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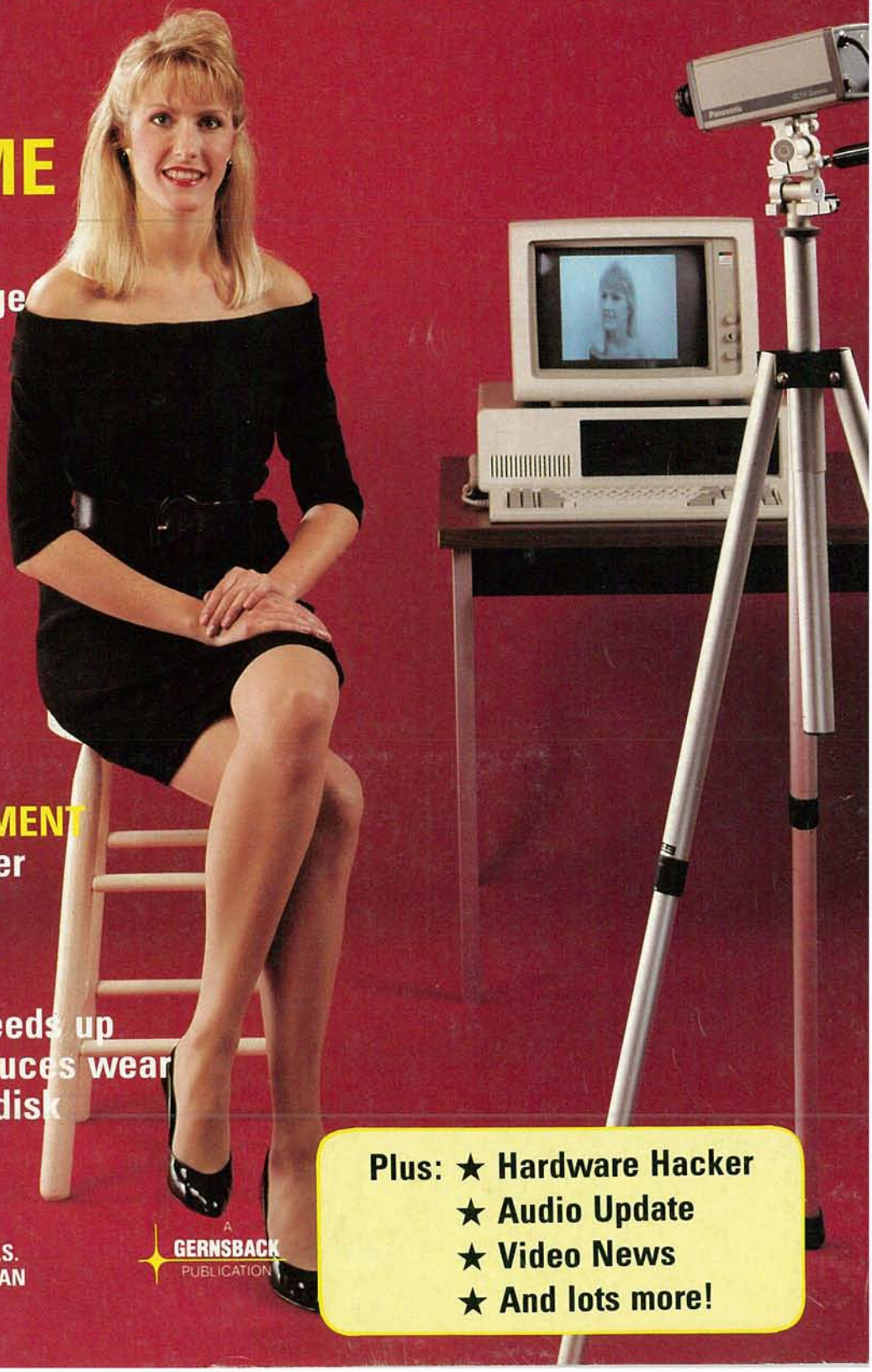
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August 1990

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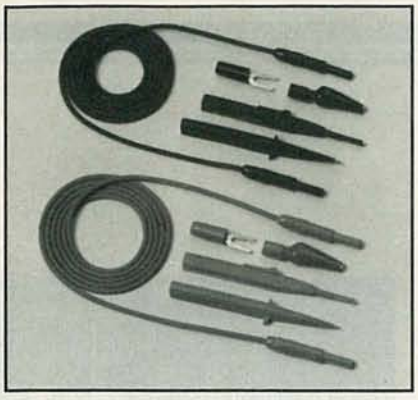
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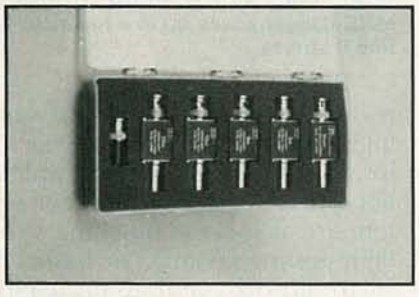
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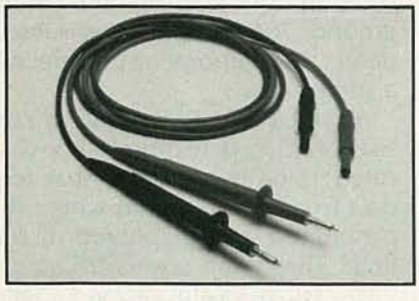
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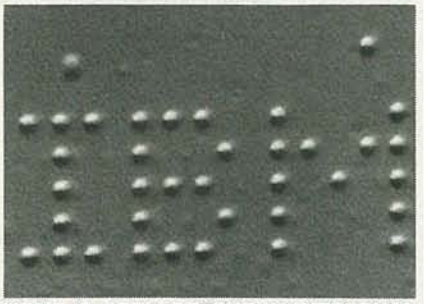
Individual atoms as building blocks

Scientists at IBM's Almaden Research Center (San Jose, CA) have managed to position individual atoms on a surface, and have used that technique to build structures one atom at a time. Besides helping scientists to better understand the fundamental behavior of atoms on surfaces—knowledge that is crucial to many industrial processes—the achievement opens the door for a broad range of future applications. Some of the possibilities are building custom molecules, making ultra-small electrical circuits, storing data on an atomic scale at densities more than a million times greater than is now possible, and perhaps even duplicating structures atom-for-atom. The technique might one day be adapted to reduce the size of semiconductor chips by a factor of more than 500.

The process, which demonstrates that atoms can be moved across a surface and accurately positioned where desired, was first used to create the letters "IBM" in xenon atoms. Next, a chain of seven xenon atoms bound together—the first atomic cluster built one atom at a time—was created. Both demonstrations required the atoms to be cooled to −269°C (−453°F), which is only slightly higher than absolute zero.

Physicists Donald M. Eigler and Erhard K. Schweizer (a visiting scientist at Almaden, on leave from the Fritz-Haber-Institut in Berlin) used a special scanning tunneling microscope (STM) to move the atoms into place and to view their progress. STM's can image individual atoms on a metal or semiconductor surface by scanning the tip of a needle over the surface at a height of only a few atomic diameters. To study how atoms and molecules interact with surfaces, Eigler built an STM that could operate with extraordinary sensitivity and precision. He placed the STM in a high vacuum, cooled it with liquid helium, and isolated it from vibrations.

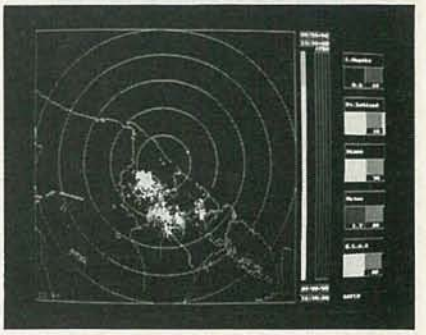
In a process similar to using the motion of a nearby magnet to move another magnet, a xenon atom can be "dragged" across a surface by placing the STM's needle tip close to the atom and moving the tip parallel to the surface. At the desired position, the tip is lifted, leaving the atom fixed in its new location. The exacting process—atoms are moved at a rate of 16 billionths of an inch per second—requires the STM operator to maintain a delicate balance of several attractive forces between the atoms. It took 22 hours to move the xenon atoms to form the letters "IBM."



"IBM" IS SPELLED OUT IN INDIVIDUAL atoms. IBM scientists used a scanning tunneling microscope to move single xenon atoms across a surface and precisely position them one at a time to form the letters. The distance between the atoms in the pattern is about 50 billionths of an inch; the image has been magnified approximately 2.9 million times.

Lightning forecaster

A system that predicts lightning before it strikes was developed by Dimensions, a French firm, in the course of research conducted at the French Matinal Institute of Aerospace Research. It is hoped that the new lightning-detection system will help to eliminate lightning-caused damage and related fatalities. The SAFIR system—which has been successfully tested at several sites, including the Kennedy Space Center—monitors storm activities in real time and issues lightning warnings through the use of radioelectric interferometry. Potential applications for the lightning-detection system are at rocket-launching sites, flight-testing centers, air bases, civilian airports, and air-navigation centers.



THE SAFIR SYSTEM MAPS STORMS IN REAL TIME AND FORECASTS LIGHTNING danger zones up to a half hour before it strikes.

As soon as it begins developing, a thunderstorm produces changes in the atmospheric electric field. The SAFIR system monitors those changes at their inception. One type of sensor detects and traces high-frequency radiating sources from the heart of a cloud to lightning discharges that strike the ground, and a second sensor measures the electrostatic field on the ground. Together, the two sensors detect the phenomena that precede a strike.

A typical SAFIR installation consists of three detection stations, located 12–62 miles apart, that feed data to a central station where it is processed and displayed in real time. That setup covers 186 square miles, with a locating accuracy ranging from a few hundred yards to three miles. The system can monitor storms as they develop, producing maps that indicate "lightning discharge danger zones" on the ground and in the air. Danger zones are detected and located up to 30 minutes before the first lightning bolts strike the ground lessening the chances of a strike. **R-E**

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AUGUST 1990

VIDEO NEWS



DAVID LACHENBRUCH,
CONTRIBUTING EDITOR

• **Video goes "wireless."** In a little-noted change in its "part 15" rules on RF interference, the FCC last year voted to allow wireless electronic products with increased frequencies and no restrictions on usage, bandwidth, or type of modulation, as long as the uses are non-interfering. That will permit such limited-area uses as wireless loudspeakers. One of the most interesting new products permitted under the new regulations is the "home TV station." The first such station actually to be tested and approved by the FCC is the *Videocaster* by accessory manufacturer Gemini Industries.

The Videocaster consists of a small transmitter and receiver, and its principal purpose will be to connect such devices as VCR's to TV's without using cables. Thus one VCR can feed all the TV's in a home, as long as each TV is equipped with a receiver. Another suggested use is monitoring a baby-sitting camera while visiting next-door neighbors. Transmissions are in the 900-MHz frequencies. The Videocaster will sell for about $100, including one transmitter and one receiver. Approvals of competing systems are expected soon.

• **Cardboard cassette.** Video junk mail has arrived—in the form of the throw-away cassette. The VHS-compatible (though not approved) cassette is made of cardboard, and in large quantities can sell for about $1.00, including tape, duplicating, and four-color label. Developed by Philmax, a Baltimore company, it's designed for premium, catalog, and give-away uses where durability isn't required. The tape is designed to be played five to ten times, although tested copies have lasted for as many as 150 plays. The developers say that the throw-away tapes won't damage VCR's. The tape stops playing when it no longer tracks correctly.

• **NEC "shakes out."** Plagued with chronic overproductions and cutthroat competition that are bringing prices below the profit level in many instances, the consumer-electronics industry saw the first victim of a widely anticipated "shakeout of the '90's" in NEC, the American subsidiary of Japan's Nippon Electric Company. NEC, which has been offering televisions, VCR's, and audio systems on the American market for nine years, has decided to abandon those traditional consumer-electronics lines. Instead, it will concentrate on such things as its sophisticated TurboGrafx video-game system, personal computers, and custom "home theaters," including the *I*mproved-*D*efinition-*TV* (*IDTV*) two-piece projection system it has developed. Its color-television factory in McDonough, GA, is being converted to the production of laptop computers and monitors.

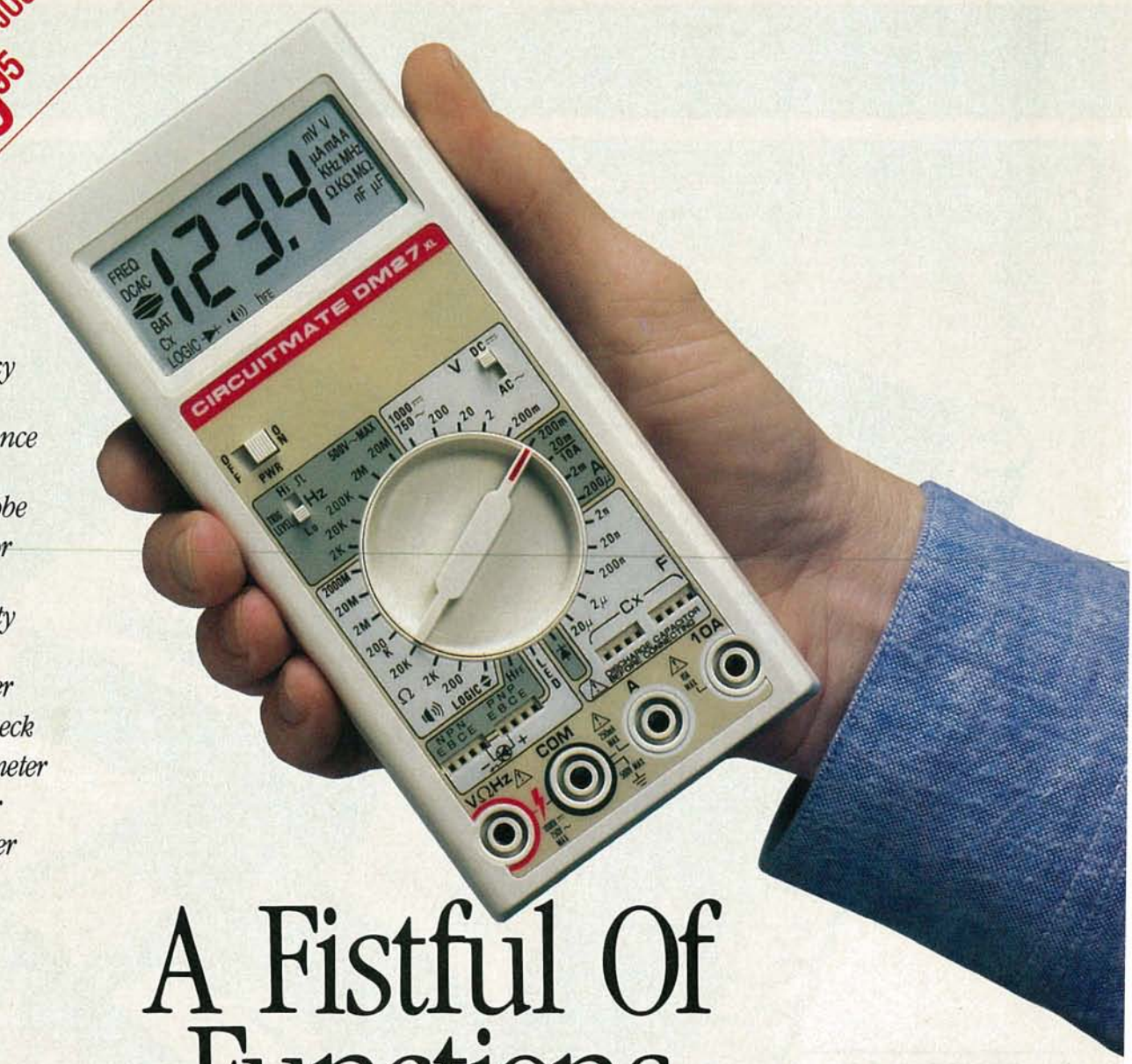
In a move also related to the worldwide competitive situation in consumer electronics, the European giant Philips (which produces Philips, Magnavox, Sylvania, and Philco products in the United States) is buying a 25% interest in the audio-video operations of Denmark's Bang & Olufsen, noted for its high-styled (and high-priced) audio and video components. Both companies that are involved said the move would help them compete in the high-priced high-end market.

• **8mm winning camcorder war.** Sony, whose Beta system lost the competition for home VCR's to JVC's VHS, is winning a victory in the struggle for format supremacy in mini camcorders, as more brands begin to move to Sony's 8mm format over JVC's VHS-C (for "compact") system. The first major consumer-electronics brand name in the VHS camp to move to 8mm will be Zenith, which will add an 8mm camcorder to their line this fall. The fact that Zenith is defecting is particularly significant. Zenith was the first traditional American brand to enter the VCR market, in 1977, when it chose the Beta format (its recorders were made by Sony). As Beta lost the race, Zenith switched to VHS machines (supplied by JVC). Zenith's new 8mm camcorder will be made by Sanyo.

Full-size VHS is still the leading camcorder format in the United States. In the first quarter of 1990, 57.5% of camcorders sold here used standard VHS cassettes. For all of 1989, the figure for VHS was 63%. **R-E**

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DTMF CONTROLLER

I'm trying to build a circuit that uses the telephone DTMF (*D*ual *T*one *M*ulti *F*requency) tones as the basis to control several different devices. My problem is that I'm having a hard time finding out exactly what frequencies are used for all the rows and columns. The books I've looked through list only the twelve telephone keys, but I thought there were more that. Could you tell me how many there are?—F. Geof, Hunter, NY

You're right that there are more than twelve standard DTMF tone combinations available, and I'm surprised how few people are aware of that. Most of the books that talk about telephones only refer to the tones produced by the standard keypad, but that's because they're only dealing with telephones, not DTMF in general.

Even though the standard telephone uses only twelve tone combinations, there are really sixteen available. There are actually eight official DTMF tones, organized as shown in Table 1. Seven of them are in everyday use with telephones, but the eighth one, the last member of the high group, isn't used in any of the common consumer telephone devices although I've heard that it has some applications in military and industrial equipment.

It used to be a real pain in the neck to build a DTMF receiver because it had to be done with lots of filters, decoders, and so on. These days, the decoding methods have become almost completely digital (as has just about everything else), and semiconductor manufacturers have produced a wide variety of chips to both generate and decode the tones with an accuracy that's way beyond the earlier circuits made with acres of discreet components.

DTMF STANDARDS	
GROUP	FREQUENCY
LOW	697 Hz
LOW	770 Hz
LOW	852 Hz
LOW	941 Hz
HIGH	1209 Hz
HIGH	1336 Hz
HIGH	1477 Hz
HIGH	1633 Hz

The official list of tone combinations is shown in Table 2, and you can see that the last four digits all use the 1633-Hz tone as one of their components. Most of the available IC's that produce and read DTMF tones will let you handle all sixteen tones but, if you want to do that, you won't be able to use a regular telephone keypad in the design. That shouldn't be much of a problem since just about all the IC's that generate DTMF will accept either a row-and-column or binary input. That means you can use any one of the commercially available matrix keyboards—or even make your own.

If your circuit can deal with straight binary, the design is even easier because chips like National Semiconductor's 5088 converts binary directly to DTMF and has an output level that will directly drive the telephone line. How things have changed!

DIY VOR GENERATOR

We would like to build a VOR generator in order for us to test IN-38 course indicators, part of the navigation system in Cessna aircraft. According to the service manual, a standard VOR input is defined as an audio signal consisting of 30 Hz and 9960 Hz at 0.5-VRMS ±0.05 VRMS. Can you offer any help?—P. Jamison, Sutter Creek, CA

Your letter isn't really clear about the form of the output signal but it seems to me that you're looking for a pair of simple oscillators. If that's the case, there's a wide variety of circuits you can use to get the job done.

Probably the easiest way to generate the frequencies you need at the required level and degree of accuracy is to build the circuit with a pair of 555 timers. The design is shown in Fig. 1. There's not much to explain about the circuit since it's one of the simplest 555 layouts you can build. Because you're looking for a pair of particular frequencies, the trimmers will let you tweak the output to get to the exact values you need.

