.

Booting DOS

The switch across J6 should be open to select the ALT88. Insert an MS-DOS system diskette in drive A, and turn on the power. If all is well, a BIOS copyright notice will appear and a memory test will execute. Then the ALT88 will boot MS-DOS from Drive A. If an error message is displayed during the boot process, refer to Table 2 for an explanation.

Installation and testing are now complete. Have fun and enjoy using your dual-processor system. R-E

INTEL

continued from page 95

repeating move instructions, and ASCII-to-decimal conversion instructions.

Interrupts and exceptions

The 386, 386SX and 376 Microprocessors can handle as many as 256 different interrupts and exceptions. The first 32 are reserved; some of those are used to report special internal exceptions.

Hardware interrupts that are caused by asynchronous external events must be distinguished from exceptions that are caused by instruction faults. As with the 8088/86 and 80286, the INT instruction generates a software interrupt; however, the 386 treats it internally as an exception known as a trap.

Actually, there are three types of exceptions; faults, traps, and aborts. Faults are exceptions that are detected prior to the execution of an instruction. When a fault occurs, a service routine corrects the cause of the fault, and returns to execute the instruction. A trap is reported immediately following the execution of the instruction that caused a problem. An abort is an exception in which the cause cannot be located precisely.

Also like the earlier generation, the microprocessor has two hardware interrupts: NMI and IRQ. The NMI input cannot be masked (temporarily disabled), but the IRQ input can. R-E

HARDWARE HACKER

continued from page 85

is in all the touch-tone chips used in telecommunications. But that is a very general technique with outstanding hacker potential.

More details on all that appear in my *CMOS Cookbook*, while all the hairy math behind it appeared in *Digital Generation of Low Frequency Sinewaves* by A. C. Davies, way back in the June 1969 *IEEE Transactions IM18, Number 2*.

For our contest this month, just dream up a new or unusual use for digitally generated sine waves, or else a unique way of doing the actual digital sine-wave generation. Paper designs are just fine. As per usual, there will be twenty *Incredible Secret Money Machine* books for the better entries, and an all-expense paid (FOB Thatcher, AZ) tinaja quest for the very best of all.

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Optical and infrared filters

If you are interested in improving the contrast of ordinary red, orange, or yellow LED displays, check out *Ulano* and ask them for some free samples of their *Rubylith* and *Amberlith* products. One sample book is enough for years of hacking.

Whenever you build an infrared remote control, it is very important to shield the receiver's photodetector from all but the transmitted infrared control signals. Otherwise, sunlight or room illumination will swamp the input and either saturate you or else give you errors.

Several hackers have asked me where you go to get suitable infrared filter material.

Well, *Rohm and Haas* makes a special *2711 Plexiglas* optimized for IR remote-control filtering. The good news is that it costs around a nickel per square inch. The bad news is that they're sold by the humongous sheet rather than by the square inch. One distributor is *Read Plastics*. Yes, they will cut.

For some real infrared filters at real infrared-filter prices ($32 each) check out *Rolyn Optics*, in particular their model 65.1385. Another possible source for filter material is *Infrared Industries*.

New tech lit

Free sample strips of most of the common engineering thermoplastics are available on a card from *Polymer/Polypenco*. Low-cost electroluminescent lamps in a variety of colors are available through *Luminescent Systems*. A $50 evaluation kit of fourteen different stick-on thin-film power heaters is available from *Minco*.

If you are into surface mounting at all, new low-cost capacitor and resistor kits are now available from *Communications Specialists*. The resistors cost three cents each; the capacitors around thirteen.

Texas Instruments now has a data sheet on the new TLC32040 Analog Interface Circuit. That dude combines both a fast 14-bit A/D and a faster D/A converter on a single chip, along with all of the needed filters and the sample-and-hold stuff. Cost is around $30.

Steve Ciarcia's new *Circuit Cellar Ink* magazine is going great guns and is an absolute must for the serious hardware hacker. Meanwhile, Craig Anderton's *Electronic Musician* magazine is also really taking off. Included are hands-on MIDI construction projects. If you are into fancy optics, there's a trade journal by the name of *Lasers and Optronics* that you might want to try and qualify for.

Turning to my own products, the *Hardware Hacker Volume II* is now shipping and contains edited and updated reprints of all of my *Radio-Electronics* stuff so far, along with additional examples of Postscript goodies. Also available are my *Ask The Guru* reprints, volumes I and II from my sister column to this one over in *Computer Shopper*. Write or call if you need any additional info. **R-E**

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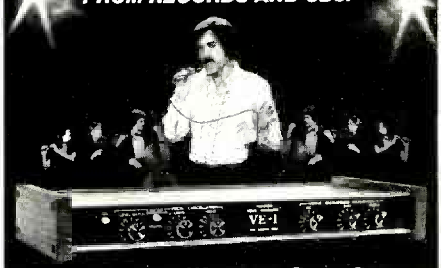

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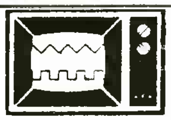

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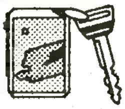

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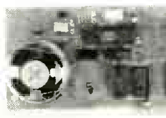

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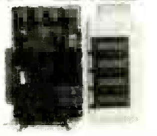

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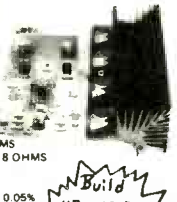

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*LOAD IMPEDANCE 4 OHMS OR 8 OHMS
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*TOTAL HARMONIC DISTORTION LESS THAN 0.05%
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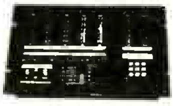
Build up your supreme Power Amp!

PROFESSIONAL COLOR LIGHT CONTROLLER SM—328 ☆



FEATURES
1. FOUR GROUPS OF INDEPENDENT OUTPUT SYSTEM1000W/CH MAX. 4680W (100 117V) 2. PROFESSIONAL COLOR CONTROL SYSTEM (KEY-BOARD TYPE) 3. INDEPENDENT INPUT SIGNAL ADJUSTMENT 4. FOUR GROUPS OF INDEPENDENT DIMMER CONTROL 5. SPEED CONTROL CHASER 6. AUTOMATIC CHASING CONTROL SYSTEM 7. FOUR KINDS OF SPECIAL CHASING PROGRAM 8. COMBINATION OF PROGRAM AND MUSIC CHASING EFFECT 9. FORWARD/BACKWARD CHASING CONTROL

SM-328 color light controller is specialized for ballroom, night club disco and advertisement lighting. It consorts with several color control characteristics, which employ professional color control system and keyboard program selection. Therefore, it is capable of producing lighting effects by using chasing program and fluctuating music signal. There are two kinds of lighting effects. The first type is controlled by 'music' signal. In order to adjust the brightness of four groups of lightings, each music signal will be separated into high, medium low A, and low B frequency range. Furthermore, each group of lightings is incorporated with an independent signal adjustment. The second kind is composed of electrical circuits and this is the main part for creating a special lighting effect. It has four chasing programme.
Dimans-ons: 14 5/16" x 8 15/16" x 3 3/16"
Ass. AND tested .... $150.00 ONLY

VIDEO/AUDIO SURROUND SOUND PROCESSOR SM—333 △△

It's a must for every modern family!

It creates high-quality simulated stereo Surround "Music Field" for most video types CD, LD, Surround Sound Encoding Disks, tapes, & etc.
This processor employs the most updated IC at its heart. It is also equipped with a "DNR" DYNAMIC NOISE REDUCTION SYSTEM IC made by NATIONAL SEMICONDUCTOR to particularly filter out the annoying noise that is commonly found on tapes or CD disk. In addition, there is six LOW NOISE OP—AMPS and all in one board design, no other external connections connect to the main board.

Other features include:
• Continuous Variable Audio Time Delay • Surround Effect & Level Control • Dynamic Noise Reduction System • High output signal (8.6V MAX) can match with any kind of Main Power Amp. • All metal construction for reliability & durability!

SPECIFICATIONS.
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KIT/ASSM WITH TESTED $72/93

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A versatile laboratory bench digital counter with FIVE FUNCTION performance FREQUENCY PERIOD UNIT (TOTALIZE) DATA HOLD & SELF CHECK
The period function makes the instrument outstanding for video tape (vcr) service applications. 0.5 Bright LED display assure easy readability of values. High stabilized dual crystal oscillators are used to ensure the accuracy in measurement. Durable alloy cabinet with a fancy looking panel. Comes complete with test lead and owners manual.
FEATURES
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Input sensitivity 10Hz 100MHz (10mV 32mV)
100MHz 1.2GHz (5mV 20mV)
Period range 0.5uS 10S
Unit counting capacity 99999999
Accuracy ±1 count ±time base accuracy
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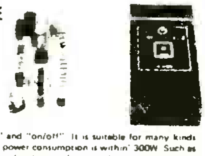

It has two modes of operation "Continuous" and "on/off". It is suitable for many kinds of electrical and electronic applications whose power consumption is within 300W. Such as light control, garage door opener, TV on/off, burgler alarm and many others.

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ASSM AND TESTED $35
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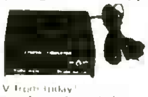
STEREO SIMULATOR TA-3000 △△

UP GRADE YOUR TV & VCR



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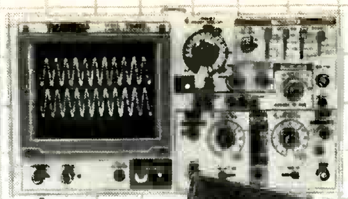


TENMA® Dual Trace 35MHz Oscilloscope

■ Dual trace model capable of displaying signals up to 35MHz ■ Versatile enough for use in production, service, and design ■ Employs a metal-back-post-accerated CRT for accurate reproduction of a wide band width

TENMA® Rotary DMM

■ A full function 3½ digit DMM with a rotary dial for rapid selection of functions and ranges ■ Measures AC/DC voltage and current; as well as resistance

For more specifications and Test Equipment see pages 8-23 of Catalog #19

Super Wash

■ Powerful spray cleans intricate electronic assembly without harming plastics ■ Dries instantly

Circuit Cooler

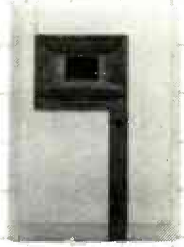
■ Cools circuits instantly for rapid location of heat related problems ■ Will not leave residue

For more Chemicals see pages 24-27 of Catalog #19

TENMA® Soldering Station

■ Adjustable temperature range of 150°-420°C (300°-790°F) ■ Grounded tip for soldering static sensitive devices ■ Overheat protection with closed loop temperature control ■ Replaceable iron clad tip ■ Improved circuit design for greater temperature stability

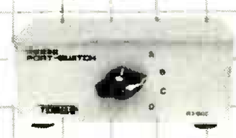
Catalog #19 contains other Soldering Equipment on pages 37-39



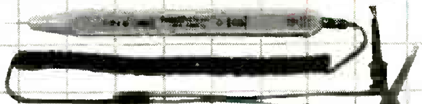
RS-232 Type Port Switches

■ All pins switched pin for pin

Four-Way



For more Computer Equipment see pages 42-52 of Catalog #19



Logic Probe with Memory

This compact and lightweight probe recognizes high, intermediate, and low level pulses in DTL, TTL, HTL, and CMOS logic circuits.

TENMA® Passive Infrared Detector

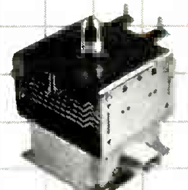
■ Contemporary design, in neutral gray color ■ Blends well with any decor or environment ■ Protects a 40 x 40 foot area

Additional Alarm Equipment may be found on pages 117-119 of Catalog #19

VCR Battery Pack

■ Fits many RCA and Panasonic portable VCRs ■ Replaces RCA battery #149722 and Panasonic #LCR1812 ■ Lead-acid type ■ 12V, 1.9Ah

For more VCR parts see pages 71-83 in Catalog #19



Replacement Magnetron

■ A quality replacement for many magnetrons on the market ■ Intended for use in microwaves of 600-700 watts, 950 watts maximum

Catalog #19 contains additional Microwave Oven Parts on page 125

TENMA® 15" Polypropylene Woofer

■ Poly cone with polyfoam surround ■ Display packaged ■ Made in USA

Magnet weight: 60 oz.
Power handling: RMS/peak 100W/144W
Frequency response: 20-3500Hz

For more Woofers see pages 102-108 of Catalog #19

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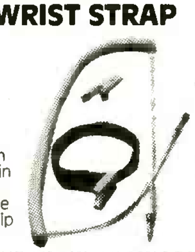

* Fully adjustable for maximum comfort
* Patented closure system
* Fully effective static drain
* One size fits all
* Complete with retractile grounding cord with clip

ACT NO: 69264

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* Protect sensitive equipment from power irregularities
* Six three-prong sockets for maximum flexibility
* Lighted on/off switch and reset button
* UL listed

ACT NO: 84017

WELLER 35 WATT PROFESSIONAL SOLDERING IRON

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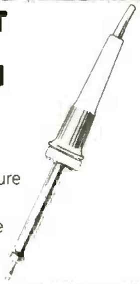

* Develops 400°C tip temperature
* Stainless steel barrel construction
* Complete with 3.17mm double coated tip
* Ultra-comfortable handle

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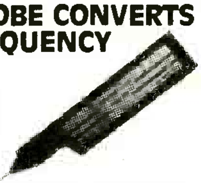

* Accurate ±0.5%
* No power required – and works with any DVM
* Measures from 200Hz to 2MHz
* Coaxial test leads included
* Ideal for QC, service or hobby applications

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* Reinforced stress points
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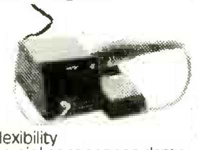

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* Self-feeding water reservoir keeps sponge damp
* Excellent temperature regulation
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* Storage for up to 6 tips

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* Measures time constant with keypad input
* Display hold function
* Also identifies transistors, zener diodes
* And more, too