The 555 is extremely stable and

TELEPHONE DTMF ASSIGNMENT				
Hz	1209	1336	1471	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	★	0	#	D

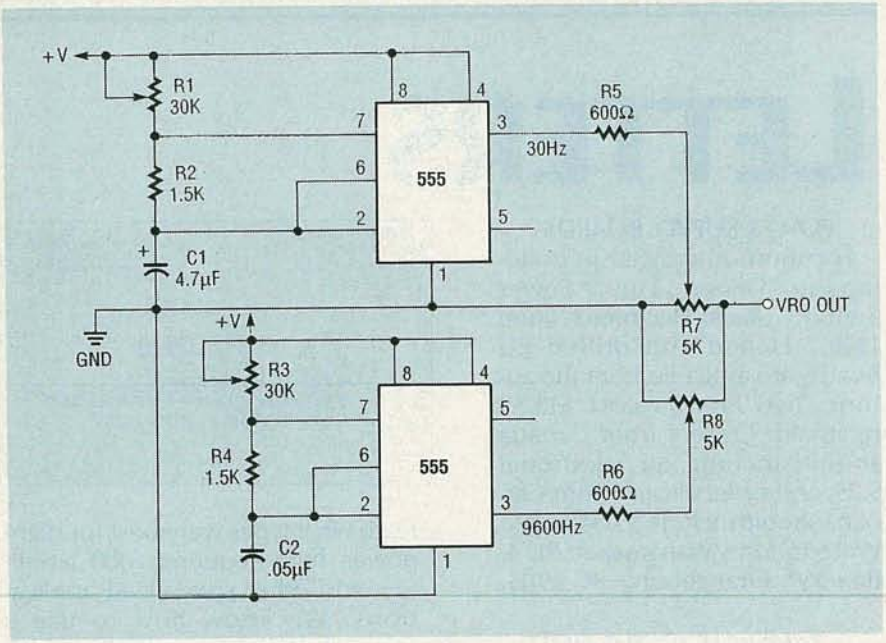


FIG. 1

the output frequency is relatively immune to changes in voltage. Unfortunately, the output voltage is going to depend on the supply voltage so it's a good idea to use a regulated supply. You can either buy one ready made or, since you're going to be laying out the circuit anyway, it's not much more work to add a three-terminal voltage regulator and pair of capacitors to the board. That will give you a stable supply voltage and peace of mind as well.

Sounds like a good deal to me.

I don't know if the two frequencies have to be mixed together and, if so, whether they have to be of equal amplitude. In any case, you can use the simple resistor summing circuit shown in the schematic to combine the two frequencies or add a mixing amplifier. If you do decide to use an amp, be careful about the one you use since adding more electronics to a circuit always introduces the possibility of more distortion.

As for the circuit itself, you don't have to make a PC board to do the job. A breadboard can be used as a temporary solution, or you can build it on a piece of perforated construction board and wirewrap the connections between components.

There's nothing critical about the parts layout and, since there are trimmers to adjust both the output frequencies and the amplitude, you can get the exact signal you want with standard-tolerance parts. It's still a good idea, however, to stay away from ceramic disc capacitors; use something like mica or tantalum. The actual value of a ceramic disc can be as much as 100% off, and even though the circuit is tolerant, there are limits to everything. **R-E**

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LETTERS



POWER SUPPLY BOARDS

For those interested in building our "Generic Linear Power Supply," (**Radio-Electronics**, June 1990): Etched and drilled PC boards are available from the author. Two boards cost $12.50 postpaid. Orders from Canada should include an additional $.25, and orders from South Carolina should include 5% sales tax. Write to John Wanamaker, Rt. 4, Box 550, Orangeburg, SC 29115.

TAKING IT TO THE LIMIT

I'm writing to thank you for an excellent magazine. **Radio-Electronics** always presents the latest in technology, such as your coverage in *What's News* (May 1990) of the world's first true digital optical processor.

In particular, I enjoyed Don Lancaster's *Hardware Hacker*. His article on op-amp noise is the first I have seen in any magazine that explains what those parameters (current noise and voltage noise) are, and how to optimize a circuit for them. I have been an electronics engineer for nine years, and they don't teach those details in school. I recently went through several days of optimizing a circuit for drift in which I learned a lot about a similar set of parameters involving offset current drift and offset voltage drift. It isn't often that you have to push a part to the edge of its specifications, but when you do, there aren't many good places to turn to for the necessary information. I would really enjoy a tutorial series by Don Lancaster on op amps that examined those parameters used when pushing the edge of technology.

On another note, I was equally unimpressed with the article in the same issue concerning how to choose the right transistor for your next design. In that article, Josef Bernard explained that as long as your design does not "push the limits," and "sticks to middle ground," it's hard to go wrong! Of course it is! I read the article in the first place to learn what types were best for high-power, high-frequency (RF) amplifier, and other specialized applications. We know how to use a general-purpose switching transistor—now show us how to use a transistor to build a UHF amplifier.
JOHN BURGAN
NORTH PALM BEACH, FL

DON'T ARGUE WITH NYQUIST!

The excellent article "Inside Digital Oscilloscopes," which appeared in the May 1990 issue of **Radio-Electronics**, presented some interesting and useful information about oscilloscope technology. While I enjoyed the article, I must quibble on one point. The article states: "... sampling rate must be at least double the bandwidth ..." of the sampled signal. The term "bandwidth" is a bit vague. As I recall, the correct application of the double-frequency law for sampled signals requires sampling at double the highest frequency component in the signal. That distinction is important. For example, a pure sine wave, say 1 MHz, has a very narrow bandwidth, although the sampling rate must be twice the frequency (not bandwidth), or 2 MHz, to reconstitute the 1-MHz signal.

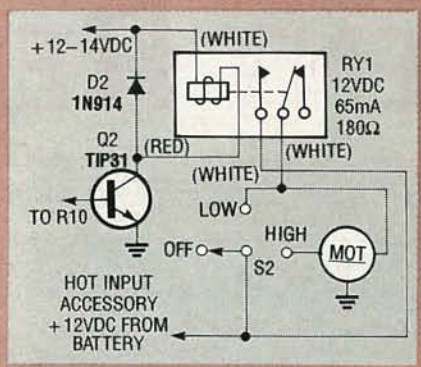
That requirement is easily understood in consideration of, first, the need to detect both positive and negative signal excursions and, second, the assumption that the signal is a perfect sine wave.

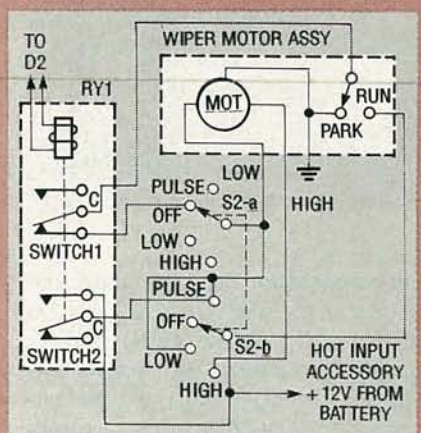
Given the sine-wave definition, and given (as Fourier proved) that any complex wave is composed of sine waves, then the sampling rate of twice the highest component fre-

CORRECTION

In our "Solid State Wiper Control" construction article (**Radio-Electronics**, April 1990), we regret that there were several editorial errors that need correcting:

- In Fig. 1 on page 47, Zener diode D1 is backward. Also, RY1 should be connected as shown in the partial reprint of Fig. 1 shown here. The center terminal of the switch in RY1 goes jointly to the LOW side of the motor (MOT) and the LOW terminal on S2. The left terminal of the switch on RY1 goes jointly to the pole terminal on S2 and the hot input accessory +12VDC from the battery.
- In Fig. 2 on page 47, RY1 should be connected as shown in the reprint of Fig. 2 shown here. Also, the last sentence of the original caption is incorrect. SWITCH 1 of RY1 goes in parallel across S2-b; the center terminal of SWITCH 1 goes to the PULSE terminal on S2-b, while the top terminal of SWITCH 1 goes to the pole terminal on S2-b.
- The parts-placement diagram of Fig. 3 on page 48 was improperly registered, and was reprinted on page 35 of the May 1990 issue. However, the power and ground leads need to be revised.





quency provides information sufficient to reconstitute the signal.
DAVE SWEENEY
SOMERS POINT, NJ

You are, of course, quite right. The article should have said either "absolute bandwidth" or "maximum bandwidth," instead of simply "bandwidth." Thanks for the clarification.—Editor

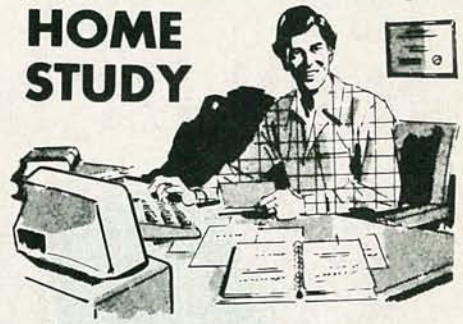
KEEP 'EM COMING!

I'm writing to show my support for Robert Grossblatt's *Drawing Board* series dealing with the generation of video signals. I am a student at the University of Miami, studying electrical engineering. After being inspired by the first article in the series, I went to the library to get more information on the subject. Although those sources covered the video signal, timing, etc., none of them discussed the hardware needed to create those signals. I would like to compliment **Radio-Electronics** on doing just that—enabling me to get first-hand experience in a subject not covered elsewhere. Keep 'em coming!
DAVID G. BURD
MIAMI, FL

DRAMA ON THE AIRWAVES

Radio-Electronics readers might want to tune into a high-tech, futuristic techno-drama, *RUBY 3*, that is being produced for radio by the ZBS Foundation. The story, set in the 21st century, follows the adventures of two women: Ruby is a tough, witty detective who is hired to find the source that is causing a buying frenzy in the City of Malls on the planet Summa Nulla and Inana is on a spiritual mission in which she faces a series of life-threatening tests. The two characters create a drama that is at once comic, action-packed, mythical, and spiritual. The series of 20 self-contained half-hour shows will be broadcast on various public-radio stations beginning on October 1, 1990.
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That seems to be the philosophy behind the *RMS225*, the newest addition to the professional line of Beckman Industrial Corporation (Instrumentation Products Division, 3883 Ruffin Road, San Diego, CA 92123-1898)

The *RMS225* measures resistance, and DC and AC voltage and current. It can also test continuity and diode junctions. A host of special features add versatility to the meter without making it more difficult to use.

The *RMS225* offers five DC voltage ranges (1.0–1000 volts full scale) with a rated accuracy of 0.25%. Three AC voltage ranges (10, 100, and 750 volts) offer a rated accuracy of 1.0% for sinewaves from 45 Hz to 2 kHz. The accuracy for the true RMS measurements decreases slightly for other waveforms. Six resistance ranges (1K–40 megohms) and three AC and DC current ranges (10 mA, 40 mA, and 10 amps) are also offered.

The meter is housed in a gray, high-impact thermoplastic case that measures about 6¾ × 2¾ × 1¼ inches and weighs less than 12 ounces. The front panel sports a 4-digit LCD readout with analog bargraph, three pushbuttons, a rotary function selector, and four input jacks. The meter fits easily in one hand, and all controls can be operated by the thumb of that one hand—something that can't be said for many other "handhelds."

Menu-selected features

Three pushbuttons below the LCD readout are used to access the meter's special functions. Hitting the MENU button calls up the menu, and allows you to scroll through the selections.

Range lock is the first feature that is menu selectable. Although the meter is in an auto-ranging mode when it is first powered up, it is possible to lock the meter scale to a given range. Like all other menu selected features, range lock can be de-selected with the CLEAR button.

Probe Hold is a convenience feature that allows the user to take a reading without looking at the meter's display—a stable reading is held in the display for later viewing. The meter beeps to indicate that it has captured a stable reading.

A relative mode is also accessed from the menu. That mode allows the user to set a reference value, and all other readings display with respect to that reference.

Auto Min Max is a mode in which the meter measures and stores the minimum and maximum values, while displaying real-time readings. It's ideal for unattended monitoring.

Using the meter

The *RMS225* is very easy to use. Although we were initially skeptical about the presence of a menu on a DMM, we were happy to find that Beckman's implementation was intuitively easy to use—even without reading the manual. Of course, we *do* encourage users to read operating manuals; this meter's manual was well written.

Unlike many other 4-digit multimeters, the *RMS225* offers a 10,000-count resolution—in other words, it's maximum reading is 9999, which results in a higher measurement resolution. For example, you can resolve 0.1-volt changes even when measuring a 500-volt signal. A 3½-digit meter would be able to resolve changes of 1 volt on the same signal.

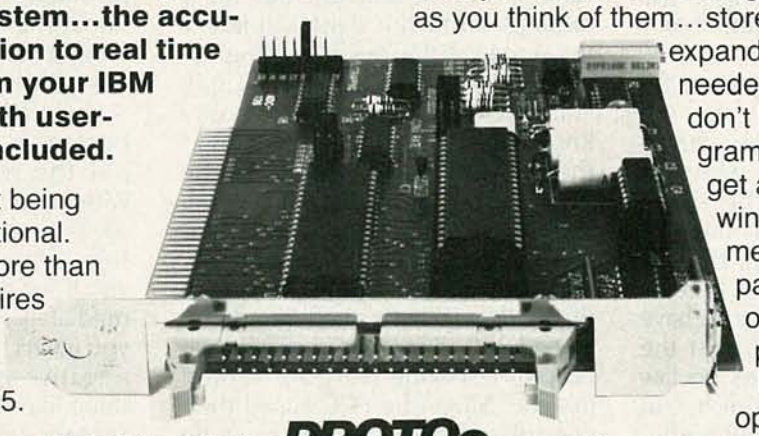
We didn't have the opportunity to overload the meter, but we know that accidents can happen. That's why we like the self-resetting fuse that protects the low-current (40 mA) input jack. We also liked the continuous tone that warns when measurements exceed the meter's input ratings, and the lightning-bolt annunciator that warns the user of a potential hazard when measured signals exceed 25 volts.

We also did not have the opportunity to try the protective holster with *Flex Strap* that is normally supplied with the meter. (Ours was an early production model.) Besides offering protection, the holster, with its probe holders and strap, can make many measurements more convenient.

The *RMS225* carries a suggested retail price of $149. That competitive pricing should get the meter into a lot of hands rather quickly. **R-E**

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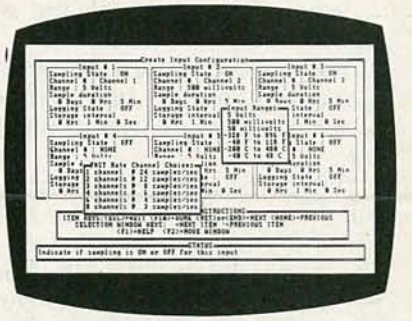
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Video-scrambling techniques



ROBERT GROSSBLATT,
CIRCUITS EDITOR

TRUST ME, PEOPLE, THIS IS THE LAST thing I'm going to have to say about video—at least for a while. You know enough now to make a pilgrimage to your local library and get a lot more information than I can squeeze into this column. And, in any event, my bench has been covered with video junk for a few months now and I'm getting the itch to start messing around with something else.

Video-signal scrambling is the only basic subject we haven't really looked at.

Scrambling methods go from the simple to the ridiculous, and the ones you're likely to encounter locally depend entirely on who you happen to be getting the signal from. Small cable companies use relatively simple methods, but the people running the satellite systems go much further because they have less control over who can get the signal. Last I heard, there's no law against owning a satellite dish, but hook into the cable without authorization and you're in really deep... trouble.

Most of the current scrambling methods fall into one or more of the following four categories:

1. Screwing around with the sync signals.
2. Screwing around with the picture.
3. Screwing around with everything.
4. Screwing around with something else.

While I'm the first to admit that it's not the most informative list in the world, it's really what's going on. It's also impossible to describe every method there is because new ones are being devised as fast as old ones get beaten. But let's look at a few of them.

Screwing up the sync

The most common method of scrambling, and one of the oldest, is to mess up the horizontal sync. If your TV can't find it, there's no way for it to lock its horizontal oscillator to the beginning of each line of video. The result will be a weirdly colored, wavy bar somewhere in the middle of the screen and a totally unwatchable picture. As you probably realize, the vertical bar is the sync portion of each line that really belongs off to the right and left of the screen. A line of video using this method looks something like Fig. 1.

It takes only a simple twist of a knob for the broadcaster to remove the horizontal signal but, since he wants to put it back in later, there has to be some way to put it back—at the right time and the right level. The information used to be buried in the IF but that's been largely replaced with encoding the information and sticking it in the vertical interval. Since the FCC eased their control of what can and can't be done during vertical retrace, people have found all sorts of uses for it. One of the newer wrinkles in the wonderful world of sync suppression is to change the transmitted sync level in each field of video. The amount of gain needed to put things back is encoded in the vertical interval. The descrambler hardware knows how to get that information and, consequently, how much gain to use to restore horizontal sync.

Screwing up the picture

One method that my cable company is starting to use now messes up both sync and picture. The basic scrambling technique is simple and makes the picture even worse than just suppressing sync. What's also interesting is that, even though it's newer, it's theoretically much easier to beat than suppressed sync.

All that's done is to inver the entire video line using 0 IRE as the center point. As you can see in Fig. 2, horizontal sync gets stuck in the picture area (positive IRE numbers) and picture information winds up in the control-signal area (negative IRE numbers). The TV can't find the horizontal sync and, since picture luminance and chroma are upside down, the colors are backward.

You might think that all that has to be done to clean everything up is to put the whole signal through a wideband, inverting amp—and you would be right—except for one thing. If you look carefully at Fig. 2, you'll see a positive-going pulse immediately following the sync area. If you invert the line, that spike will be negative-going, and look something like a delayed version of horizontal sync. The bottom line is that it's going to confuse the horizontal circuitry in the TV and the picture will still be messed up.

The way to beat the system is to invert the picture and then run it through a circuit that does two things: First it watches for horizontal sync, and then, during the period that the spike is being transmitted, it adds a version of the spike that's 180 degrees out of phase. That will null out the spike and leave a restored picture.

The circuitry needed to beat this is simple. As a matter of fact, you already know enough to design it. You'll need an amp that can handle video frequencies (top around 6 MHz), a sync separator, a counter,

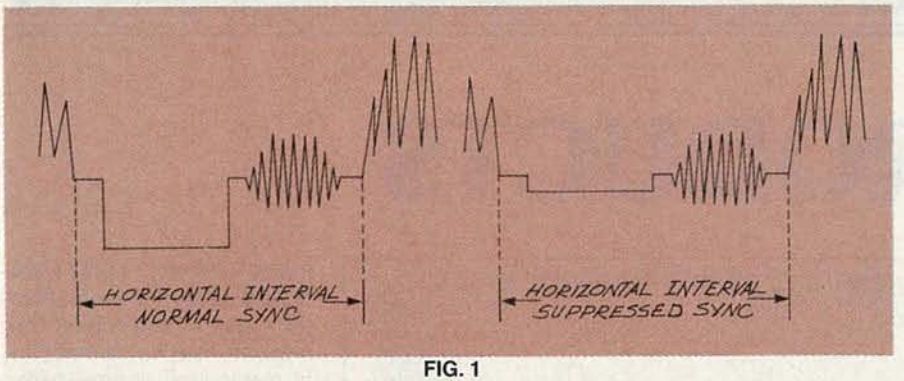


FIG. 1

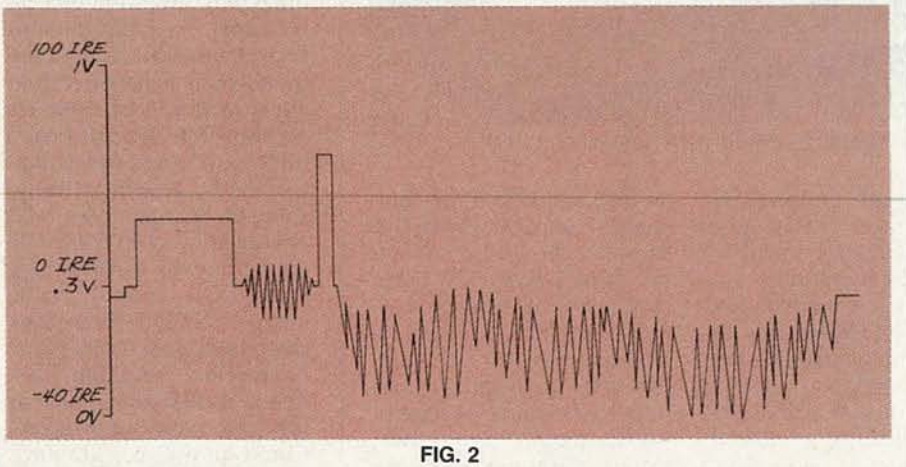


FIG. 2

and finally, a mixing amp.