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WO8M	10509	2/1.43
2KBPC10M	10511	2/1.47
KBPC102	10008	2/2.08
KBL02	10002	2/2.83
KBL04	10055	1.47
KBL06	10056	1.58
KBPC602	10493	1.47
KBPC606	10082	1.36
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1N4734ATR	01094	5/1.03
1N4735ATR	01095	5/1.03
1N4736ATR	01301	5/1.03
1N4739A	01098	5/1.03
1N4744ATR	01101	5/1.03
1N5221B	01349	6/1.03
1N5231BTR	01359	6/1.03
1N5234BTR	01362	6/1.03
1N5240BTR	01368	6/1.03
1N5242BTR	01370	6/1.03
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4051BPC	08525	2/1.25
4052BPC	08530	2/1.25
4053BPC	08535	2/1.25
4060BPC	08540	2/1.25
4066BPC	08545	3/1.03
4069UBPC	08565	4/1.25
4070BPC	08575	4/1.25
4071BPC	08580	4/1.25
4081BPC	08615	4/1.25
4093BPC	08630	2/1.03
4099BPC	08640	2/1.64
4503BPC	08650	2/1.03
4508BPC	08655	1.65
4510BPC	08660	2/1.36
4511BPC	08665	2/1.50
4514BPC	08675	1.58
DIODES		
1N914BTR	01160	25/1.03
1N4001TR	01411	25/1.03
1N4002	01412	25/0.97
1N4003TR	01413	25/1.03
1N4004TR	01414	20/1.03
1N4005TR	01415	20/1.03
1N4007TR	01416	15/1.00
1N4148	01165	25/1.03
1N5402	01186	3/1.03
1N5404TR	01150	4/1.03
1N5406TR	01119	3/1.03
1N5817TR	01244	2/1.47
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7806U	09431	3/1.58
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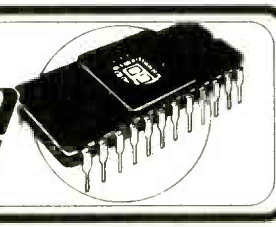

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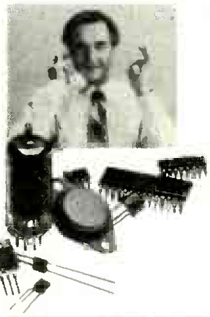

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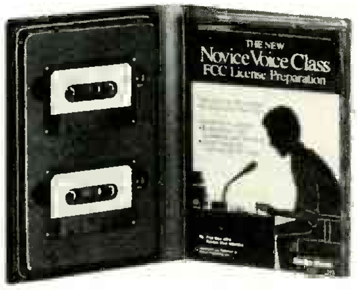

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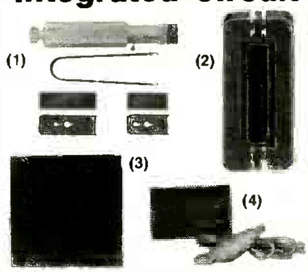

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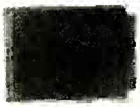

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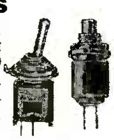

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Submini SPST Momentary. 0.5A at 125VAC. Normally open. ⅜" mtg. hole. #275-1571..Set of 2/2.39

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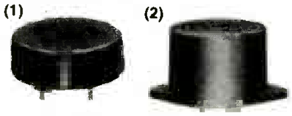

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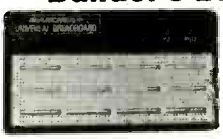
Builder's Breadboard



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Our Finest Model

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10-megohm sensitivity! Measures to 1000 AC/DC volts, to 10 DC amps, to 100 megohms and decibels. Requires one 9V and one "C" battery. #22-220

"Pro" Soldering Station

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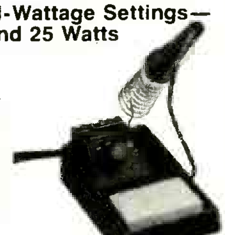
Dual-Wattage Settings—15 and 25 Watts



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7400

Part No.	1-9	10+	Part No.	1-9	10+
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7402	.29	.19	7486	.45	.35
7404	.29	.19	7489	1.95	1.85
7405	.35	.25	7490	.49	.39
7406	.39	.29	7493	.45	.35
7407	.39	.29	74121	.39	.29
7408	.35	.25	74123	.49	.39
7410	.29	.19	74125	.55	.45
7414	.49	.39	74126	.55	.45
7416	.35	.25	74143	4.95	4.85
7417	.35	.25	74150	1.35	1.25
7420	.29	.19	74154	1.35	1.25
7430	.29	.19	74158	1.49	1.39
7432	.39	.29	74173	.79	.69
7438	.39	.29	74174	.59	.49
7442	.49	.39	74175	.59	.49
7445	.79	.69	74176	.79	.69
7446	.89	.79	74181	1.95	1.85
7447	.89	.79	74189	1.95	1.85
7448	1.95	1.85	74193	.79	.69
7472	.39	.29	74198	1.85	1.75
7473	.39	.29	74221	.99	.89
7474	.39	.29	74273	1.95	1.85
7475	.49	.39	74365	.59	.49
7476	.45	.35	74367	.59	.49

74LS

74LS00	.26	.16	74LS165	.75	.65
74LS02	.28	.18	74LS166	.89	.79
74LS04	.28	.18	74LS173	.39	.29
74LS05	.28	.18	74LS174	.39	.29
74LS06	.59	.49	74LS175	.39	.29
74LS07	.59	.49	74LS189	3.95	3.85
74LS08	.28	.18	74LS191	.59	.49
74LS10	.26	.16	74LS193	.69	.59
74LS14	.49	.39	74LS221	.69	.59
74LS27	.35	.25	74LS240	.59	.49
74LS30	.28	.18	74LS243	.69	.59
74LS32	.28	.18	74LS244	.69	.59
74LS42	.49	.39	74LS245	.79	.69
74LS47	.89	.79	74LS259	.99	.89
74LS73	.39	.29	74LS273	.89	.79
74LS74	.35	.25	74LS279	.49	.39
74LS75	.39	.29	74LS322	3.49	3.39
74LS76	.39	.29	74LS365	.49	.39
74LS85	.59	.49	74LS366	.49	.39
74LS86	.29	.19	74LS367	.49	.39
74LS90	.49	.39	74LS368	.49	.39
74LS93	.49	.39	74LS373	.79	.69
74LS123	.49	.39	74LS374	.79	.69
74LS125	.49	.39	74LS393	.89	.79
74LS138	.49	.39	74LS590	5.95	5.85
74LS139	.49	.39	74LS624	1.95	1.85
74LS154	1.19	1.09	74LS629	2.49	2.39
74LS157	.45	.35	74LS640	1.09	.99
74LS158	.39	.29	74LS645	1.09	.99
74LS163	.49	.39	74LS670	.99	.89
74LS164	.59	.49	74LS688	2.39	2.29