Screwing up everything else

All the methods we've looked at so far are the kinds of things you find done by cable companies. They're all fairly easy to implement, and the circuitry to do the job (on both ends) can be produced at manageable economic levels.

Satellite systems don't have the luxury of an exclusive client list. Anyone who has a dish can get their signal so they need some sort of scrambling that's going to be more difficult to beat. Most of these guys use scrambling methods that really tear the video apart. A system like this is much more difficult to break. It's not impossible, just much more difficult.

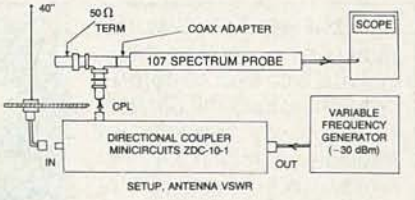
If you look at some of them on a scope, you'll see things that don't even look like video. Sync (both horizontal and vertical) seems to be nonexistent and the video is strange as well. That's understandable since a lot of satellite scramblers change the order of lines and sometimes even superimpose miscellaneous waveforms on top of the whole mess.

The initial stage of designing any circuitry to decode scrambled signals is to look at the waveform. Because there are so many ways that the signal can be screwed up, the only piece of advice I can give you is to use a dual-trace scope. Put a line of plain video on one channel and the scrambled signal on the other. By triggering off real video, you may be able to see a pattern.

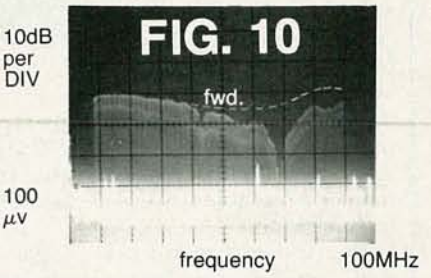
Breaking scrambled video is not something you can toss off between breakfast and lunch. It takes a lot of analysis and design. And, of course, depending on what you do with your new knowledge, you may be risking a paid vacation in the slammer. That isn't to say that digging into a scrambling technique is not fun to do—I'm a firm believer in having a good time at the bench. If you do have an urge to try it, remember that there's always some pattern to the scrambled signal. Keep an eye out for a horizontal and vertical interval. A good rule of thumb is that no matter what's done to the signal, it has to be put back together, and the numbers we worked out a few months ago regarding field- and frame-repetition rates should give you a starting point. **R-E**

evaluating an
ANTENNA (MATCH)

FIG. 9



SETUP, ANTENNA VSWR



The degree of match between a 50 Ω source and an antenna is obtained with the set-up illustrated in fig. 9. The tuning, Q, and reflection loss are available. The CPL output with either an open or direct short on IN is plotted as the fwd line in fig. 10. Then the cable to the antenna is attached, and the scope photo of fig. 10 results. The difference between these lines is desired. The scope indication of "37 dB" forward, "12 dB" reverse, indicates the reflected loss is down 25 dB at 68 MHz; (1.1 VSWR) 1/320=0.3% of the applied power is reflected or about 99.7% of the available power is radiated (or at least absorbed) by the antenna. Conversely, 99.7% of the received power is applied to a 50 Ω receiver. Since the probe can "see" a low level, only a low radiated signal is required. The discrete lines are signals received by the antenna. The logarithmic response allows evaluation of good matches.

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CIRCLE 10 ON FREE INFORMATION CARD

The system provides real-time, non-invasive emulation of the microcontroller. Time-saving features include a window-oriented user interface, menu-driven commands, single-step execution, symbolic debugging, software breakpoints, continuous run mode, and memory mapping. As the system is the first commercial product based on Motorola's 68332, which replaces the equivalent of nine peripheral chips, the *CDS8/05* takes advantage of the 32-bit microcontroller's advanced integration.

To make it completely portable, the *CDS8/05* was designed with alternate power sources: either a universal 85–265-volts AC, 50–60-Hz power supply or a 9–18-volts DC converter. The system also features a bus analyzer that contains an 8K-by-80 real-time trace buffer. The bus analyzer can connect to on-board non-volatile RAM that stores macros loaded in the lab for use in the field.

The included software-development package runs on an IBM PC, XT, AT, or compatible computer, which also serves as the host computer for the *CDS8/05*. PC interconnect software and a macro assembler/linker are included with the software. The interface features symbolic debugging of assembly-language programs, macro definition and state collection, help screens and escape to DOS.

The *CDS8/05* development system costs $2950.00.—**Motorola Inc.**, Microprocessor Products Group, 6501 William Cannon Drive West, Austin, TX 78735-8598; Tel. 512-891-3184.

THREE-CHANNEL OSCILLOSCOPE. For easy analysis of low-level and high-speed signals, *Leader Instrument's model 1100* 100-MHz, three-channel, dual-timebase oscilloscope features six-trace capability with 500-μV maximum sensitivity and 5-ns maximum sweep speed. Other features include alternate triggering, alternate time base, and variable holdoff. The *1100's* high-intensity CRT and extensive triggering controls provide a bright, stable display, even of complex signals. TV-V1, TV-V2, and TV-H sync-separator circuits allow optimum triggering of video signals, and alternate timebase allows simultaneous observation of vertical and horizontal TV signals.



CIRCLE 11 ON FREE INFORMATION CARD

The model *1100* oscilloscope costs $1545.00.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788; Tel. 800-645-5104 (in NY, 516-231-6900).

SURGE-PROTECTED TRIPLE OUTLET. Designed for situations where electrostatic discharge (ESD) is a concern, *Plastic Systems'* model *SP-0301* has three surge-protected outlets configured in one unit, and also provides assurance that the electrical ground is accurate. Two highly visible LED's allow quick verification of surge protection and ground suitability. The monitor also provides a plug-in ground point for a standard 0.175-inch banana plug that is grounded for safety through a one-megohm resistor.



CIRCLE 12 ON FREE INFORMATION CARD

The model *SP-0301* spike-and-ground-alert outlet costs $29.50.—**Plastic Systems, Inc.**, 261 Cedar Hill Street, Marlboro, MA 01752; Tel. 508-485-7390.

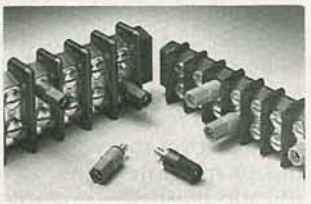
FILTER-SUBSTITUTION BOXES. With the *Krohn-Hite 3000 Series Flexi-Filters,* the response can be changed to fit many applications—without purchasing additional filter cards. As many as four filter channels have independently variable parameters to allow tailoring of their response. With the push of a button, the user selects Butterworth, Bessel, Chebyshev, or RC responses with attenuation slopes from 6–48 dB/octave in 6-dB/octave steps. Each channel can be independently set to be low-pass, high-pass, band-pass, band-reject, amplifier only, or any combination (such as low-pass with band-reject). Cutoff frequencies are tunable from 0.001 Hz to 200 kHz. The filter boxes, which have differential or single-ended-inputs, separately adjustable input-output gains of up to 10,000, and output gain adjustable in 0.1-dB steps, can be fine-tuned to suit the user's application. Additional features include up to two oscillator outputs, battery power, and IEEE-488 control of all parameters.



CIRCLE 13 ON FREE INFORMATION CARD

The *3000 Series* filter-substitution boxes range in price from $1995.00 to $3600.00.—**Krohn-Hite Corporation**, Avon Industrial Park, Bodwell Street, Avon, MA 02322; Tel. 508-580-1660, ext. 31.

THREADED BANANA JACKS. To solve the problem of "not enough hands" while handling test equipment and making multiple test contact points on terminal blocks



CIRCLE 14 ON FREE INFORMATION CARD

and strips, *ITT Pomona Electronics* has introduced a threaded banana jack. Available in three standard thread sizes, each unit is an integrally machined banana-jack receptacle and screw, with an insulated hex-head housing. The terminal strip jacks thread directly into industry-standard barrier and terminal strips.

The integral threaded studs, which are nickel-plated for corrosion resistance and low contact resistance, meet or exceed the torque specifications for the screws that they replace in the terminal strips. The insulated heads are 5/16 hex, to match the most common hex drivers.

Models *5699*, *5700*, and *5701* are 6-32, 8-32, and 10-32 thread, respectively. Each is available in seven colors for easy recognition. The list price is $2.75 each, with quantity discounts available.—**ITT Pomona Electronics**, 1500 East Ninth Street, P.O. Box 2767, Pomona, CA 91769; Tel. 714-623-3463.

TELEPHONE-NETWORK SIMULATORS. Two additions have been made to *Telecom Analysis Systems'* popular *TAS 100* family of telephone-network simulators. Designed for testing modems, fax machines, voice/data terminals, transmission test sets, and telephone sets, models *TAS 121* and *TAS 122* are compact tools for development, reliability testing, manufacturing, field support, and maintenance.



CIRCLE 15 ON FREE INFORMATION CARD

The *TAS 122* provides simultaneous bi-directional simulations of trunk impairments, and the *TAS 121* provides uni-directional impairments. On both units, impairment features include attenuation and noise; gain and group-delay distortion; phase jitter and frequency offset; nonlinear distortion; gain hits, phase hits, and impulses; and satellite delay and echo. Simulation of central office (exchange) variables is also provided, including loop current, ring voltage, ring frequency, and signaling frequencies and cadences. Both models simulate 4- and 2-wire private lines and 2-wire switched lines. Automatic calibration and diagnostics assure test integrity. Standard GPIB and RS-232C remote-control interfaces are provided.

Prices for the *TAS 121* and *TAS 122* telephone-network simulators start at $11,950.00.—**Telecom Analysis Systems, Inc.**, 34 Industrial Way East, Eatontown, NJ 07724; Tel. 201-544-8700.

ELECTROMAGNATIC-RADIATION MONITOR. Designed to meet the rising concern about the potential hazards of low-level electromagnetic radiation, *Walker Scientific's ELF-50D* field monitor is a hand-held instrument that provides accurate readings instantly on a digital display.



CIRCLE 16 ON FREE INFORMATION CARD

The *ELF-50D* measures the extra-low-frequency (ELF) electromagnetic radiation that is generated from power lines, TV's, video displays, home appliances, and other

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CIRCLE 187 ON FREE INFORMATION CARD

equipment. By simply switching the unit on and holding it where radiation is suspected, a reading is instantly provided on the 3½-digit display.

The *ELF-50D* is calibrated to measure with ±1% accuracy the electromagnetic radiation generated from any 50- or 60-Hz device. It has two switch-selectable measurement ranges: a low range from 1 milligauss to 2 Gauss, and a high range up to 20 Gauss.

The *ELF-50D* electromagnetic-radiation monitor has a suggested list price of $225.00.—**Walker Scientific, Inc.**, Rockdale Street, Worcester, MA 01606; Tel. 800-962-4638.

CAPACITANCE METER. *Boonton Electronics'* model *7200* capacitance meter accurately measures 1-MHz capacitance in the presence of loss—and measures the parallel conductance loss as well. The unit will compute and display on command the parallel resistance, dissipation, quality factor (Q), the equivalent series capacitance and resistance, ΔC, and Δ%. It features a 0–2000-pF capacitance range and a conductance range of 0 to 2000 μS. Test levels are programmable from 15 to 100 mV.



CIRCLE 17 ON FREE INFORMATION CARD

The *7200* accepts, measures, and displays external bias voltages to ± 200 V. an optional internal supply provides programmable bias voltages to ±100 V. That, together with fast analog C, G, and V outputs, make the instrument useful for C-V and G-V plots of semiconductor devices. When operated on the GPIB bus, the C, G, and V information is available simultaneously for rapid data transfer.

The model *7200* capacitance meter costs $4,495.00.—**Boonton Electronics Corp.**, 791 Route 10, Randolph, NJ 07869; Tel. 201-584-1077.

PORTABLE FUNCTION GENERATOR. A versatile general-purpose signal source, *Beckman Industrial's* model *FG2A* function generator performs over seven frequency ranges (0.2 Hz through 2 MHz) and a very large array of signal outputs, including both TTL pulse outputs and adjustable low-distortion sine-, square- or triangle-wave signals. The instrument offers the convenience of push-button selection of power, frequency range, and wave form. It is housed in a durable case that has a cushioned handle/tilt stand and recessed areas in the top cover for easy stacking of multiple units. Applications for the portable field-test instrument include such things as testing vibration, servo systems, audio systems, and ultrasonic devices, as well as in R&D and in teaching electronics.



CIRCLE 18 ON FREE INFORMATION CARD

Various controls provide flexibility. The duty-cycle control allows users to change the nominal 50% duty cycle of the signal to any desired value, and the DC offset control adds a variable DC-offset voltage to the signal. The VCF input, which permits the frequency to be controlled with an external DC control voltage, is useful for generating 1000.1 or 1.1000 sweep signals.

The model *FG2A* function generator has a suggested list price of $215.00.—**Beckman Industrial Corporation**, Industrial Products Division, 3883 Ruffin Road, San Diego,

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NTSC-PAL-SECAM TV/MONITOR/VCR. Incompatible TV-broadcasting systems—NTSC, PAL, SECAM—have created problems in international communications for years. The *Multicombo* and *Super Multicombo* TV/monitor/VHS VCR's allow PAL tapes to be enjoyed with no loss of quality. *Ten-Lab* describes the units as the first "built-in, up-dated American (NTSC) video centers that have foreign systems capabilities."



CIRCLE 19 ON FREE INFORMATION CARD

Both cable-ready sets are available in either 20- or 27-inch sizes, and feature 155 channels, wireless remote controls, double multi-function on-screen color display, hi-fi stereo sound, MTS broadcast stereo decoder, and two built-in full-range speakers. The *Multicombos* provide play-back of NTSC and PAL videotapes in color, and SECAM playback in black-and-white. The *Super Multicombos* also allow PAL and SECAM recording (in full color), as well as PAL and SECAM monitoring (PAL in color, SECAM in B&W). For the proper color, video quality, sound linearity, and synchronism, the sets provide 525 lines, 60 Hz for NTSC and 625 lines, 50 Hz for PAL.

The 20- and 27-inch *Multicombos* cost $1345.00 and $2495.00 and the 20- and 27-inch *Super Multicombos* cost $2100.00 and $3200.00, respectively.—**Ten-Lab Multisystem Video Products**, 11064 Mississippi Avenue, Los Angeles, CA 90025; Tel. 213-473-66551.

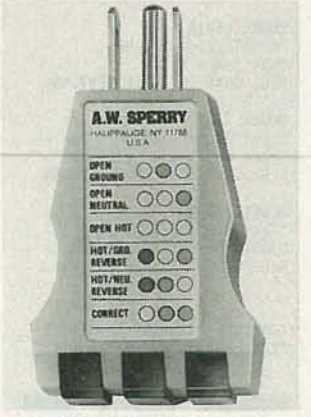


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SYNTHESIZER/CLOCK GENERATOR. Designed for engineers who require an affordable, basic frequency source, *Novatech's 2901A* synthesizer/clock generator offers 10-ppm accuracy, stability, good spectral purity, and low harmonic distortion. The instrument's output frequency is adjustable from 200 kHz to over 32 MHz with 5-digit resolution. Sinewave and TTL-compatible outputs are available on the front panel. The sinewave output amplitude is adjustable from 100 mV to 1.1 volts peak-to-peak. The *2901A* also has an auxiliary sinewave-tracking output on the rear panel that is equal to the front-panel sinewave output plus 128 MHz. The unit is housed in a convenient bench-top case with tilt-up bail.

The *Novatech 2901A* frequency synthesizer/clock generator costs $750.00.—**Novatech Instruments, Inc.**, 1530 Eastlake Avenue East, Suite 303, Seattle, WA 98102; Tel. 206-328-6902.

THREE-WIRE CIRCUIT ANALYZER. *A.W. Sperry's* easy-to-use, hand-held circuit analyzer, model *CA-300A*, warns against faulty wiring in 3-wire receptacles. As soon as the



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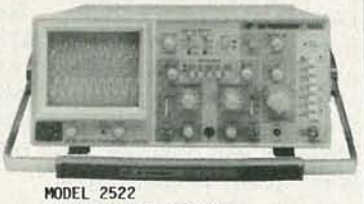
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unit is plugged in, a succession of yellow and red indicators signal exactly which wire in the receptacle is the defective one.

The *CA-300A* will not normally trip a GFCI (Ground-Fault Circuit Interrupter). It is intended for use on 110- to 125-VAC circuits.

The *CA-300A* 3-wire circuit analyzer costs $4.50.—**A.W. Sperry Instruments, Inc.**, 245 Marcus Blvd., Hauppauge, NY 11788; Tel. 516-231-7050.

REMOTE/WALL SWITCH ON/OFF CONTROL. For security purposes, or just for the sake of convenience, the versatile model *72-320* from *Midland* can be used manually or remotely to control on/off functions as well as to dim lights.



CIRCLE 22 ON FREE INFORMATION CARD

A keychain-size transmitter controls both functions from a dstance of up to 50 feet away.

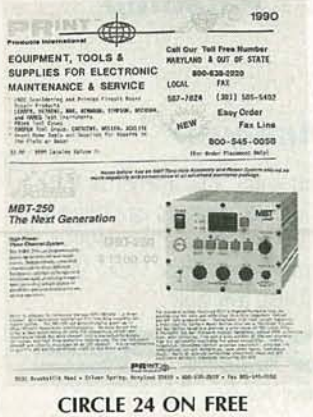
The transmitter, which uses UHF radio technology on coded channels, can handle up to 400-watt incandescent bulbs in indoor or outdoor settings. (For example, a porch or garage light can be controlled from within a car.)

All kinds of household devices can also be manually turned on and off, and lights dimmed, using the permanently installed wall switch.

The model *72-320* remote control/wall switch with the included light-dimmer function fits in a standard-sized electrical box. It has a suggested retail price of $39.95.—**Midland International Corporation**, Consumer Communications Division, 1690 North Topping, Kansas City, MO 64120; Tel. 816-241-8500.

NEW LIT

EQUIPMENT, TOOLS & SUPPLIES FOR ELECTRONIC MAINTENANCE AND SERVICE 1990 (Volume 01). PRint Products International Inc., 8931 Brookville Road, Silver Spring, MD 20910; Tel. 800-638-2020; $2.00



CIRCLE 24 ON FREE INFORMATION CARD

PRint Products' 1990 catalog contains a wide selection of products for electronic troubleshooting, maintenance, and repair. Several major manufacturers are represented. Some of the items featured in the 64-page brochure are Pace desoldering and PC-board repair products; Leader, Hitachi, B&K, Kenwood, Simpson, Beckman, and Hameg test instruments; tools and supplies from Cooper, Crescent, Weller, and Xcelite; and PRint's own line of tool cases.

COOL-AMP/CONDUCTO-LUBE BROCHURES. The Cool-Amp Conducto-Lube Co., 8603 S.W. 17th Avenue, Portland, OR 97219; Tel. 503-244-2230.

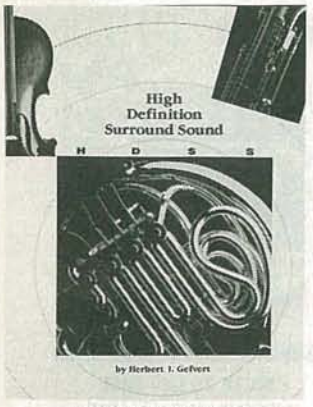
These two booklets highlight the uses of *Conducto-Lube*, an electrically conductive lubricant, and *Cool-Amp*, a product developed for silver-plating high-amperage connections on the job. Originally developed for high-speed air-blast breakers, Conducto-Lube is highly conductive because it contains pure silver. Power losses and overheating can be reduced using *Cool-Amp*, which deposits a coat of silver that provides lasting protection against oxidation. It is widely used in radio and TV stations.



CIRCLE 25 ON FREE INFORMATION CARD

HIGH DEFINITION SURROUND SOUND; by Herbert I. Gefvert. Audio Video Technologies, Inc., 60 East Ida, Antioch, IL 60002; 312-395-6321; $6.00, postpaid; $10.00 with room templates.

This fact-filled guide, written to help those who plan to install a surround-sound system to select the best format for their listening rooms, covers all aspects of sound theory. All of the various surround-sound formats are discussed, including Dolby,



CIRCLE 26 ON FREE INFORMATION CARD

Sony SRS, Lucas THX, and Audio Video Technologies' own Omnisound. Dispelling the idea that surround sound requires spending a lot of money and sophisticated electronic components, the booklet explains how effective surround sound can be accomplished without using decoders and black-box amplifiers. To help the reader customize a system to his environment, room templates are available.

THE ABC's OF DMMs. John Fluke Mfg. Co., Inc., P.O. Box 9090, Everett, WA 98206; 1-800-44-FLUKE; free.

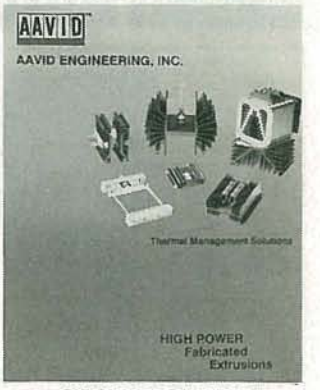
Offering a short course on the operation, capabilities, and selection of a digital multimeter, this 16-page brochure can also be used as a quick-reference guide. It features sections on the common uses of the instrument—AC- and DC-voltage measurements; resistance, continuity, and diode tests; and DC- and AC-current measurements. In addition, multimeter safety is discussed, and accessories are described. Each section of the booklet is clearly illustrated and includes a glossary of electronic and multimeter-related terms.



CIRCLE 27 ON FREE INFORMATION CARD

THERMAL MANAGEMENT SOLUTIONS: HIGH POWER FABRICATED EXTRUSIONS. Aavid Engineering, Inc., One Kool Path, P.O. Box 400, Laconia, NH 03247; 603-528-3400; free.

This solution-oriented illustrated catalog describes Aavid's full line of fabricated extrusions for cooling high-power semiconductors. Standard and customized extrusions are offered for virtually all medium- and high-power devices, including power modules and stud-mount devices, transistors, rectifiers, GTO's, and SCR's. Extrusions for cooling DC-to-DC converters and press-pack (hockey puck) devices are also covered. The catalog includes detailed dimension drawings, performance curves, and mounting specifications. The extrusions are available in a variety of anodized and chromate finishes.



CIRCLE 28 ON FREE INFORMATION CARD

1990 DATA ACQUISITION AND CONTROL CATALOG. Analog Devices, Literature Center, 70 Shawmut Road, Canton, MA 02021; 1-800-4-ANALOG; free.

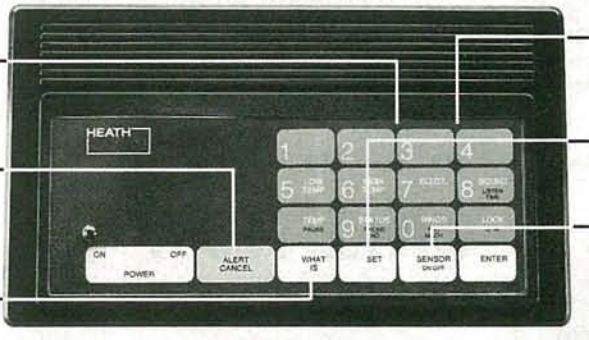
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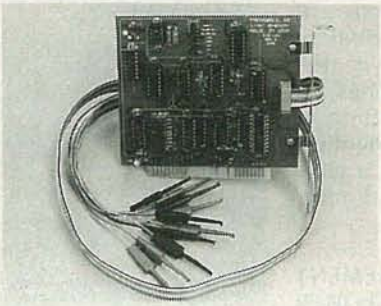
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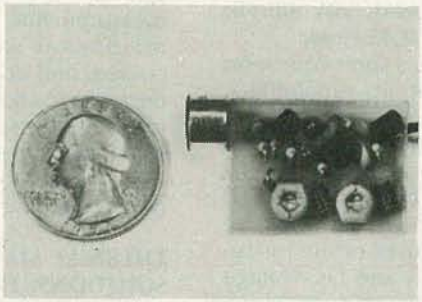
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log provides complete product descriptions, configuration charts, block diagrams, specifications, and pricing for sensor-to-host subsystems. Featured are products such as modular signal controllers, PC-compatible data-acquisition adapter boards, distributed data-acquisition and -control hardware, and a variety of applications software. A helpful tutorial and reference section guides users through the selection and configuration process.

DATA CONVERSION PRODUCTS SHORT FORM CATALOG 1990. Micro Networks/ Unitrode, 324 Clark Street, Worcester, MA 01606; 508-852-5400; free.

This 12-page booklet provides an overview of data-conversion products for high-end-industrial and military/aerospace applications. It contains more than 75 product groups, organized



CIRCLE 30 ON FREE INFORMATION CARD

into easy-to-read specifications tables. It includes digital-to-analog converters, analog-to-digital—including sampling and multi-channel—converters, and data-acquisition systems. A broad selection of track/hold amplifiers is highlighted. **R-E**

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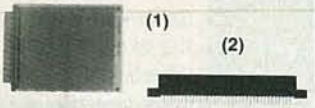
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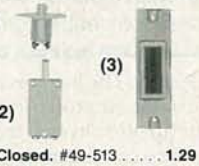
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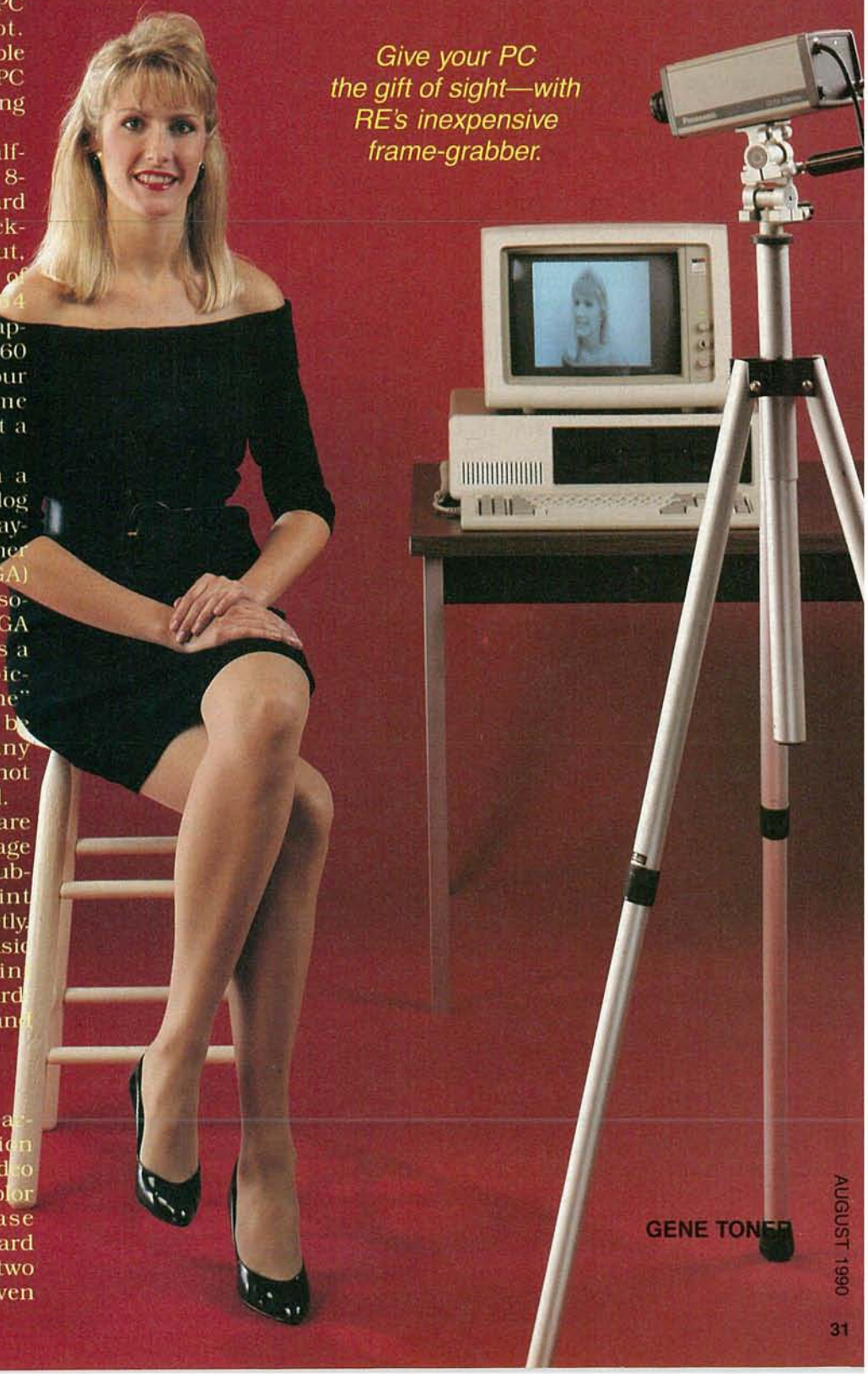
Our frame grabber is a half-length card that plugs into any 8- or 16-bit expansion slot. The card accepts standard NTSC black-and-white or color video input, and digitizes it at a resolution of 256 by 256 pixels, with 64 shades of gray. Images are captured in real time at a rate of 60 per second; depending on your PC's video system, the frame grabber can display images at a rate of about two per second.

The card works best with a VGA system, because its analog inputs are amenable to displaying gray-scaled data, but all other standards (Hercules, CGA, EGA) are supported, but at lower resolution. When displayed on a VGA system, the image approaches a black-and-white broadcast picture in quality. The "real-time" video capture allows images to be digitized on the fly from any source, so the source need not stand still or be freeze-framed.

Images that you capture are stored in the TIFF (*T*agged *I*mage *F*ile) format; most desktop publishing and pixel-based paint programs read TIFF files directly. Our software also includes basic editing functions and a print function that lets you get hard copy on common dot-matrix and laser printers.

How it works

Our image capture board accepts any RS-170 specification video signal, be it from a video camera, camcorder, or VCR, color or black-and-white. In case you're new to the field, a standard video signal is composed of two *fields*, one in which the even



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scan lines are displayed, the other in which the odd scan lines are displayed. Our board captures the even field.

Figure 1 shows a block diagram. The video signal is applied to a differential video amplifier (IC1) that serves two purposes: signal gain and noise rejection. The video amplifier must have sufficient bandwidth for the application. We chose an LF353 dual-FET input op-amp; it has a 4-MHz bandwidth, which is enough for our application. The output of the video amp drives the sync separator (IC2) and the video DC restoration block (IC3 and IC4).

A National LM1881 is the hub of the sync separator. (see Fig. 2). That IC is a video engineer's delight, as it provides composite sync, vertical sync, odd/even frame detection, and burst-gate/black-level timing information. The odd/even frame signal is used to detect and capture the even frame, since this frame has a full line of video on line one. The black-level timing signal is used by an LM398 sample-and-hold amplifier (IC3) to sample the video for its black-level reference. This level is later subtracted from the amplified video to fix the reference level at ground for subsequent digitization.

The subtraction process leaves us with a ground-referenced video signal with an amplitude of about 3.3 volts at the white level, just right for digitization by A/D converter IC13.

To digitize the incoming video at the frame rate, a flash A/D converter must be used. Other types of A/D converters (such as the common successive-approximation type) are too slow to digitize six bits of information in the 200 ns required by this application. A flash A/D converter has 2^{nmil} comparators so that a conversion can be done in one clock cycle. The low phase of the clock initiates conversion, and the high phase transfers the data to the capture memory. In our case, $n=6$.

The digitization hardware is controlled by software; the two communicate via a two-bit command latch that together with the six data bits occupy several addresses in the PC's I/O space. The two command-latch bits are connected to data-bus lines D0 and D1. To avoid conflict with other boards, the I/O address is configurable via a pair of address-selection jumpers (JU6 and JU7) that allow you to select one of four base addresses (02E0, 02F0, 03E0, and 03F0). The circuit occupies four addresses in the I/O space, but only two are actually used.

The software checks for the presence of the image-capture board in a PC as follows: First it writes to the command latch (sets D0 and D1 high) and then reads back the data port (IC16) and checks the two high bits (D6 and D7). That bit displacement ensures that the software finds our card and not any others.

The decoding scheme is implemented by IC17, an eight-bit magnitude comparator (74HC688), and IC18, a triple three-input OR gate (74HC4075). The latter provides three outputs: $\overline{WR0}$, which is used to clock the command latch; $\overline{WR1}$, which is used to reset the pixel counters; and $\overline{RD0}$, which is used to read captured data into the host PC.

The command latch consists of both halves of IC19, a dual-D flip-flop (74LS74). The two bits of this latch control the two operating modes of the card: capture and read. We'll discuss each in turn.

Capture mode

To initiate a capture, the software first resets the pixel counters and the line counters (IC9–12) by writing to the base address plus one. After reset, the board is ready to take a picture. To do so, a capture request and the start of an even frame must be synchronized.

Synchronization is accomplished by writing ones to the command latch. Doing so drives the Q output of IC19-a high, which in turn clocks a capture request into IC8-a, a dual-D flip-flop. Its output enables the output of the gated oscillator and divide-by-four circuit (XTAL1, IC6, and IC7), which clocks the A/D converter (IC13). The enabled

Resistors

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

- **R1** ..... *75 ohms*
- **R2, R3** ..... *511 ohms, 1%*
- **R4, R5** ..... *2300 ohms, 1%*
- **R6** ..... *390 ohms*
- **R7** ..... *150 ohms*
- **R8** ..... *680,000 ohms*
- **R9, R14** ..... *1000 ohms*
- **R10–R13** ..... *10,000 ohms, 1%*
- **R15, R16** ..... *330 ohms*
- **R17** ..... *2200 ohms*
- **R18** ..... *220 ohms, ½ watt*
- **R19, R20** ..... *5100 ohms*

Capacitors

- **C1, C2** ..... *150 pF*
- **C3, C8** ..... *0.22 µF, metal film*
- **C4, C5** ..... *0.1 µF, metal film*
- **C7** ..... *68 pF, disk*
- **C10** ..... *0.1µF, disk*
- **C6, C9, C11** ..... *1 µF*
- **C12–C22** ..... *0.01 µF, disk*
- **C23** ..... *22 pF*

Semiconductors

- **IC1, IC4** ..... *LF353N dual bi-FET op-amp*
- **IC2** ..... *LM1881N video sync separator*
- **IC3** ..... *LF398N FET sample/hold amplifier*
- **IC5** ..... *74LS04 hex inverter*
- **IC6** ..... *74LS00 quad two-input NAND gate*
- **IC7, IC19** ..... *74LS74 dual-D flip-flop (National Semiconductor)*
- **IC8** ..... *74HC74 dual-D flip-flop*
- **IC9–IC12** ..... *74LS193 synchronous up/down binary counter*
- **IC13** ..... *MP7682JN 6-bit flash A/D converter*
- **IC14, IC15** ..... *43256-15 32K × 8 static RAM, 150 ns*
- **IC16** ..... *74LS244 tri-state octal buffer*
- **IC17** ..... *74HC688 8-bit magnitude comparator*
- **IC18** ..... *74HC4075 triple three-input OR gate*
- **D1, D2** ..... *1N4148 switching diode*
- **D3** ..... *1N5226B, 3.3-volt Zener diode*

Other components

- **J1** ..... *PC-mount RCA video connector*
- **JU1, JU2** ..... *not used*
- **JU3–JU8** ..... *single-row 2-pin header*
- **XTAL1** ..... *20-MHz crystal*

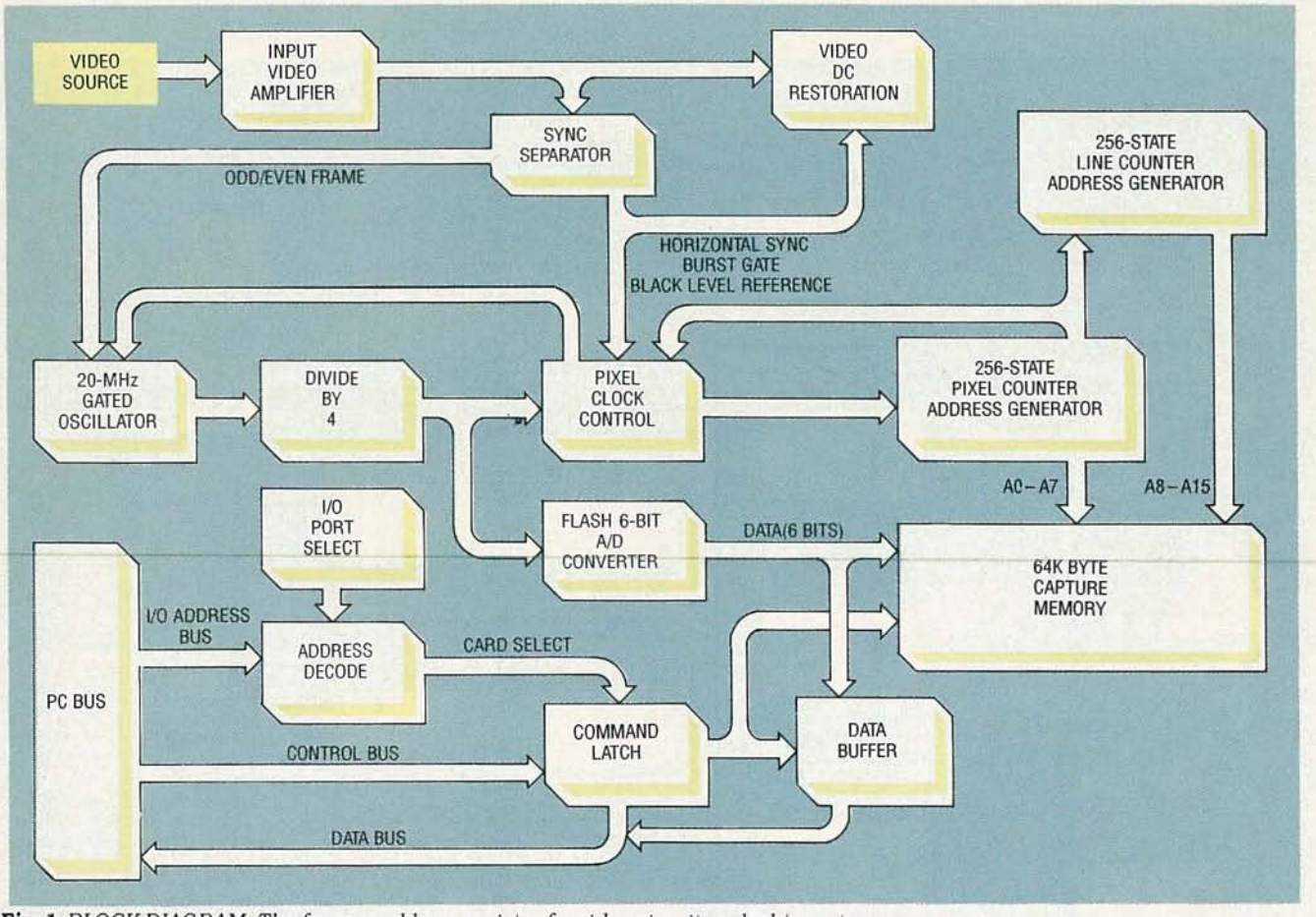


Fig. 1. *BLOCK DIAGRAM. The frame grabber consists of a video circuit, a clock/counter circuit, a bus interface, the A/D converter, and 64K of static RAM.*

clock signal (via pin 6 of IC6) also drives the pixel counters (IC9–IC12) when the second bit (pin 9 of IC19) of the command latch is high.

At this point, the A/D converter's output is enabled and the outputs of the capture memories are disabled, thereby giving the D/A converter control of the local data bus. When a high from the pixel clock is presented to the A/D converter, a conversion is completed. Then, when the pixel clock goes low, the data is transferred to the output buffers of the A/D and presented to the capture memories. When the pixel clock again goes high, the rising edge of that signal strobes the data on the local bus into the capture memories, and simultaneously starts another conversion.

That cycle proceeds until 256 samples have been taken. Then the output of the second pixel counter (pin 13 of IC10) goes low, and that signal resets IC8-b, which causes the gated oscillator to stop. The circuit remains disabled until the black-level reference signal (at the start of the next horizontal scan line) goes low and then high, which clocks a high into flip-flop IC8-b, and thereby allows the gated oscillator to resume.