74S/PROMS*

74S00	.25	74S188*	1.49
74S04	.25	74S189	1.49
74S08	.29	74S196	1.49
74S10	.25	74S240	1.39
74S32	.29	74S244	1.19
74S74	.29	74S253	.59
74S85	.89	74S287*	1.49
74S86	.29	74S288*	1.49
74S124	1.49	74S373	1.49
74S174	.49	74S374	1.49
74S175	.49	74S472*	2.95

74F

74F00	.25	74F139	.59
74F04	.25	74F157	.59
74F08	.25	74F193	2.95
74F10	.25	74F240	.69
74F32	.25	74F244	.69
74F74	.29	74F253	.59
74F86	.39	74F373	.79
74F138	.59	74F374	.79

CD—CMOS

CD4001	.19	CD4076	.59
CD4008	.59	CD4081	.22
CD4011	.19	CD4082	.22
CD4013	.29	CD4093	.35
CD4016	.29	CD4094	.89
CD4017	.49	CD40103	1.49
CD4018	.59	CD40107	.49
CD4020	.59	CD4510	.69
CD4024	.45	CD4511	.69
CD4027	.35	CD4520	.75
CD4030	.35	CD4522	.79
CD4040	.65	CD4538	.79
CD4049	.29	CD4541	.89
CD4050	.29	CD4543	.79
CD4051	.59	CD4553	3.95
CD4052	.59	CD4555	.79
CD4053	.59	CD4559	7.95
CD4063	1.49	CD4566	1.95
CD4066	.29	CD4583	.59
CD4067	1.49	CD4584	.49
CD4069	.19	CD4585	.69
CD4070	.25	MC14411P	7.95
CD4071	.22	MC14490P	4.49
CD4072	.22		

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Part No.	Price
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WD9216	3.95
Z80, Z80A, Z80B SERIES	
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Z80-CTC	1.29
Z80-PIO	1.29
Z80A	1.29
Z80A-CTC	1.65
Z80A-DART	4.95
Z80A-PIO	1.89
Z80A-SIO/0	3.95
Z80B	2.75
Z80B-CTC	3.95
Z80B-PIO	3.95
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6502	2.65
65C02 (CMOS)	7.75
6520	1.95
6522	2.95
6532	5.49
6551	2.95
65C802 (CMOS)	15.95
6800	1.95
6802	2.95
6810	1.25
6821	1.75
6840	3.49

6500/6800/68000 Cont.

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6850	1.95
6852	.75
6854	1.19
MC68000L8	9.95
MC68000L10	11.95
MC68010L10	49.95
MC68020RC12B	99.95
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80C31	9.95
8035	1.49
8073	6.95
8080A	2.25
8085A	2.49
8086	3.95
8086-2	6.95
8087 (5MHz)	99.95
8087-1 (10MHz)	229.95
8087-2 (8MHz)	159.95
8088	4.95
8088-2	6.95
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8155	2.49
8155-2	3.49
8156	2.95
8203	6.95
8212	2.29
8224	2.25

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8253-5	1.95
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8255A-5	2.95
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8751 (3.5-8MHz)	39.95
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ADC0804LCN	2.79
ADC0808CCN	5.95
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ADC1205CCJ-1	19.95
DAC0808LCN	1.75
DAC1008LCN	5.95
AY-3-1015D	4.95
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Part No.		Price
8052AHBASIC	CPU w/BASIC Interpreter	$24.95
MC68000P12	16-Bit MPU (12MHz)	$12.95
MC68701	8-Bit EPROM Microcomputer	$14.95
MC68705P3S	8-Bit EPROM Microcomputer	$9.95
MC68705U3S	8-Bit EPROM Microcomputer	$10.95
80286-10	16-Bit Hi Performance MPU	$69.95
80287-8	Math Co-processor (8MHz)	$244.95
80287-10	Math Co-processor (10MHz)	$309.95
80387-16	Math Co-proc. (16MHz) GRID ARRAY	$474.95
80387-20	Math Co-proc. (20MHz) GRID ARRAY	$749.95

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Part No.			Price
*4116-15	16,384 x 1	(150ns)	1.39
4128-20	131,072 x 1	(200ns) (Piggyback)	3.25
*4164-100	65,536 x 1	(100ns)	3.49
*4164-120	65,536 x 1	(120ns)	2.95
*4164-150	65,536 x 1	(150ns)	2.59
*4164-200	65,536 x 1	(200ns)	1.75
*TMS4416-12	16,384 x 4	(120ns)	7.75
*41256-80	262,144 x 1	(80ns)	13.49
*41256-100	262,144 x 1	(100ns)	12.49
*41256-120	262,144 x 1	(120ns)	11.95
*41256-150	262,144 x 1	(150ns)	11.49
*41464-15	65,536 x 4	(150ns) (4464)	14.75
*511000P-10	1,048,576 x 1	(100ns) 1 Meg	39.95
*514256P-10	262,144 x 4	(100ns) 1 Meg	59.95
STATIC RAMS			
*2016-12	2048 x 8	(120ns)	4.49
2018-45	2048 x 8	(45ns)	6.95
2102	1024 x 1	(350ns)	.89
2114N	1024 x 4	(450ns)	.99
2114N-2L	1024 x 4	(200ns) Low Power	1.49
21C14	1024 x 4	(200ns) (CMOS)	.49
5101	256 x 4	(450ns) (CMOS)	2.95
*6116P-3	2048 x 8	(150ns) (CMOS)	4.95
*6116LP-3	2048 x 8	(150ns) LP CMOS	5.99
*6264LP-12	8192 x 8	(120ns) LP CMOS	10.49
*6264P-15	8192 x 8	(150ns) (CMOS)	9.95
*6264LP-15	8192 x 8	(150ns) LP CMOS	10.25
6514	1024 x 4	(350ns) (CMOS)	3.75
*43256-15L	32,768 x 8	(150ns) Low Power	15.25
*62256LP-12	32,768 x 8	(120ns) LP CMOS	16.95
EPROMS			
TMS2516	2048 x 8	(450ns) 25V	6.95
TMS2532	4096 x 8	(450ns) 25V	5.95
TMS2532A	4096 x 8	(450ns) 21V	4.49
TMS2564	8192 x 8	(450ns) 25V	6.95
TMS2716	2048 x 8	(450ns) 3 Voltage	6.95
1702A	256 x 8	(1µs)	4.95
2708	1024 x 8	(450ns)	6.95
2716	2048 x 8	(450ns) 25V	3.75
2716-1	2048 x 8	(350ns) 25V	4.25
27C16	2048 x 8	(450ns) 25V (CMOS)	4.25
2732	4096 x 8	(450ns) 25V	3.95
2732A-20	4096 x 8	(200ns) 21V	4.25
2732A-25	4096 x 8	(250ns) 21V	3.95
27C32	4096 x 8	(450ns) 25V (CMOS)	4.95
2764-20	8192 x 8	(200ns) 21V	4.25
2764-25	8192 x 8	(250ns) 21V	3.59
2764A-25	8192 x 8	(250ns) 12.5V	3.69
2764-45	8192 x 8	(450ns) 21V	3.39
27C64-15	8192 x 8	(150ns) 12.5V (CMOS)	5.95
27128-20	16,384 x 8	(200ns) 21V	6.95
27128-25	16,384 x 8	(250ns) 21V	5.95
27128A-25	16,384 x 8	(250ns) 12.5V	5.25
27C128-25	16,384 x 8	(250ns) 21V (CMOS)	5.95
27256-20	32,768 x 8	(200ns) 12.5V	6.95
27256-25	32,768 x 8	(250ns) 12.5V	5.49
27C256-25	32,768 x 8	(250ns) 12.5V (CMOS)	6.25
27512-20	65,536 x 8	(200ns) 12.5V	10.95
27512-25	65,536 x 8	(250ns) 12.5V	9.95
EEPROMS			
2816A-25	2048 x 8	(250ns) 5V Read/Write	6.25
2817A	2048 x 8	(350ns) 5V Read/Write	7.95
2865A-30	8192 x 8	(300ns) 5V Read/Write	9.95
52B13 (21V)	2048 x 8	(350ns) 5V Read Only	1.49

COMMODORE CHIPS

Part No.	Price
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WD1770	8.95
SI3052P	1.25
6504A	1.19
6507	2.95
6510	12.95
6522	2.95
6525	4.95
6526	14.95
6532	5.49
6545-1	3.95
6560	10.95
6567	24.95
6569	15.95
6572	10.95
6581 (12V)	12.95
6582 (9V)	14.95
8502	7.95
8564	4.95
8566	9.95
8701	9.95
8721	14.95
8722	13.95
*251104-04	12.95
310654-05	9.95
318018-03	12.95
318019-03	12.95
318020-04	12.95
325302-01	14.95
325572-01	17.95
*82S100PLA**	15.95
901225-01	15.95
901226-01	15.95
901227-03	15.95
901229-05	15.95

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

74C/CMOS

74C00	.29	74C174	.49
74C02	.29	74C175	.49
74C04	.29	74C221	1.79
74C08	.29	74C240	1.19
74C10	.19	74C244	1.79
74C14	.49	74C373	1.95
74C32	.29	74C374	1.95
74C74	.49	74C912	7.95
74C85	1.49	74C915	1.39
74C86	.29	74C920	4.95
74C89	3.95	74C921	4.95
74C90	.99	74C922	3.95
74C154	2.95	74C923	3.95
74C173	.59	74C925	5.49

MISC. COMPONENTS

TANTALUM CAPACITORS

TM.1/35 .1µf @ 35V	.19	TM4.7/35 4.7µf @ 35V	.45
TM1/35 1µf @ 35V	.19	TM6.8/35 6.8µf @ 35V	.49
TM2.2/35 2.2µf @ 35V	.25	TM10/35 10µf @ 35V	.59

POTENTIOMETERS

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

43PXX ¾ Watt, 15 Turn	.99	63PXX ½ Watt, 1 Turn	.89

TRANSISTORS AND DIODES

PN2222	.13	PN2907	.13	1N4004	.12
2N2222A	.29	2N4401	.12	1N4148	.07
2N3055	.65	1N270	.25	1N4735	.29
2N3904	.12	1N751	.15	C106B1	.49

SWITCHES

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

D-SUB CONNECTORS

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

LEDS

XC556R T1¾, Red	.13	XC556Y T1¾, Yellow	.17
XC556G T1¾, Green	.17	XC556C T1¾, Clear/Red	.17

IC SOCKETS

Low Profile		Wire Wrap (Gold) Level #2	
8LP	.11	8WW	.59
14LP	.12	14WW	.65
16LP	.13	16WW	.69
24LP	.25	24WW	1.19
28LP	.27	28WW	1.39
40LP	.29	40WW	1.89

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

74HC HI-SPEED CMOS

Part No.	Price	Part No.	Price
74HC00	.19	74HC175	.59
74HC02	.19	74HC221	.89
74HC04	.19	74HC240	.69
74HC08	.19	74HC244	.79
74HC10	.25	74HC245	.79
74HC14	.29	74HC253	.49
74HC30	.25	74HC259	.49
74HC32	.29	74HC273	.59
74HC74	.29	74HC373	.69
74HC75	.35	74HC374	.69
74HC76	.35	74HC595	1.29
74HC85	.55	74HC688	1.49
74HC86	.35	74HC943	8.95
74HC123	.69	74HC4040	.89
74HC125	.49	74HC4049	.39
74HC132	.49	74HC4050	.39
74HC138	.45	74HC4060	.99
74HC139	.45	74HC4511	1.19
74HC154	1.49	74HC4514	1.79
74HC163	.49	74HC4538	1.19
74HC174	.59	74HC4543	1.19

74HCT — CMOS TTL

74HCT00	.17	74HCT139	.39
74HCT02	.17	74HCT157	.29
74HCT04	.19	74HCT174	.35
74HCT08	.17	74HCT175	.39
74HCT10	.17	74HCT240	.69
74HCT32	.19	74HCT244	.59
74HCT74	.29	74HCT245	.69
74HCT86	.25	74HCT373	.49
74HCT138	.39	74HCT374	.49

LINEAR

DS0026CN	1.95	LM1458N	.35
TL074CN	.99	LM1488N	.45
TL084CN	.89	DS14C88N (CMOS)	1.19
AF100-1CN	8.95	LM1489N	.45
LM307N	.39	DS14C89N (CMOS)	1.19
LM309K	1.25	LM1496N	.69
LM311N	.39	MC1648P	2.95
LM317T	.65	LM1871N	1.95
LM318N	.99	LM1872N	1.95
LM319N	1.29	LM1896N-1	1.49
LM323K	3.49	ULN2003A	.75
LM324N	.35	XR2206	3.95
LM338K	4.95	XR2211	2.95
LM339N	.39	XR2243	1.95
LF347N	1.49	26LS29	2.95
LM348N	.69	26LS31	.99
LM350T	2.95	26LS32	.99
LF351N	.39	26LS33	1.49
LF353N	.49	LM2901N	.25
LF355N	.79	LM2907N	1.29
LF356N	.79	LM2917N (8 pin)	1.79
LF357N	.89	MC3419CL	3.95
LM358N	.49	MC3446N	.99
LM360N	1.95	MC3450P	.49
LM361N	1.49	MC3470P	1.19
LM380N-8	.99	MC3471P	.99
LM386N-3	.89	MC3479P	3.95
LM387N	1.09	MC3486P	1.19
LM393N	.39	MC3487P	.99
LM399H	3.49	LM3900N	.49
LF411CN	.79	LM3905N	1.25
TL497ACN	1.49	LM3909N	.89
NE540H (C540H)	.99	LM3914N	1.79
NE555V	.29	LM3916N	1.49
XRL555	.59	NE5532	.69
LM556N	.45	NE5534	.69
NE558N	.79	7805K (LM340K-5)	1.39
LM565N	.89	7812K (LM340K-12)	1.39
LM567V	.75	7815K (LM340K-15)	1.59
NE592N	.75	7805T (LM340T-5)	.45
LM741CN	.29	7812T (LM340T-12)	.45
LM747CN	.49	7815T (LM340T-15)	.45
MC1350P	.89	7905K (LM320K-5)	1.49
MC1377P	2.29	7905T (LM320T-5)	.49
MC1398P	4.95	75472	.49
LM1414N	.99	75477	1.29
		MC145106P	1.95
		MC145406P	2.95