The output of the pixel counter is differentiated by the network consisting of D2, C8, and R17. Otherwise a continuous low would be presented to the reset input of IC8-b, thus causing continuous reset and system lockup after one video line had been captured. The diode prevents the voltage at pin 10 of IC8 from exceeding V_{CC} + 0.7. The IC specified for IC8 is a 74HC74, which can take a voltage exceeding V_{CC} by 1.5 volts, as opposed to a 74LS74, which can only take V_{CC} + 0.5 volts.

When the next black-level reference pulse is encountered, the line-capture cycle is repeated. The cycle repeats until 256 lines have been captured, at which point the output of the second line counter (pin 13 of IC12) goes low.

That action resets the enable-capture flip-flop (IC8-a) as well as the command latch (IC19-a, IC19-b). The software can read the contents of the command latch, so that reset provides a convenient means of signalling end-of-capture.

Ordering Information

The following are available from IDEC, Inc.
P.O. Box 69
Fountainville, PA 18923
(215) 249-0673

Assembled and tested board, software, and User's Manual with one-year warranty **$199**

Complete kit including PC board, all parts, software, and User's Manual **$140**

Partial kit including PC board, IC2, IC6, IC7, IC8, IC13, IC19, J1, XTAL1, D3, brackets, screws, jumpers, software, and User's Manual **$75**

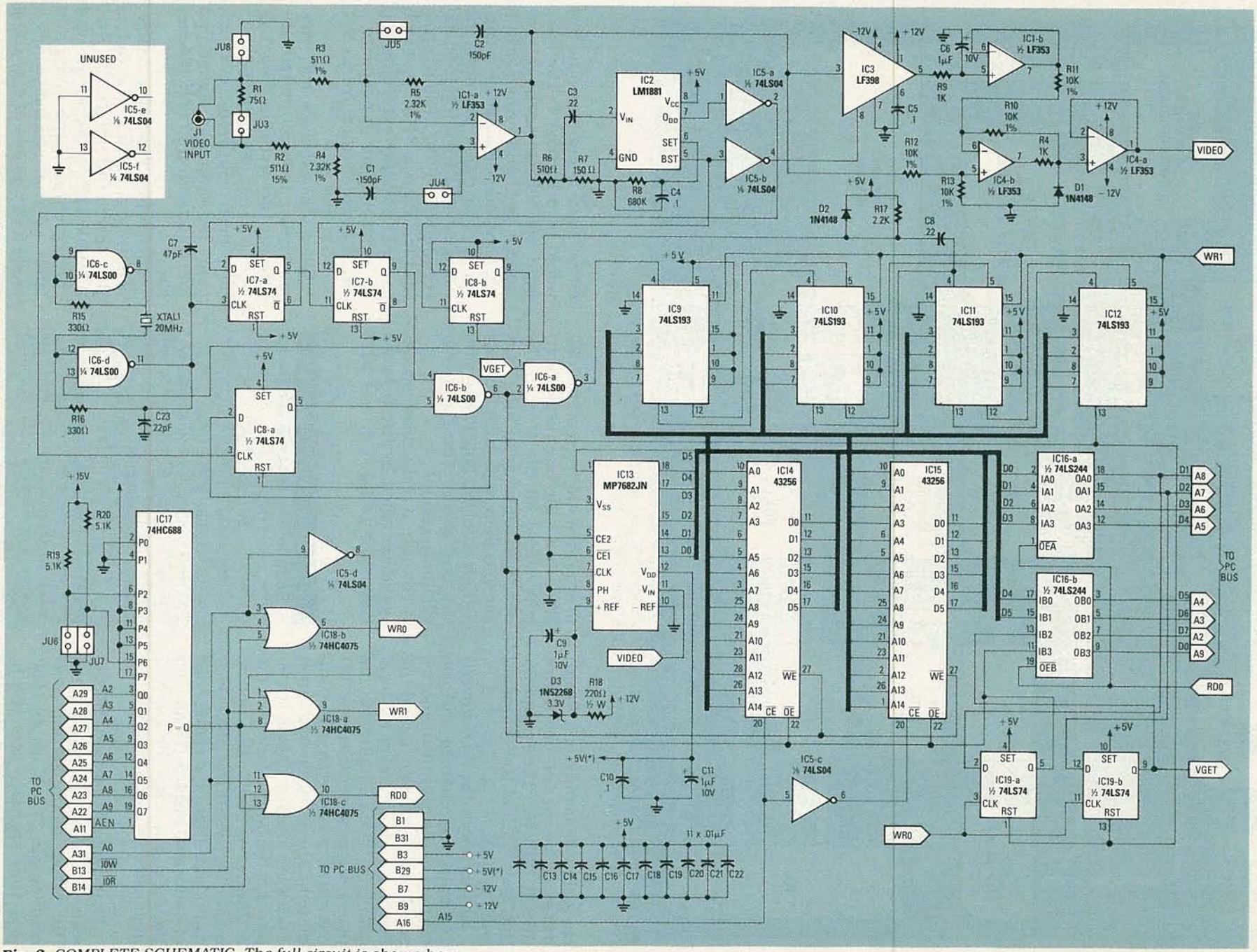


Fig. 2. *COMPLETE SCHEMATIC. The full circuit is shown here.*

Read mode

The next step is for the software to read the captured data into main memory. This is done by setting bit 0 of the command latch low, which enables the capture memories and disables the A/D converter. The counters are again reset by a write to base plus one, and the data read at the data port. Only the lower six bits of the data port are of interest, as the upper two bits reflect the contents of the command latch, and must be masked off by the software. The pixel counters are advanced to the next pixel by strobing bit two of the command latch first low and then high. That sequence must be repeated until all pixels have been read into memory, from where they can be processed, saved to disk, etc.

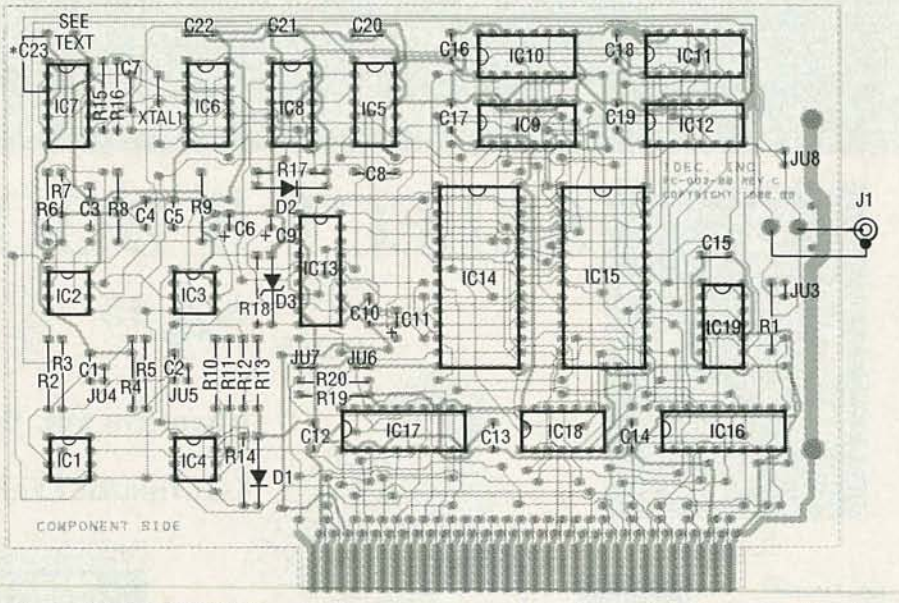


Fig. 3. PARTS LAYOUT. Mount all components as shown here. Note the connections for C23.

Construction

Due to the high frequencies involved, we recommend that you build the frame grabber on a PC board. Patterns are shown in PC Service; if you make your own PC board, remember that you'll have to solder many lands on both sides of the PC board. As an alternative, you may want to purchase a PC board from the source mentioned in the parts list. Kits and assembled versions are also available.

Construction of the board is straightforward and should present no problems. Figure 3 shows where all parts are mounted. When mounting parts, observe the polarities of all diodes, IC's, and electrolytic capacitors.

On the PC board, pads for C23 are shown just above IC7. Mount the capacitor instead between the pad above pin 1 and directly to pin 3 of IC7, as shown in Fig. 4. Doing so lets C23 provide a stable load for the crystal oscillator. Check all solder joints after mounting the components, and then remove all flux residue.

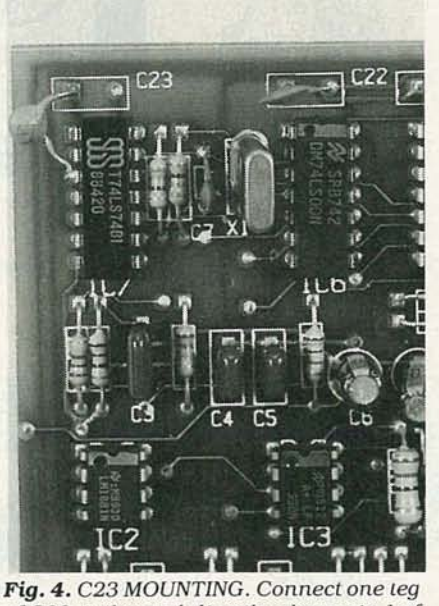


Fig. 4. C23 MOUNTING. Connect one leg of C23 to the pad directly above pin 1 of IC7, and the other leg directly to pin 3 of IC7.

Installation

First install jumpers as follows:

- JU3: If installed, the computer is the last device on the video cable. Normally installed.
- JU4/JU5: Set both jumpers the same way, installed for sources with a strong video carrier, uninstalled for normal sources. Normally uninstalled.
- JU6/JU7: Selects I/O port address according to Table 1.
- JU8: Install to ground input cable shield. Normally installed.

Then install the board in an empty 8- or 16-bit expansion slot. Copy the software to a subdirectory of your working disk and then run VSETUP. The program asks you to specify your PC's video adapter and printer. Then you can run the main program, VGRAB.

TABLE 1—I/O PORT SETTINGS

I/O Port	JU6	JU7
03F0	Off	On
03E0	On	Off
02F0	Off	Off
02E0	On	On

In bringing up the board for the first time, feed a good, clean RS-170 video signal to the card—not a signal from an inexpensive video modulator.

If you have a problem, be sure that there is valid output from pin 1 of IC4, especially if you have to reset the computer to regain control. The signal there should resemble a standard video signal, with the end of the horizontal-sync pulse at ground and the white level at about 3.3 volts.

The LM1881 is very sensitive to the value of R8 (680K). If solder with water-soluble flux is used, be sure that the area around this resistor is clean, as the flux is conductive and may alter the effective value of the resistor.

Using VGRAB

As shown in Fig. 5, the software has a friendly user interface with drop-down menus and status panels. The software is available on the RE-BBS (516) 293-2283; download the file called VGRAB.ARC. Going from left to right, the first menu allows

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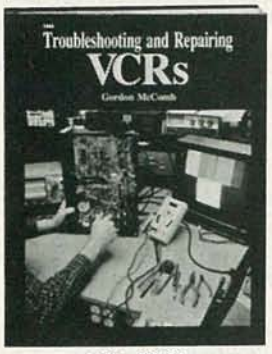
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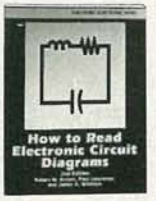
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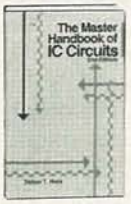
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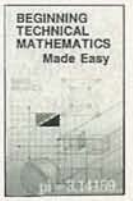
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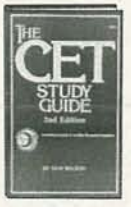
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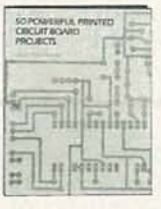
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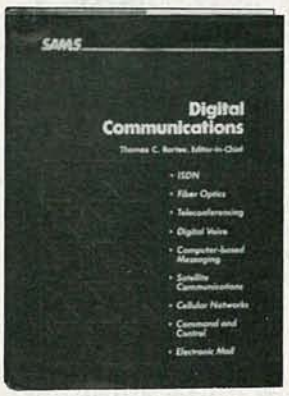
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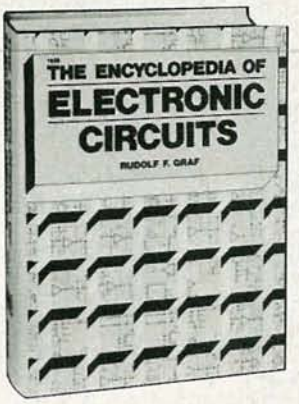
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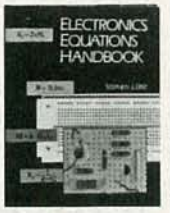
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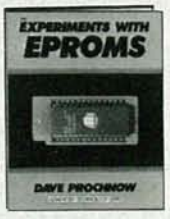
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THESE SCREEN SHOTS HINT at the versatility of the VGRAB software. Clockwise from the top left, the same image is shown in: VGA mode with 64 shades of gray; EGA mode with 4 gray levels; CGA mode with 2 gray levels; a negative image; a line drawing; and a horizontally flipped image with a black/white threshold condition applied.

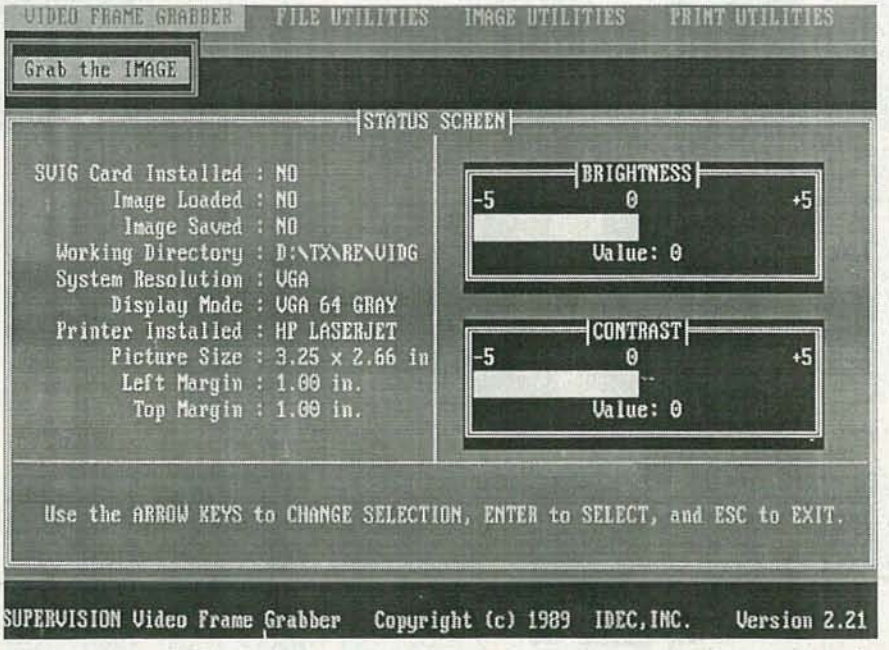


Fig. 5. *VGRAB SOFTWARE. The menu bar across the top line provides access to the capture, file, image-manipulation, and print functions.*

you to capture the currently displayed image from the board. The next menu contains file utilities (save, load, etc.). The third menu contains functions for manipulating the image. You can reverse it horizontally and vertically, turn it into a negative or line drawing, adjust contrast and brightness, change the display resolution, etc. (The box above shows some examples.) The last menu allows you to set print parameters and print the image.

Images are saved in the TIFF file format, which is just right for importing into desktop publishers (Ventura, PageMaker), and modern word processors (Word, WordStar, etc.) that support the format.

Idec has developed software that interacts with database programs such as Ashton-Tate's dBASE III. These programs allow dBASE III to capture, display, and print images from normal dBASE III record fields, allowing the construction and maintenance of image databases. Contact Idec at the address in the "Ordering Information" box for more information. **R-E**



DIGITAL PRESSURE GAUGE

Now you can take pressure readings the modern way using our electronic pressure gauge.

ANTHONY J. CARISTI

MOST OF US ARE FAMILIAR WITH AN ORDINARY pressure gauge, such as that used for tires that measures pressure in *p*ounds per *s*quare *i*nch (psi). They are usually analog devices with an indicator bar or a moving needle whose movements depend on the specific pressure. However, with the advance of solid-state technology, it is possible to construct an accurate electronic pressure gauge with a resolution as low as 0.1 psi.

Our digital pressure gauge operates from a 9-volt battery, so it is completely portable. The circuit uses only 4 milliamperes, so battery life will be extremely long. A large two-digit LCD is used to display pressure readings, but we'll also show you how to build it with a 3½-digit display.

The full-scale range of the pressure gauge is determined by the selection of the pressure sensor; in this case we have used a 0–100 psi semiconductor sensor, manufactured by Sensym (1255 Reamwood Ave, Sunnyvale CA 94089). Other sensors are available in full-scale ranges of 1, 5, 15, 30, 100, and 150 psi. Using a 15-psi sensor, for example, would result in a display resolution of 0.1 psi with a two-digit readout.

Pressure is measured by connecting a flexible hose between the sensor and source of pressure. If the project is to be used for differential pressure measurements, two hoses must be connected to the sensor and the device under test. Vacuum measurements require only one hose connection.

The circuit

The sensor is a differential device, which allows two pressure connections, and it measures the difference between the two. The sensor also permits vacuum measurements when one side of the sensor is exposed to the atmosphere and vacuum applied to the other. Pressure and vacuum measurements may be taken on any noncorrosive and non-toxic media such as air, dry gases, etc. The portable nature of the unit allows it to be used almost anywhere, such as for checking tire pressure or a compressed air tank.

The heart of this project is a differential piezoresistive pressure sensor which is constructed using integrated-circuit technology. It consists of four resistors connected in a Wheatstone bridge configuration, which are deposited on a silicon diaphragm that separates two chambers of the sensor housing. Each side of the diaphragm can be exposed to a pressure source by means of "ports" called P1 and P2. Any pressure difference between port P1 and port P2 will be detected by the sensor, providing a differential pressure reading. Figure 1 shows a closeup of the sensor.

The common pressure gauge which many people are familiar with is, in reality, a differential pressure gauge, with atmospheric pressure (14.7 psi) being the reference pressure. Thus, when no pressure is applied to the sensing port of the common gauge, the reading is zero. The same goes for our gauge; pressure is applied to P2 while P1 is exposed to the atmosphere.

When the pressure sensor is at rest, there is no stress on the silicon diaphragm and the values of the resistors are essentially equal. The Wheatstone bridge is thus balanced and its output voltage is virtually zero. During a pressure measurement, any difference in pressure between the two ports of the sensor result in mechanical stress of the silicon diaphragm and a change in the values of the four resistors. Two resistors increase in value and two de-

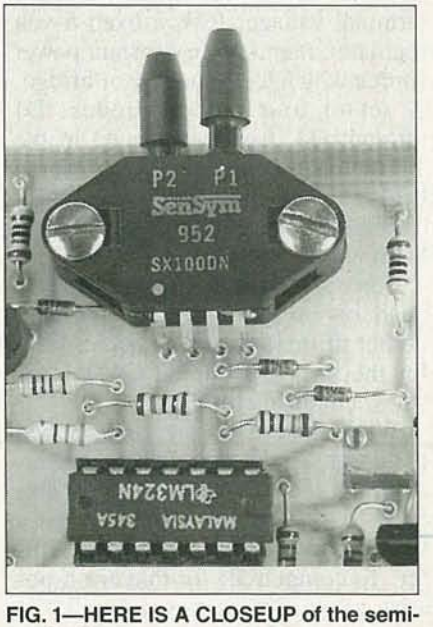


FIG. 1—HERE IS A CLOSEUP of the semiconductor pressure sensor.