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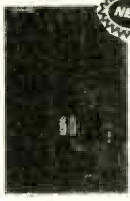
NEW



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JE1016 Pictured

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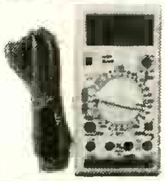

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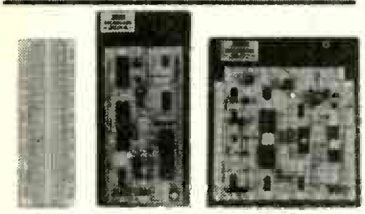

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Part No.	Dim. L" x W"	Contact Points	Binding Posts	Price
JE20	6½ x ¾	200	0	$ 2.95
JE21	3¼ x 2⅛	400	0	$ 4.95
JE22	6½ x 1⅜	630	0	$ 5.95
JE23	6½ x 2⅛	830	0	$ 7.95
JE24	6½ x 3⅛	1,360	2	$14.95
JE25	6½ x 4¼	1,660	3	$22.95
JE26	6⅞ x 5¾	2,390	4	$27.95
JE27	7¼ x 7½	3,220	4	$37.95

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400041	NSC Linear Data Book-Vol. I (88)	$14.95
400042	NSC Linear Data Book-Vol. II (88)	$ 9.95
400043	NSC Linear Data Book-Vol. III (88)	$ 9.95
210830	Intel Memory Handbook (88)	$17.95
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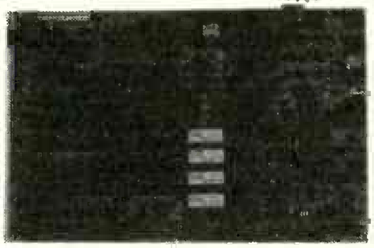

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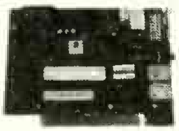

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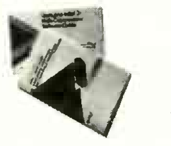

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74LS03	.18	74LS124	2.75	74LS244	.69
74LS04	.16	74LS125	.39	74LS245	.79
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74LS08	.18	74LS132	.39	74LS253	.49
74LS09	.18	74LS133	.49	74LS257	.39
74LS10	.16	74LS138	.39	74LS258	.49
74LS11	.22	74LS138	.39	74LS259	1.29
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74LS38	.26	74LS162	.49	74LS368	.39
74LS42	.39	74LS163	.39	74LS373	.79
74LS47	.75	74LS164	.49	74LS374	.79
74LS48	.85	74LS165	.65	74LS375	.95
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74HC08	.25	74HC273	.69	74HCT157	.59
74HC14	.35	74HC367	.69	74HCT161	.79
74HC32	.35	74HC373	.69	74HCT240	.89
74HC74	.35	74HC390	.79	74HCT244	.89
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4017	.49	4047	.69	14433	14.95
4018	.69	4049	.29	14497	6.95
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7404	.19	74150	1.35	74S04	.29
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7407	.29	74153	.55	74S10	.29
7408	.24	74154	1.49	74S32	.35
7410	.19	74157	.55	74S74	.49
7411	.25	74159	1.65	74S86	.35
7414	.49	74161	.69	74S112	.50
7416	.25	74164	.85	74S124	2.75
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7430	.19	74367	.65	74S157	.79
7432	.29			74S158	.95
7438	.29	74F/74S		74S163	1.29
7442	.49	74F00	.35	74S175	.79
7445	.69	74F02	.35	74S195	1.49
7447	.89	74F04	.35	74S240	1.49
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12.0	1.95
14.31818	1.95
16.0	1.95
18.0	1.95
18.432	1.95
20.0	1.95
22.1184	1.95

OSCILLATORS

1.0MHz	5.95
1.8432	5.95
2.0	5.95
2.4576	5.95
2.5	5.95
4.0	4.95
5.0	4.95
5.0688	4.95
6.0	4.95
6.144	4.95
8.0	4.95
10.0	4.95
12.0	4.95
14.31818	1.95
15.0	1.95
16.0	4.95
18.432	4.95
20.0	4.95
24.0	4.95

DISCRETE

1N751	.49	2N4403	.25
IN5402	.25	2N6045	1.75
IN4004	10/1.00	MPS-A13	.40
IN4148	25/1.00	TIP31	.49
KBP02	.55	4N26	.69
PN2222	.10	4N27	.69
2N2222	.10	4N28	.69
2N2907	.25	4N33	.89
2N3055	.79	4N37	1.19
2N3904	.10	MCT-2	.59
2N3906	.10	MCT-6	1.29
2N4401	.25	TIL-111	.99

CAPACITORS

TANTALUM

1.0µf	15V	.12
6.8	15V	.42
10	15V	.45
22	15V	.99
1.0µf	35V	.45
2.2	35V	.19
4.7	35V	.39
10	35V	.69

DISC

10pf	50V	.05
22	50V	.05
33	50V	.05
47	50V	.05
100	50V	.05
220	50V	.05
.001µf	50V	.05
.005	50V	.05
.01	50V	.07
.05	50V	.07
.1	12V	.10
.1	50V	.12

ELECTROLYTIC

RADIAL

1µf	50V	.14
4.7	50V	.11
10	50V	.11
47	35V	.13
100	16V	.15
100	50V	.23
220	35V	.20
470	25V	.30
2200	16V	.70
4700	25V	1.45

AXIAL

1µf	50V	.14
10	16V	.14
10	50V	.16
22	16V	.14
47	50V	.19
100	35V	.19
470	50V	.29
1000	16V	.29
2200	16V	.70
4700	16V	1.25

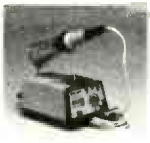
SOLDER STATION

UL APPROVED

- ADJUSTABLE HEAT SETTING
- TIP TEMPERATURE READOUT
- REPLACEMENT TIPS AVAILABLE $2.95

168-2C

$49.95



FULL 1 YEAR WARRANTY ON EVERY PRODUCT!

WIREWRAP PROTOTYPE CARDS

FR-4 EPOXY GLASS LAMINATE WITH GOLD PLATED EDGE-CARD FINGERS AND SILK SCREENED LEGENDS.