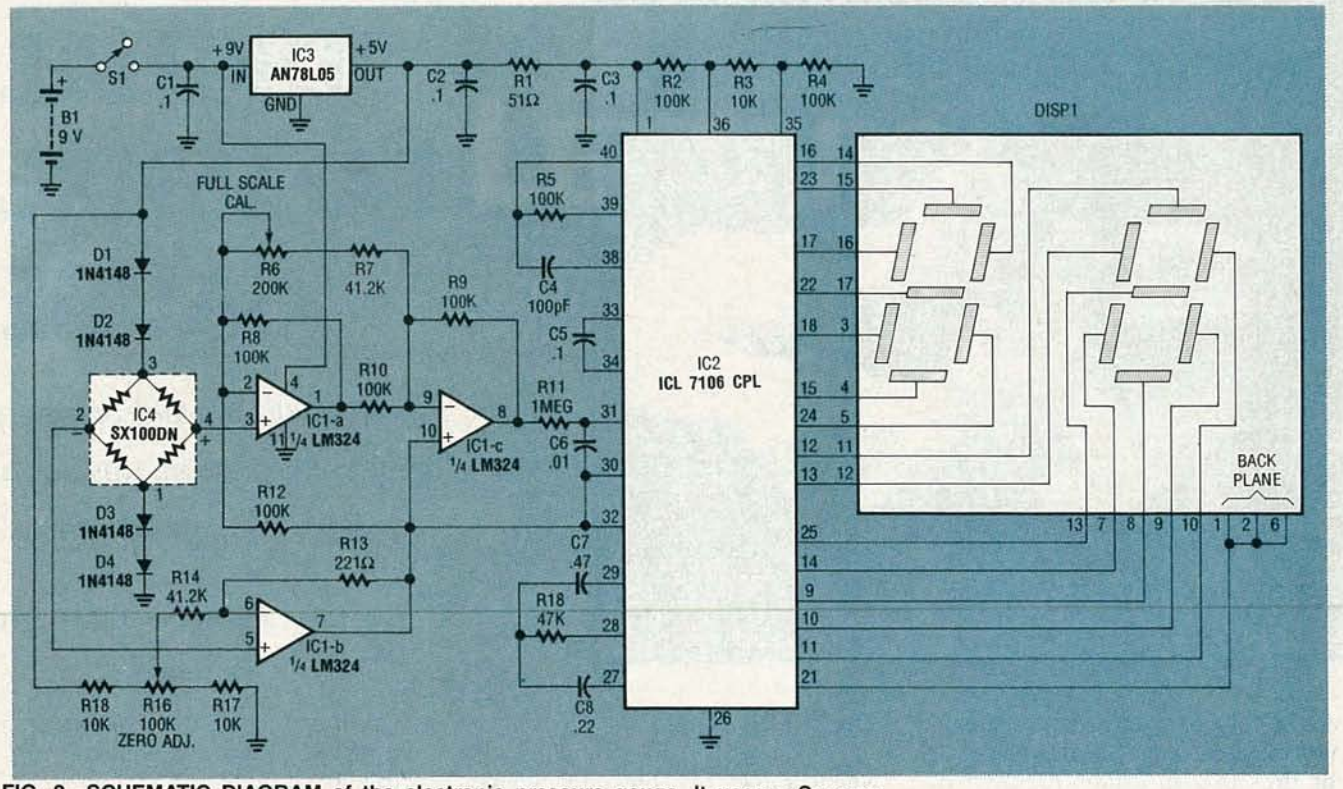


FIG. 2—SCHEMATIC DIAGRAM of the electronic pressure gauge. It uses a Sensym semiconductor pressure sensor.

crease. That causes the Wheatstone bridge to become unbalanced, producing an output voltage which is proportional to the difference in pressure between the two ports of the sensor. That voltage, which in the millivolt range, is amplified and used to provide the drive signal to the display section of the circuit.

The schematic diagram is shown in Fig. 2. In order to preserve the accuracy of the pressure measurement with respect to variations in battery terminal voltage, IC3, a fixed 5-volt regulator, maintains a constant power source which feeds the sensor bridge. A set of four silicon diodes, D1 through D4, has been placed in the circuit to temperature compensate the bridge. That eliminates changes in calibration of the circuit due to ambient temperature effects.

Three sections of IC1, an LM324N quad op-amp, amplify the millivolt output of the bridge to a useful level for the analog-to-digital (A/D) converter circuit that follows.

When there is no pressure applied to the sensor, the voltage between terminals 2 and 4 of the sensor is essentially zero; however, there may be a small output voltage, called zero offset. To compensate for that error, potentiometer R16 allows a small DC voltage to be fed to the amplifier circuit which negates the offset voltage of the sensor.

When the sensor is exposed to 100 psi, the output of the bridge circuit will generate approximately 34 millivolts. However, there may be variations in output voltage of as much as 30% between different sensors. To compensate for any given sensor, the amplifier gain is adjustable by means of potentiometer R6.

The display section consists IC2, which is a combination A/D converter/7-segment decoder/display driver, capable of driving a 3½-digit LCD (we've used only a two-digit display, DSP1). It is driven by the voltage between pins 7 and 8 of op-amp IC1. The sensitivity of the A/D converter is set by the reference voltage applied between pins 35 and 36. The reference voltage, which is about 238 millivolts, is set by the divider composed of R2, R3, and R4.

In this project only two digits are required since the resolution of the project is 1 psi and full scale is 100 psi. However, note that if you measure exactly 100 psi, the readout will display 00, since the hundreds digit is not present.

Note that for readings greater than 99 psi, or for 0.1 psi resolution, the circuit can modified to use the most significant and least significant digits of the A to D chip. In this case you'd need to use a 3½-digit readout, and its decimal place would be illuminated as required. If you wish to use a 3½-digit LCD, Fig. 3 shows the additional connections to the A/D converter that are required. However, note that the 3½-digit display is a 40-pin device that won't fit on the provided PC board. You must either hardwire it or design your own board.

Because of the characteristics of the pressure sensor, the display will read up-scale regardless of which port of the sensor is pressurized. However, you should use the same port for which the project was calibrated. If the project is to be used for vacuum or differential pressure measurements, the display will indicate the pressure difference in psi, with no polarity indication. The A to D converter used in this circuit does have an output terminal to indicate polarity, but it is not used.

Construction

The project is constructed on a single-sided PC board. A foil pattern is provided in PC Service. The circuit can also be hard wired on a perforated construction board if you wish. The parts-placement diagram is shown in Fig. 4. Note that the LCD readout is mounted on the copper side of the

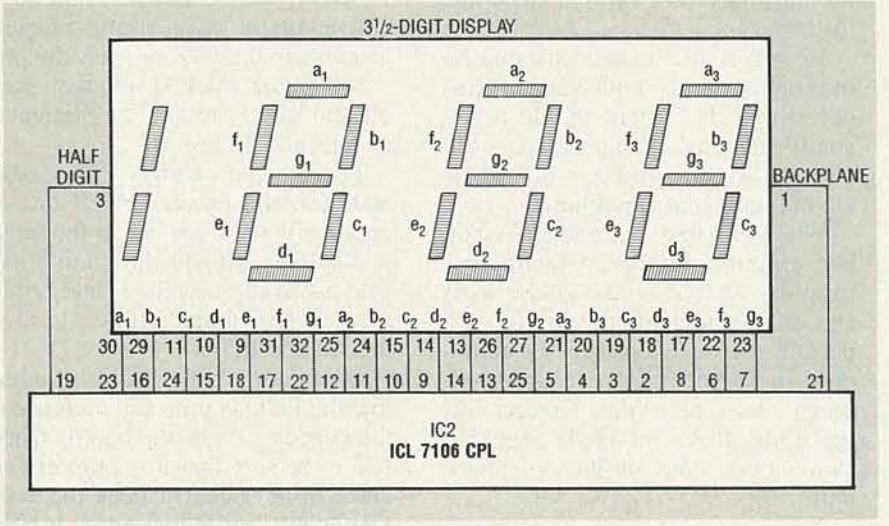


FIG. 3—HERE ARE THE ADDITIONAL CONNECTIONS to the A/D converter that are required for a 3½-digit display. Note that the 40-pin display won't fit on the PC board—you'll have to hardwire it or design your own board.

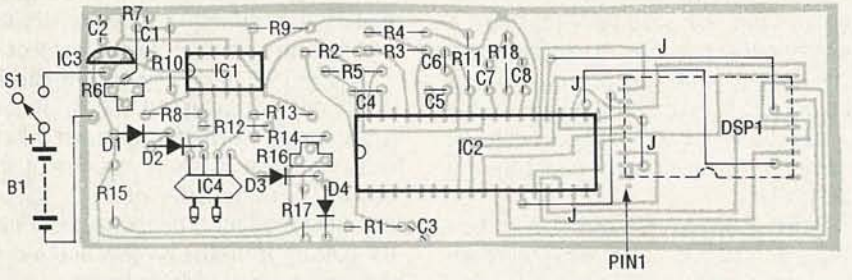


FIG. 4—PARTS-PLACEMENT DIAGRAM. Note that the LCD readout is mounted on the copper side of the board.

board. That allows the relatively flat side of the PC board to be mounted next to the side of a suitable enclosure containing a cutout or window to expose the readout for viewing.

You should use sockets for both of the IC's. Especially for IC2, which is a 40-pin chip and not inexpensive. The cost of a socket is minor compared to the IC itself, and you can never predict when an IC will have to be removed from a PC board. Once the sockets are in place, continue installing components, but do not insert the IC's yet.

The 5-volt regulator, IC3, looks like a small transistor; simply solder it directly to the board, and be sure to watch its orientation. Also be sure that the diodes are properly oriented.

The circuit requires four jumpers; the short jumper wire between pins 2 and 6 of the LCD can be a piece of bare wire, but the other three should be insulated to avoid shorts.

Many of the resistors specified in the parts list are metal-film types which exhibit excellent temperature stability. Since we want the project's calibration to remain stable with varying temperature, you should not substitute other types of resistors.

The LCD and the pressure sensor are fragile and must be handled carefully to avoid breakage. It is suggested that the readout be mounted to the board last. You may wish to use a socket for the readout, and you can make one by taking an ordinary 18-pin DIP socket and cutting it in half lengthwise. Remember, the socket (and readout) will be placed on the copper side of the board, so you must allow some space between the plastic of the socket and the board itself to allow room for soldering.

Before mounting the LCD, take note of where pin 1 is. If you look at Fig. 5, the black border around it has a marking on one side. Looking at that marking, pin 1 is where you'd normally see it on any ordinary IC.

The pressure sensor may be fastened to the board using two #4 machine screws and nuts, but be very careful not to over-tighten them; it could result in a cracked plastic assembly. Note that one of the terminals of the sensor is marked with a small dot. That is pin 1, so be sure to mount it as shown in Fig. 4. The four terminals of the sensor are very fragile, and must be carefully bent into position using a needle-nose pliers to support the leads next to the body of the part. If you attempt to bend the leads with-

PARTS LIST

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

R1—51 ohms
R2, R4, R8–R10, R12—100,000 ohms, 1% metal film
R3, R15, R17—10,000 ohms, 1% metal film
R5—100,000 ohms
R6—200,000 ohms, PC-mount potentiometer
R7, R14—41,200 ohms, 1% metal film
R11—1 megohm
R13—221 ohms, 1% metal film
R16—100,000 ohms, PC-mount potentiometer
R18—47,000 ohms

Capacitors

C1–C3, C5—0.1 µF, ceramic disc
C4—100 pF, ceramic disc
C6—0.01 µF, ceramic disc
C7—0.47 µF, ceramic disc
C8—0.22 µF, ceramic disc

Semiconductors

IC1—LM324N quad op-amp
IC2—ICL7106CPL 3½-digit A/D converter (Intersil)
IC3—AN78L05 5-volt regulator
IC4—differential semiconductor pressure sensor,
SX01DN for 1 psi full scale
SX05DN for 5 psi full scale
SX15DN for 15 psi full scale
SX30DN for 30 psi full scale
SX100DN for 100 psi full scale
SX150DN for 150 psi full scale
(Sensym, 1255 Reamwood Ave, Sunnyvale CA 94089)
D1–D4—1N4148 silicon diode
DSP1—two-digit LCD module (DigiKey LCD001)
Optional—3½-digit module (Digikey LCD002)

Other components

S1—SPST toggle or slide switch, N.O.
B1—9-volt battery
Miscellaneous: battery clip, enclosure, IC sockets, hose w/fitting, clamps, wire, solder, etc.

Note: A PC board is available for $14.95 and a pressure sensor for $35.00 from A. Caristi, 69 White Pond Road, Waldwick, NJ 07463. Add $2.50 postage and handling per order.

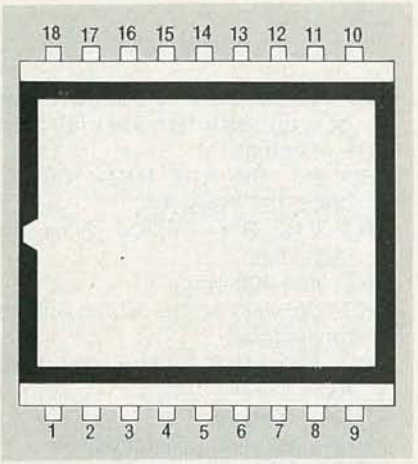


FIG. 5—THE BLACK BORDER around the display has a marking on one side. Using the marking as a reference, pin 1 is where you'd normally see it on any ordinary IC.

out such support, you risk breaking the wires.

A suitable pressure hose must be connected to port P2 of the sensor, and secured with a small metal clamp that has been designed to handle high pressures. Such clamps can be obtained from automotive supply outlets. It cannot be over-stressed that pressures greater than 10 psi are substantial, and the hose and clamp must be able to withstand such force.

If you want to use the project to measure tire pressure, you need a hose from a bicycle shop with a fitting at the end that depresses the valve stem during a pressure measurement. You might be able to take an old tire pressure gauge and modify it for use with our digital pressure gauge. As with the pressure-sensor connection, you will need to clamp the valve fitting to the hose.

You may wish to use a normally open pushbutton switch for your project. That will prevent accidentally leaving the power on and depleting the battery.

Be sure to use a connector clip for the battery to ease replacement when necessary. The battery should be securely mounted in the project's enclosure so that it does not rattle around and break anything.

When you have completed assembly, examine the circuit board very carefully for bad solder connections and inadvertent short circuits, especially between adjacent IC terminals. Bad solder joints often are dull, rough blobs of solder. Correct any problems that you find. Figure 6 shows both sides of the completed unit.

Checkout

To check out the project you will need a DC voltmeter, as well as a source of air pressure such as a portable air tank. Be sure tank pressure is not over 100 psi. For the preliminary checkout it is not necessary to know the precise pressure of the source, but it should be in the range near the maximum measurement capability of the project.

Before putting IC1 and IC2 in their sockets, set the calibration potentiometers to mid-position. Connect a 9-volt battery, and turn on power.

Measure the voltage across C2; you should obtain a reading between 4.8 and 5.2 volts DC. If you do not obtain the correct reading, do not proceed with the checkout until you troubleshoot the problem. Check IC3 for proper orientation. Check the terminal voltage of the battery to verify that it is delivering at least 7 volts. Disconnect the battery and measure the resistance across C2 to verify that you do not have a short circuit between the 5-volt bus and ground.

When you are satisfied that the 5-volt regulator is operating properly, disconnect the battery from the project and insert the IC's into their sockets. Be sure to follow the orientation as indicated in Fig. 4.

Reconnect the battery to the project and turn the power switch on. No pressure is to be applied to the sensor at this time. The display should indicate a two digit reading, and adjustment of R16 should allow you to set the reading to 00.

If you don't get any display, check that the LCD is properly mounted on the copper side of the board. Check IC2 to be sure that it is properly oriented in its socket. Check the 5-volt regulator to verify that power is being applied the circuit. If your meter is capable of measuring DC current, you can check the current draw from the battery to determine if it is approximately 4 milliamperes, which is the normal current draw of the project.

If you obtain a display but the illuminated segments of the digits are not entirely correct, the most likely cause is open or short circuits at the output connections of IC2 which drive the readout. Disconnect IC2 and the battery from the project and locate the fault using an ohmmeter.

Note that the display may, on occasion, indicate 01 instead of 00. This is not to be construed as a defect in the circuit; it merely means that your zero adjustment is not centered exactly.

When you are satisfied that the zero adjustment of the display is correct, you may apply full pressure to the P2 port of the sensor. When that is done, the readout will indicate some number. Adjust R6 for a display equal to the pressure of the source, if known.

continued on page 83

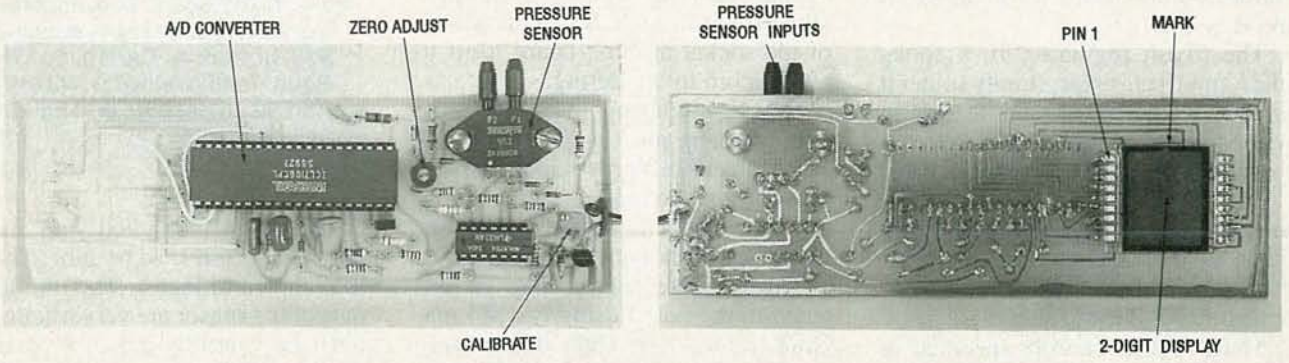


FIG. 6—HERE ARE BOTH SIDES of the completed unit. notice how the display goes on the foil side.

This month we discuss the motor-controller board.

Build the Lawn Ranger



RAYMOND RAFAELS

LAST MONTH WE DIDN'T GET A CHANCE TO FINISH THE MOTHERBOARD and the motor-controller board. So let's finish up those two boards now, and then continue with the story.

Construction

Assemble the motherboard by soldering the three edge connectors onto the PC board with the connector pins protruding through the circuit side of the PC board. The schematic is shown in Fig. 1. The circuit side of the board contains the large ground plane.

Figure 2 shows the parts-placement diagram for the motor-controller board. First, solder the IC sockets to the PC board (one can be obtained from TSI or you can make one from the foil pattern provided in PC Service). Next, solder in all remaining components except for the following components that require special installation: R71, R76, R85, R88, R93, C6, C17, C46, C48–C51, D20, and D22.

Capacitors C6, C17, and C46 are tall and have radial leads (both leads stick out of the bottom). In order to keep the height of the motor-controller board at a minimum, we need to mount those capacitors on their side. That can be accomplished by adding ⅛-inch of insulating plastic sleeving to each of the leads before the capacitor is installed. Then solder, trim leads, and bend the capacitor over on its side. A small drop of RTV or epoxy can be added to secure the capacitors to the PC board.

Diodes D20 and D22 must be soldered in series, and then installed as a single component in the location indicated in Fig. 2. Resistors R93 and R1 consists of two 16-ohm, ½-watt resistors connected in parallel. The resistors are then installed as a single component as indicated in Fig. 10. Resistors R71, R76, R85, and R88 should have 0.1 μF capacitors soldered in parallel with them before installation. The capacitors are identified in Fig. 2 as C48, C49, C50, C51, respectively.

There are some jumpers that must be installed on the solder side of the board. The first one goes from J22 pin 41 to IC1 pin 4. Another goes from J22 pin 47 to IC2 pin 6. Next, two twisted pairs of jumpers, each pair consisting of a length red and black wire twisted together, must also be installed on the solder side of the board. The red wire of the first pair must go from J22 pin 42 to R81, and the black wire goes from J22 pin 45 to R82. The red wire from the second twisted pair goes from J22 pin 38 to R63, and the black wire goes from J22 pin 39 to R64.

Alignment

Alignment of the motor-controller board consists of adjusting potentiometers R201, R202, and R203. R201 and R202 are used to adjust the speed of the left and right drive motors, respectively, and R203 adjusts the offset voltage to the D/A circuit.