FOR PS/2

JDR-PR32	32 BIT PROTOTYPE CARD	69.95
JDR-PR16	16 BIT WITH I/O DECODING LAYOUT	49.95
JDR-PR16PK	PARTS KIT FOR JDR-PR16 ABOVE	15.95
JDR-PR16V	16 BIT FOR VIDEO APPLICATIONS	39.95

FOR AT

JDR-PR10	16BIT WITH I/O DECODING LAYOUT	34.95
JDR-PR10PK	PARTS KIT FOR JDR-PR10 ABOVE	12.95

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IBM-PR1	WITH +5V AND GROUND PLANE	27.95
IBM-PR2	AS ABOVE WITH I/O DECODING LAYOUT	29.95

POWER SUPPLIES

APPLE TYPE SUPPLY
- APPLE CONNECTOR
- +5V @ 6A, +12V @ 3A, -5V @ 1A, -12V @ 1A

PS-A $49.95

FLOPPY DRIVE SUPPLY
- +5V @ 2.5A, +12V @ 2A, -12V @ .1A
- +5V @ 5A, IF +12 NOT USED

PS-ASTEC $24.95

75 WATT SUPPLY
- UL APPROVED
- +5V @ 7A, +12V @ 3A, -5V @ 300MA, -12V @ 250MA

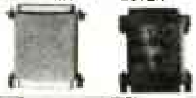
PS-1558 $34.95

MICRO SUPPLY
- UL APPROVED, 144 WATTS
- +5V @ 18A, +12V @ 4A, -12V @ 500MA

PS-1554 $29.95

GENDER CHANGERS

GENDER-FF	FEMALE-FEMALE	7.95
GENDER-MM	MALE-MALE	7.95
GENDER-MF	MALE-FEMALE	7.95
GENDER-NM	NULL MODEM	8.95
GENDER-JB	JUMPER BOX	8.95
GENDER-MT	MINITESTER	14.95



BIT RATE GENERATORS

MC14411	9.95
BR1941	4.95
4702	9.95
COM5016	16.95
COM8116	8.95
MM5307	4.95

BYPASS CAPACITORS

.01xx	CERAMIC DISC	100/5.00
.01xx	MONOLITHIC	100/10.00
.1xx	CERAMIC DISC	100/6.50
.1xx	MONOLITHIC	100/12.50

CLOCK CIRCUITS

MC146818	5.95	MM58174	9.95
MM58167	9.95	MSM5832	2.95

DISK CONTROLLERS

1771	4.95	2797	29.95
1791	9.95	8272	4.39
1793	9.95	UPD765	4.39
1795	12.95	MB8876	12.95
1797	12.95	MB8877	12.95
2791	19.95	1691	6.95
2793	19.95	2143	6.95

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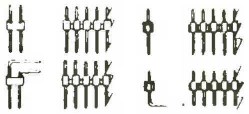
CAN BE SNAPPED APART TO MAKE ANY SIZE HEADER, ALL WITH .1" CENTERS

1x40	STRAIGHT LEAD	.99
1x40	RIGHT ANGLE LEAD	.49
2x40	2 STRAIGHT LEADS	2.49
2x40	2 RIGHT ANGLE LEADS	2.99

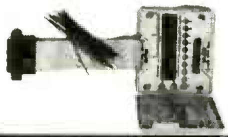


RS-232 BREAKOUT BOX

FOR TROUBLESHOOTING SERIAL COMMUNICATIONS

- OPEN/CLOSE INDIVIDUAL CIRCUITS
- 20 JUMPERS CROSS-CONNECT ANY TWO CIRCUITS
- 10 LEDS SHOW CIRCUIT ACTIVITY

GENDER-BO $34.95



IDC CONNECTORS/RIBBON CABLE

DESCRIPTION	ORDER BY	CONTACTS					
		10	20	26	34	40	50
SOLDER HEADER	IDHxxS	.82	1.29	1.68	2.20	2.58	3.24
RIGHT ANGLE SOLDER HEADER	IDHxxSR	.85	1.35	1.76	2.31	2.72	3.39
WIREWRAP HEADER	IDHxxW	1.86	2.98	3.84	4.50	5.28	6.63
RIGHT ANGLE WIREWRAP HEADER	IDHxxWR	2.05	3.28	4.22	4.45	4.80	7.30
RIBBON HEADER SOCKET	IDSxx	.63	.89	.95	1.29	1.49	1.69
RIBBON HEADER	IDMxx	–	5.50	6.25	7.00	7.50	8.50
RIBBON EDGE CARD	IDExx	.85	1.25	1.35	1.75	2.05	2.45
10' PLASTIC RIBBON CABLE	RCxx	1.60	3.20	4.10	5.40	6.40	7.50

FOR ORDERING INSTRUCTIONS, SEE D-SUBMINIATURE CONNECTORS BELOW

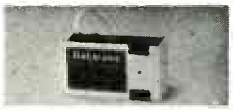
EPROM ERASERS

SPECTRONICS CORPORATION

Model	Timer	# of Chips	Intensity (uW/Cm²)	Unit Cost
PE-140	NO	9	8,000	$ 89
PE-140T	YES	9	8,000	$139
PE-240T	YES	12	9,600	$189

DATARASE *$34.95*

- ERASES 2 EPROMS IN 10 MINUTES
- VERY COMPACT, NO DRAWER
- METAL SHUTTER PREVENTS UV LIGHT FROM ESCAPING



D-SUBMINIATURE CONNECTORS

DESCRIPTION		ORDER BY	CONTACTS					
			9	15	19	25	37	50
SOLDER CUP	MALE	DBxxP	.45	.56	.69	.69	1.35	1.85
	FEMALE	DBxxS	.49	.69	.75	.75	1.39	2.29
RIGHT ANGLE PC SOLDER	MALE	DBxxPR	.49	.69	–	.79	2.27	–
	FEMALE	DBxxSR	.55	.75	–	.85	2.49	–
WIREWRAP	MALE	DBxxPWW	1.69	2.55	–	3.89	5.60	–
	FEMALE	DBxxSWW	2.76	4.27	–	6.84	9.95	–
IDC RIBBON CABLE	MALE	IDBxxP	1.39	1.99	–	2.25	4.25	–
	FEMALE	IDBxxS	1.45	2.05	–	2.35	4.49	–
HOODS	METAL	MHOODxx	1.05	1.15	1.25	1.25	–	–
	PLASTIC	HOODxx	.39	.39	–	.39	.69	.75

ORDERING INSTRUCTIONS:
INSERT THE NUMBER OF CONTACTS IN THE POSITION MARKED "xx" OF THE "ORDER BY" PART NUMBER LISTED. EXAMPLE : A 15 PIN RIGHT ANGLE MALE PC SOLDER WOULD BE DB15PR.