First adjust R201 and R202 to their center position. R203 should be adjusted until the D/A output (pin 7 of IC4-b) is 0 volts when the D/A input is as follows: DA0 = 0, DA1 = 1, DA2 = 1, DA3 = 1, DA4 = 1, and DA5 = 0. The D/A input can be set by temporarily applying +5 volts for a "1" and ground for a "0" when the

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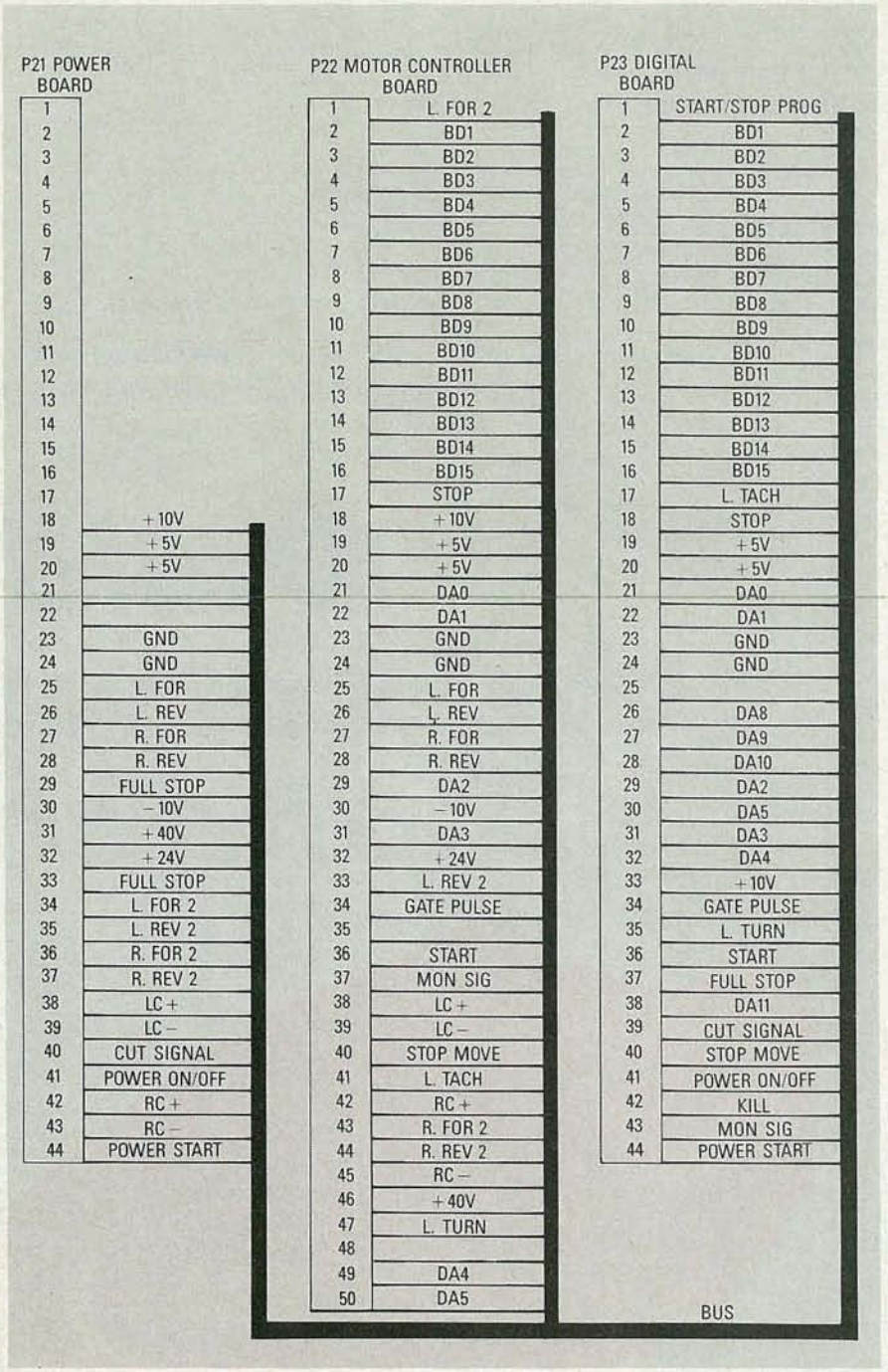


FIG. 1—ALL OF THE INTER-BOARD CONNECTIONS are made via the motherboard.

PC board is disconnected from the motherboard. The same D/A inputs could be established by temporarily blocking (with electrical tape) grass sensors 1–8 after the Lawn Ranger is completely assembled.

Motor controller test

The best way to test the motor-controller board is after the Lawn Ranger is completely assembled. By blocking grass sensors with your fingers or electrical tape, you can simulate a grass border that the Lawn Ranger can track. As you block different grass sensors, you can verify that the motor controller is working properly by observing the drive wheels as they change speed and direction.

However, that will have to wait until next month, when we will discuss the construction and operation of the power board. We'll also discuss the manual controller and mechanical frame. Start building your own Lawn Ranger now so you can have fun learning valuable electronic skills and, at the same time, produce a personal robot that can perform useful work while amazing your friends

Power board

The power board is responsible for providing regulated DC voltages, controlling the power on/off function, switching +24-volts DC to the motors (for forward and reverse rotation), and stopping the cutting motors after power is turned off. Figure 3 shows a photograph of an assembled power board.

Figure 4 shows the block diagram of the power board. The +24-volt DC input power is supplied by two 12-volt lead-acid batteries that are connected in series. The batteries are rechargeable and can be purchased from suppliers of electric wheel chair batteries for about $35–$45 a piece.

Three DC/DC converters are used to efficiently convert the +24-volt input to ±10-, +5-, and +30-volts DC. The DC/DC converters can be purchased from Power General directly (see parts list).

The left and right motor power drive circuits energize the drive motors. The circuitry contains a series of power MOSFET's that act as low-resistance (0.035 ohm) switches. The MOSFET switches can turn the motors on and off, as well as apply a reverse voltage to make the drive wheels spin in reverse.

The cutting-motor drive circuitry controls the rate at which the cutting disks spin when they are initially turned on. The amount of current that is sent to the cutting motors is monitored and limited to 15 amps (peak) or approximately 10 amps (average). The circuitry is also used to quickly stop the cutting motors when power is turned off by shorting the motor leads together. That technique is typically referred to as dynamic braking. The shorting of the motor leads causes a reverse magnetic field to be generated inside the motors causing the cutting blades to stop within 3 seconds. A 0.01-ohm resistor (R32) is used to limit the motor current to a safe level during dynamic braking.

Circuit description

Figure 5 shows a detailed schematic of the power board. The +24-volt battery power is routed through J11 pins 4 and 5 and fuse F1. Relay RY1 is used to connect and disconnect power from the entire robot. Power is switched on by the operator when the ignition key is turned. The momentary ignition switch grounds J21 pin

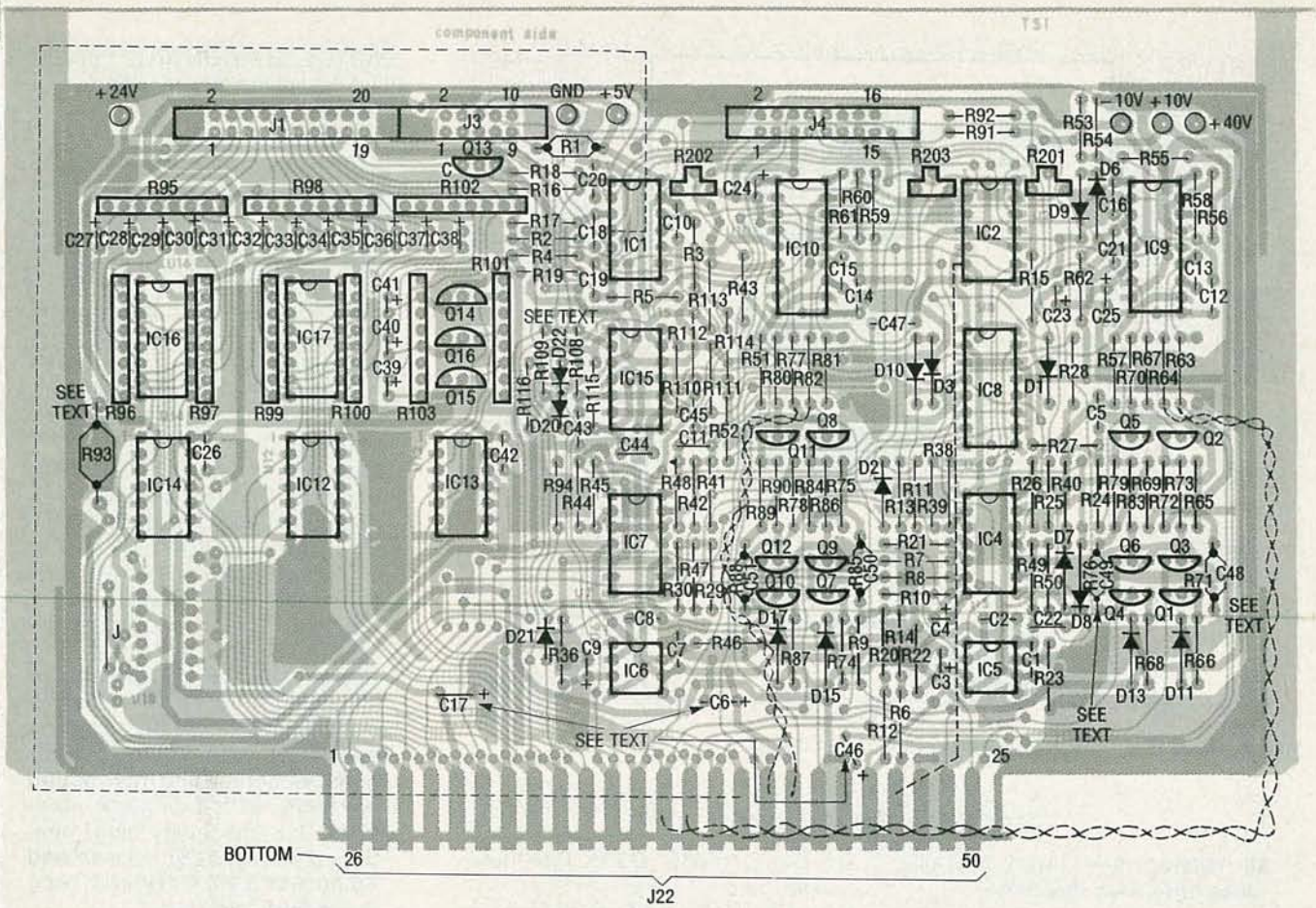


FIG. 2—PARTS-PLACEMENT DIAGRAM for the motor-controller board.

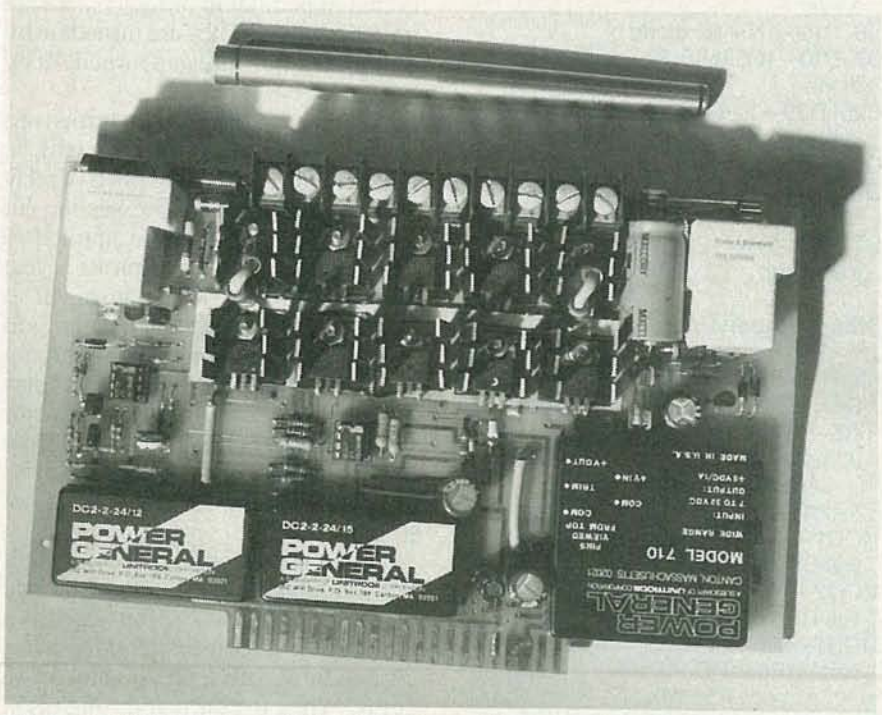


FIG. 3—AN ASSEMBLED POWER BOARD should look similar to this one.

44 and energizes the relay. When the relay switches, the three DC/DC converters will begin to produce the appropriate voltages and the CPU board will come alive. The CPU board will begin to run diagnostic checks and then place +5 volts on J21 pin 41 in order to turn Q11 on; that keeps the relay energized after the operator removes the key.

Forward/reverse motor drive

Transistors Q3–Q6 and Q7–Q10 are power MOSFET's that are used to control the left and right drive motors, respectively. When the left drive motor spins in the forward direction, Q3 and Q5 are turned on and Q4 and Q6 are turned off. Figure 6-a shows the path that current follows when the left drive motor is going forward. On the other hand, if Q3 and Q5 are turned off and Q4 and Q6 are turned on, the current will flow through the motor in the opposite direction causing the motor to spin in reverse (see Fig. 6-b).

Cutting-motor control

The cutting motor circuitry contains power MOSFET's (Q13 and Q14) for switching, as well as a feedback control system for current limiting. Current limiting allows the cutting motors to come up to speed in a controlled manner by limiting large current spikes when the CUT button is pushed. The MOSFET's are con-

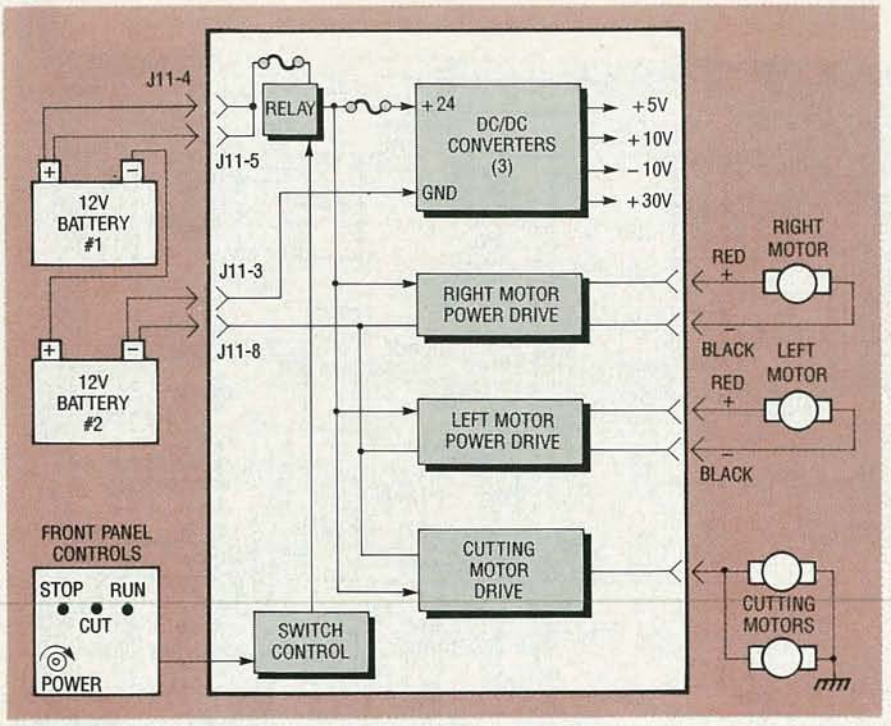


FIG. 4—HERE IS A BLOCK DIAGRAM of the power board.

PARTS LIST—POWER BOARD

All resistors are ⅛-watt, 5%, unless otherwise indicated.

R1–R10, R13–R15, R17, R18, R20–R28, R45–R49—not used
R11, R44, R50—3300 ohms
R12—680,000 ohms, 6-pin, ¼-watt, SIP resistor network
R16, R19, R32, R43—0.01 ohm, 5 watts
R29—150,000 ohms
R30, R31, R34, R35—270,000 ohms
R33, R36—1 megohm
R37—147,000 ohms, ¼-watt, 1%
R38—10,000 ohms, potentiometer
R39—82,000 ohms
R40—100,000 ohms
R41—27,000 ohms
R42—22,000 ohms
R51–R54—560,000 ohms

Capacitors

C1–C5, C7–C13, C16, C17—not used
C6—1000 µF, 35 volts, axial electrolytic
C14, C15, C23–C26—0.1 µF, 50 volts
C18, C21—100 µF, 50 volts, radial electrolytic
C19, C20—100 µF, 16 volts, radial electrolytic
C22—220 µF, 16 volts, radial electrolytic

Semiconductors

IC1, IC2—not used
IC3—LF412N op amp
D1, D2, D11–D13, D30, D31—not used
D3, D4, D16, D17, D20–D24, D33–D38—1N4001 diode
D5, D14, D18, D19, D32—1N4148 diode
D6, D15—1N5402 diode
D7–D10—1N5256B 30-volt Zener diode
D25–D29—1N4740 10-volt Zener diode
Q1, Q2, Q12—not used
Q3–Q10, Q13, Q14—IRFZ42 MOSFET
Q11, Q15, Q16—293904 NPN transistor

Other components

J11—terminal strip
RY1—T90N1D12-24 relay (Potter Brumfield)
RY2—68P-111P-US-DC24 relay (Omron)
F1—3AG 30-amp fast-blow fuse
F2—2AG 0.5-amp fast-blow fuse
MOD1—Model DC2-2-24/12, ± 12-volt DC converter (Power General)
MOD2—Model DC2-2-24/15, ± 15-volt DC converter (Power General)
MOD1—Model 710, 5-volt DC converter (Power General)

Miscellaneous: 3AG fuse holder, 2AG fuse holder, solder posts for the "E" terminals, 18-gauge solid insulated wire, 18-gauge stranded insulated wire, solder, etc.

PARTS LIST—CONTROL PANEL

S1–S4—momentary pushbutton switch
S5—SPDT switch
LED1—red light-emitting diode
Wire and sheet metal for the panel itself

Note: The following equipment can be purchased from Technical Solutions, Inc., P.O. Box 284, Damascus, MD 20872 (301-253-4933): etched and drilled PC boards for CPU Board, Motor Controller Board, Power Board, and Motherboard, $39 each; programmed EPROM, $39; grass sensors, $8.99 each; hand-held manual controller kit, $39; full kit for CPU Board, $129 (PC board, EPROM, all parts); full kit for Motor Controller Board, $169 (PC board and all parts); full kit for Motherboard, $69 (PC board and all parts); Power Board kit (PC board, and all parts except DC/DC converters), $149; Detailed drawing package, $59; Lawn Ranger demo videotape and information package, $19; complete electronic kit with everything mentioned above, $757. Please add $8.00 for S/H. Maryland residents add sales tax.

nected in parallel in order to share the switching load. They are turned on by pull-up resistor R42 and turned off by Q16.

After the MOSFET's are turned on, the +24-volt power supply will be routed to through R32 to pin 5 of relay RY2. As the operator presses the cut button, +5 volts will be applied to J21 pin 41 and Q15 will turn on; that grounds pin 4 of RY2 causing it to switch the +24-volt battery power to the cutting motors. The cutting motors will begin to spin, and as they begin to, the current through resistor R32 will rise sharply; R32 is used as a current monitor and the voltage across it will rise in proportion to the current flow.