MOUNTING HARDWARE 59¢

- 30 DAY MONEY BACK GUARANTEE
- 1 YEAR WARRANTY ON ALL PRODUCTS
- TOLL-FREE TECHNICAL SUPPORT
- COMPLETE CUSTOMER SATISFACTION
- KNOWLEDGEABLE SALES STAFF

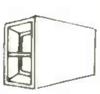
IC SOCKETS/DIP CONNECTORS

DESCRIPTION	ORDER BY	CONTACTS								
		8	14	16	18	20	22	24	28	40
SOLDERTAIL SOCKETS	xxST	.11	.11	.12	.15	.18	.15	.20	.22	.30
WIREWRAP SOCKETS	xxWW	.59	.69	.69	.99	1.09	1.39	1.49	1.69	1.99
ZIF SOCKETS	ZIFxx	–	4.95	4.95	–	5.95	–	5.95	6.95	9.95
TOOLED SOCKETS	AUGATxxST	.62	.79	.89	1.09	1.29	1.39	1.49	1.69	2.49
TOOLED WW SOCKETS	AUGATxxWW	1.30	1.80	2.10	2.40	2.50	2.90	3.15	3.70	5.40
COMPONENT CARRIERS	ICCxx	.49	.59	.69	.99	.99	.99	.99	1.09	1.49
DIP PLUGS (IDC)	IDPxx	.95	.49	.59	1.29	1.49	–	.85	1.49	1.59

FOR ORDERING INSTRUCTIONS SEE D-SUBMINIATURE CONNECTORS ABOVE

SHORTING BLOCKS

5/$1.00



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- 6.8V FOR 286/386 COMPUTERS
- MOTHERBOARD CONNECTOR
- ADHESIVE VELCRO STRIP FOR EASY MOUNTING

LITHIUM 6.8V $11.95

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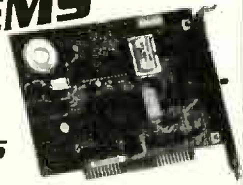
2400 BAUD MODEMS



$129^95

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PROMETHEUS

SAVE TIME AND TELEPHONE CHARGES WITH A HIGH SPEED 2400 BAUD MODEM FROM JDR.

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- AUTO DIAL ANSWER
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- HAYES & BELL SYSTEMS COMPATIBLE
- FULL OR HALF DUPLEX
- MIRROR II COMMUNICATIONS SOFTWARE INCLUDED

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EXTERNAL 2400 BAUD
- 2400/1200/300 HAYES COMPATIBLE
- 8 EASY-TO-READ STATUS LED'S
- CALL PROGRESS MONITORING & ADJUSTABLE VOLUME
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MACINTOSH 2400 BAUD EXTERNAL AS ABOVE WITH CABLE AND PROCOM-M SOFTWARE.

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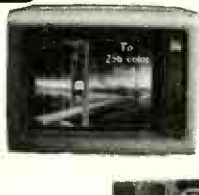

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- 320 X 200 IN 256 COLORS
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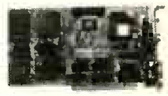
- FULLY VGA, EGA, CGA, HERCULES & MONOCHROME COMPATIBLE



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- 640 X 200/350 RESOLUTION
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- SERIAL INTERFACE (DB25)
- 4 STATUS INDICATORS

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CITIZEN PRINTER
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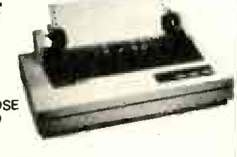

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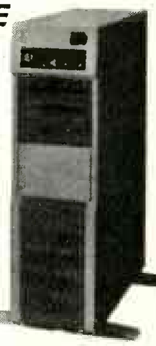

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- MOUNTING HARDWARE, FACEPLATES & SPEAKER INCLUDED

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MODULAR CIRCUIT TECHNOLOGY
ENHANCED STYLE LAYOUT
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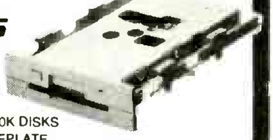

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- ALSO WORKS WITH 720K DISKS

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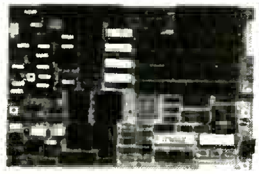

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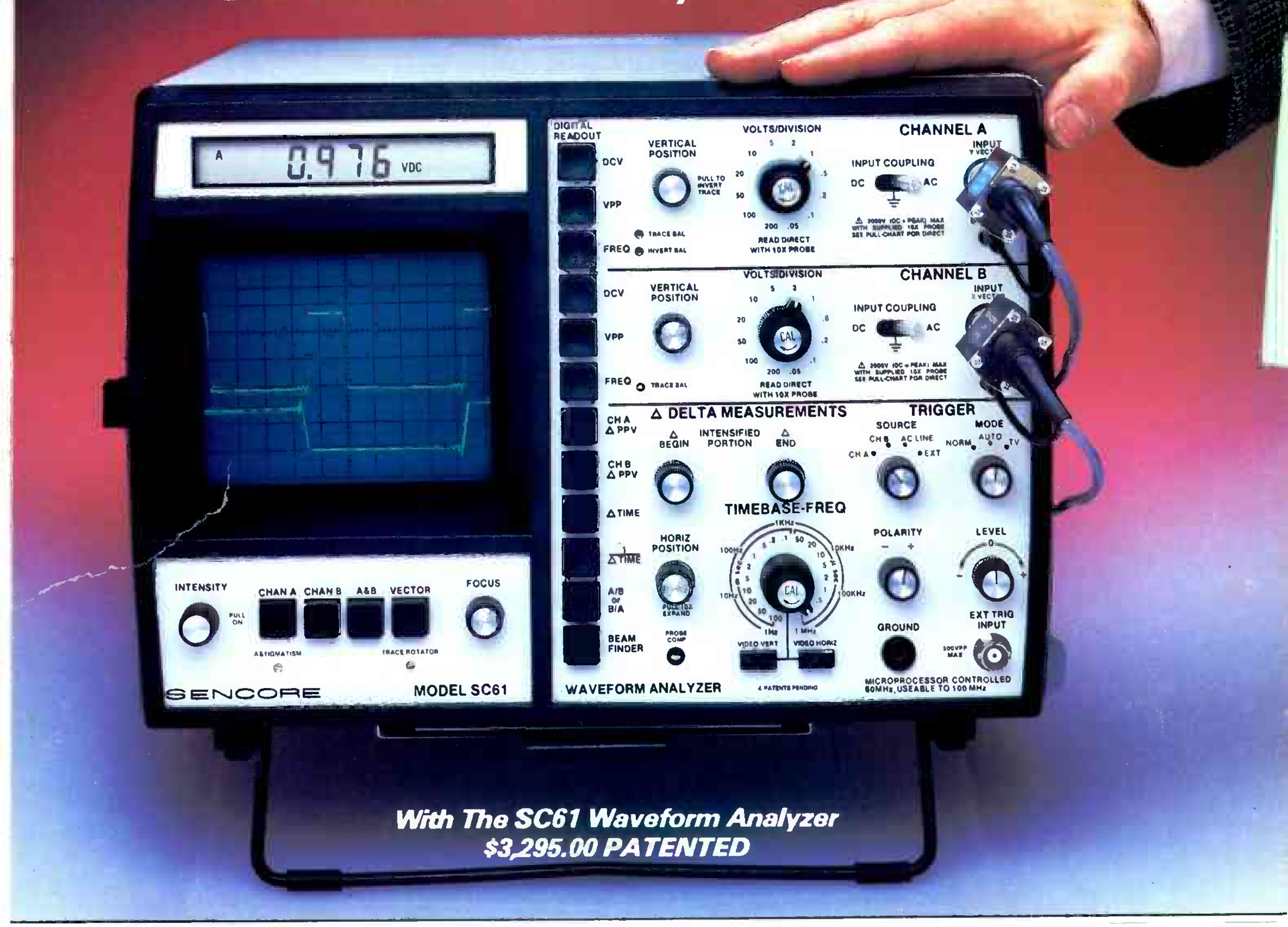

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