Differential amplifier IC3-a amplifies the voltage drop across R32 and feeds it to pin 5 of IC3-b, which is a comparator circuit that compares the current flow with a preset value of 15 amps. When the current through R32 reaches 15 amps, the comparator output (IC3-b pin 7) will swing positive and Q16 will turn on. The power MOSFET's will turn off and the current will stop flowing through the cut-

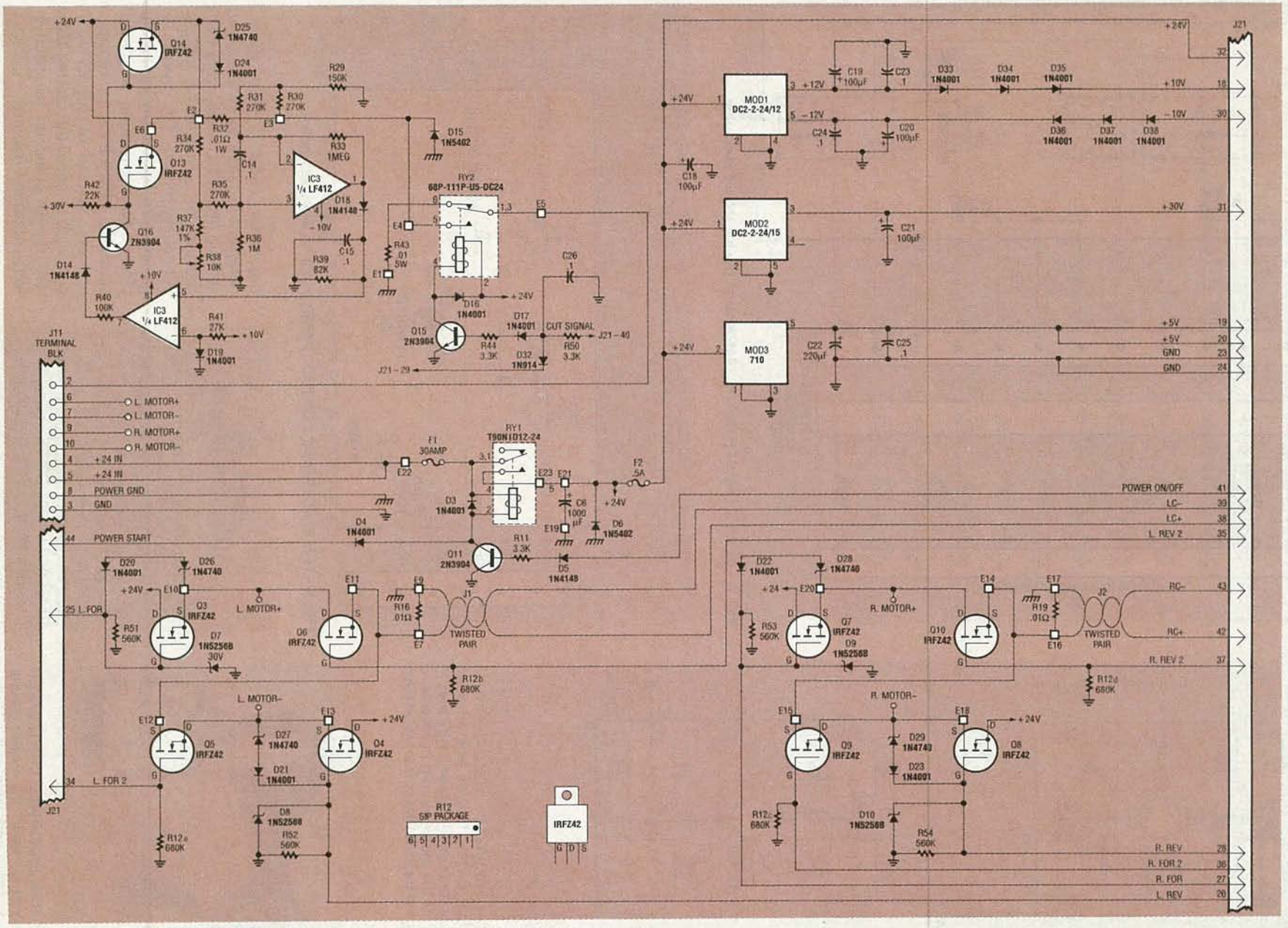


FIG. 5—DETAILED SCHEMATIC of the power board. High-current jumpers have to be installed on the solder side of this board.

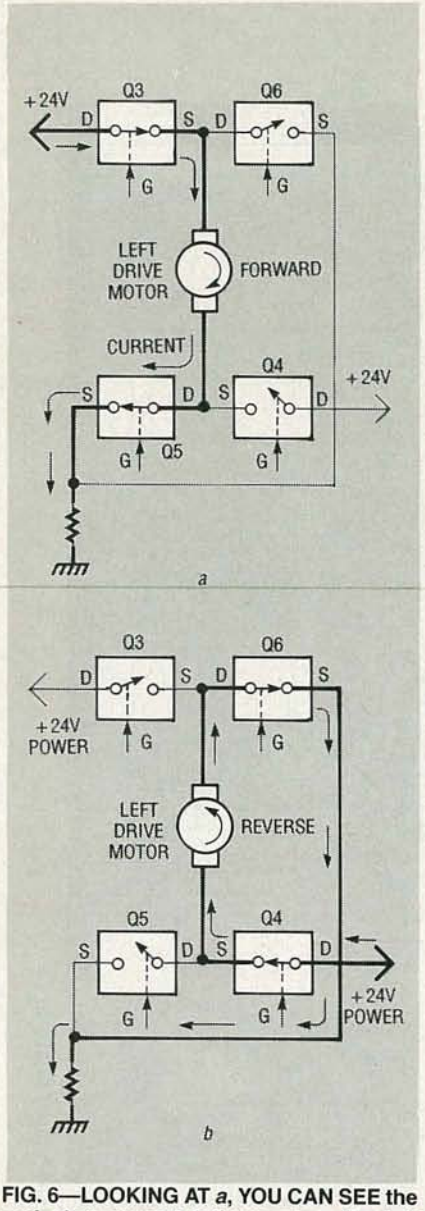


FIG. 6—LOOKING AT *a*, YOU CAN SEE the path that current follows when the left drive motor is going forward. However, in order for the motor to spin in reverse, *b* shows the path that the current must take.



FIG. 7—THE HAND-HELD CONTROLLER allows you to "walk" the mower around the yard to cut a perimeter for it to follow.

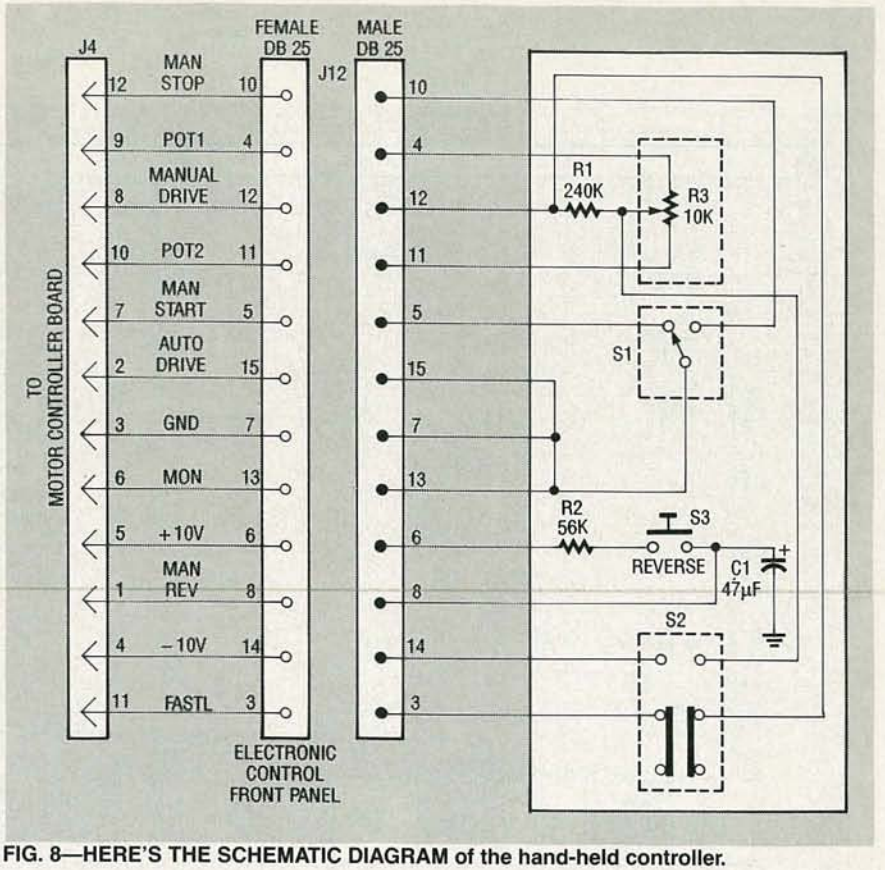


FIG. 8—HERE'S THE SCHEMATIC DIAGRAM of the hand-held controller.

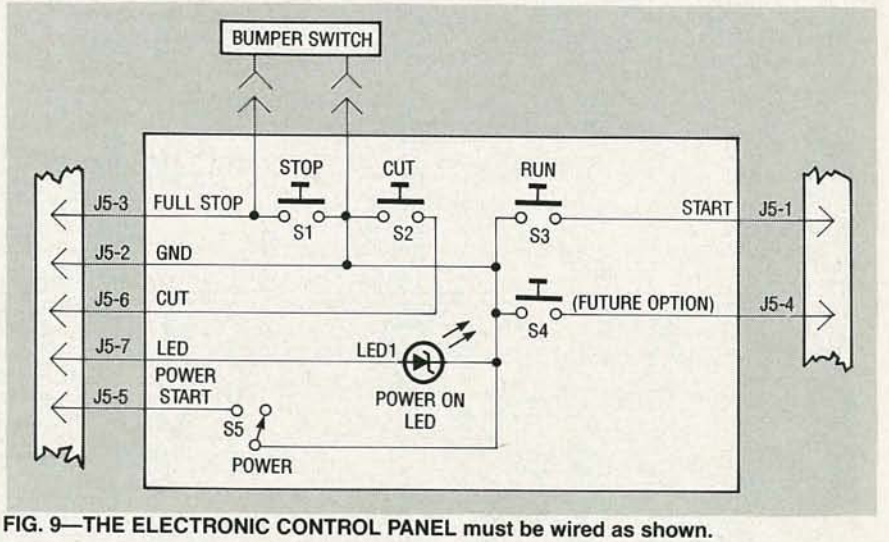


FIG. 9—THE ELECTRONIC CONTROL PANEL must be wired as shown.

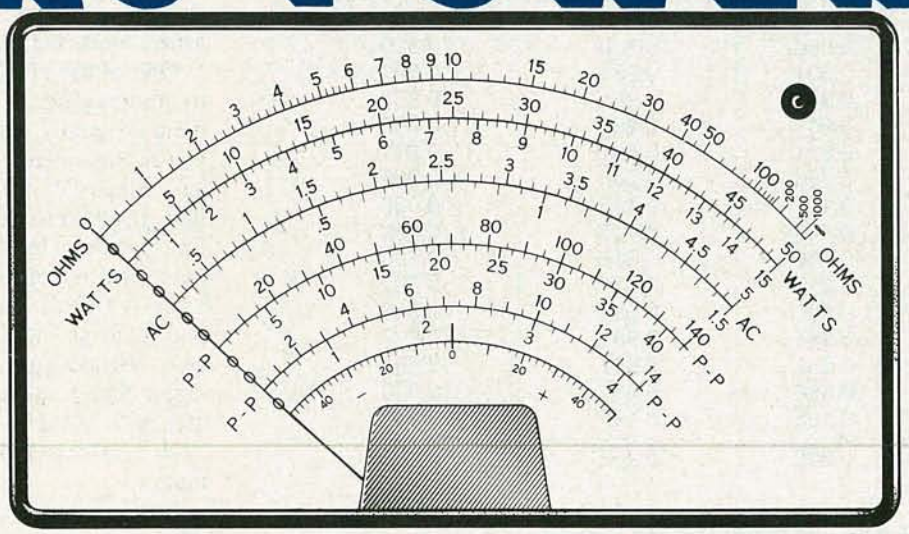
PARTS LIST
HAND CONTROLLER

R1—240,000-ohm resistor
R2—56,000-ohm resistor
R3—10,000-ohm potentiometer
C1—47 µF electrolytic
S1—SPDT switch
S2—DPDT slide switch
S3—momentary pushbutton switch
Male and female DB-25 connectors, ribbon cable, suitable enclosure

ting motors and R32. That causes the comparator output to swing negative and the MOSFET's will again turn on causing the current to be applied to the cutting motors. The process is repeated until the cutting motors have reached their maximum velocity. Because the MOSFET's are turning on and off, instead of supplying full power all at once, the cutting motors will slowly come up to speed in a well-controlled manner.

(Continued on page 80)

AC POWER MEASUREMENT



Learn the principles of measuring power.

HARRY L. TRIETLEY

AC POWER MEASUREMENT: YOU PROBABLY don't think about it very much. Most engineers and technicians normally don't even give it a second thought. Nonetheless, it's an extremely important and pervasive area of electronics, used in a wide variety of fields, include determining RF transmitter power and field strength, radar, motor and generator testing, sonar, stereo, and acoustics, and one area that affects all our daily lives, commercial AC power distribution.

We're all billed using a kilowatt-hour (kWh) meter, and obviously want it to be accurate. Utilities need to measure true usage, because it affects generator loading and fuel consumption. Consumers likewise need to control operating efficiency, peak load usage, and billing. With rising fuel costs and the need for conservation, the subject has become increasingly relevant. AC power isn't always easy to measure, because it's affected by such factors as phase shift and waveform distortion. This article discusses techniques of measuring AC power, using some special IC's designed for this purpose.

True power and RMS voltage

Let's review DC power; the power law, $P = E \times I$, and Ohm's law, $E = I \times R$, produce the 12 equations in Fig. 1. They're for DC only, and omit capacitive and inductive reactances. They're valid for AC *if* the load is purely resistive (causing no phase shift), and *if* E and I are true *R*oot *M*ean *S*quare (RMS) values. RMS means *the square root of the average of the squares* of a series of voltages or currents. The RMS concept is necessary, because the time-average value of a sinusoidal voltage or current with no DC component is zero. Let's see why, and how this relates to power.

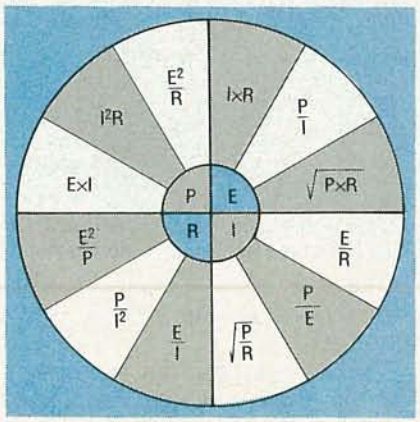


FIG. 1—OHM'S LAW AND THE POWER EQUATION combine to form 12 basic equations for resistive circuits.

Figure 2-*a* shows a sinusoidal voltage sampled 16 times, applied across R1 in Fig. 2-*b*. As each sample varies, the dissipated power is $P(t) = e^2(t)/R1$. To find the approximate RMS coefficient for time-average power, the power is found for each sample, and the average of the values is determined. Increasing the number of intervals increases resolution, and improves accuracy.

Table 1 shows the calculations; the average sampled instantaneous power is $P = 0.503 \times V^2_{PK}/R1 = (0.709 \times V_{PK})^2/R1$. The letters A–P in Fig. 2 correspond to the same letters in parentheses in the left-hand column of Table 1. The RMS value for

Table 1—DETERMINING THE AVERAGE AND RMS CONVERSION FACTORS

Sample Angle, deg	Sample Value	Sample Absolute Value	Square of Sample Value
11.25 (A)	0.195	0.195	0.038
33.75 (B)	0.566	0.566	0.320
56.25 (C)	0.831	0.831	0.691
78.75 (D)	0.981	0.981	0.962
112.25 (E)	0.981	0.981	0.962
134.75 (F)	0.831	0.831	0.691
146.25 (G)	0.566	0.566	0.320
168.75 (H)	0.195	0.195	0.038
191.25 (I)	–0.195	0.195	0.038
213.75 (J)	–0.566	0.566	0.320
225.25 (K)	–0.831	0.831	0.691
247.75 (L)	–0.981	0.981	0.962
281.25 (M)	–0.981	0.981	0.962
303.75 (N)	–0.831	0.831	0.691
326.25 (O)	–0.566	0.566	0.320
348.75 (P)	–0.195	0.195	0.038
Sums:	0.000	10.292	8.044

Average conversion factor: 10.292/16 = 0.643.
RMS conversion factor: 8.044/16 = 0.503, $\sqrt{0.503} = 0.709$.

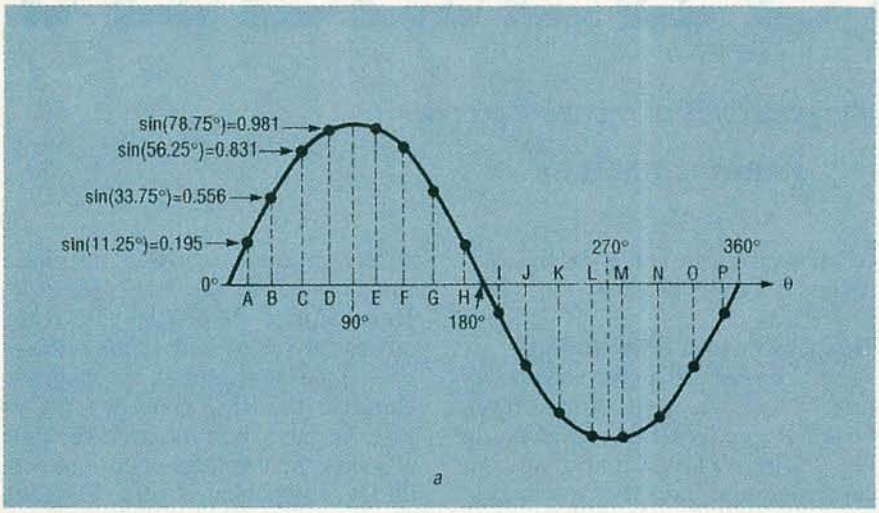


FIG. 2—A SINUSOID SAMPLED IN 16 EQUISPACED locations in (*a*) is applied across R1 in (*b*). This is the first step in the approximate calculation of the RMS conversion factor.

sinusoidal current is found similarly. If the RMS value for a different waveshape were desired, the process would be repeated using new samples. This crude approximation gives an RMS value of $0.709 \times V_{PK}$, versus a correct value of $V_{PK}/\sqrt{2} = 0.7071 \times V_{PK}$, an error of only 0.27461%.

The average or mean value *isn't* just the average of the actual sinusoidal samples, since this is 0 volts, as mentioned earlier. To find the average value, the *average of the absolute value* of the samples in Table 1 (the full-wave rectified case) is $0.643 \times V_{PK}$. The correct value is $0.6366 \times V_{PK}$, an error of only 1.01%. Fig. 3 shows the peak, RMS, and average values for several waveforms, with sketches of each.

One of the more difficult concepts to understand about power is that there are really two separate types of power, instantaneous and time-average. Since DC values are time-invariant, instantaneous and time-average DC powers are always equal. The term used when referring to an RMS value is that of "equivalency." RMS power, in an AC context, is considered "equivalent" to DC power. The major factor for judging this equivalency is what is referred to as the "I^2R" effect, from the power formula.

RMS power yields the same *heat dissipation* in a resistive load as an equal value of DC power. Reactive loads (those with inductance or capacitance) cause a phase angle difference between voltage and current equal to the phase angle of the load impedance. Such a load may have both resistive (real) and reactive (imaginary) components; real "I^2R" power (heat) dissipation occurs *only* in the *real* part, *never* the imaginary part. The imaginary part refers to the energy stored in capacitive electric fields, and inductive magnetic fields.

You should know the meaning of the word "imaginary" in this context; it refers only to the phase difference between voltage and current, *never* that these quantities aren't physically present. As you've probably heard before, "imaginary" voltages and currents are quite capable of causing real shocks.

Measuring true RMS voltage

You may have heard of "average-responding" and "true RMS" AC meters. Average-responding meters, shown in Fig. 4, are simpler; they rectify and filter AC to give the average value as a DC voltage, that's then scaled to display RMS. Thus, a sine wave with $V_{PK} = 1$ volt produces 0.6366 volt going into the display, but the display is calibrated to read 0.7071 volt. Because the relationship between RMS and average depends on the waveform, the reading is accurate *only* for sinusoids.

For example, average-responding meters aren't useful for measuring

RMS power in most modern circuits, since nonsinusoidal waveforms are very often used in SCR controllers and variable-speed motor drives, necessitating true RMS measurements. The most common methods are thermal, direct (explicit) computation, and implicit computation. In implementing these approaches, we'll also examine two RMS-to-DC converter IC's that take the work out of true RMS measurement.

Thermal RMS measurement

Thermal techniques find RMS voltage by exploiting the fact that the real component of power is dissipated as heat in a resistor, as mentioned earlier. In Fig. 5, R1 = R2; the measured voltage is amplified, buffered, and/or scaled by A1, and passed to R1. Similarly, R2 is connected to A2, a high-gain differential amplifier producing DC. Matched series-opposing temperature sensors, usually thermocouples, are in physical contact with R1 and R2, and A2 responds to their temperature difference. If R1 is hotter than R2, the output of A2 increases until the temperatures of R1 and R2 are equal. The two temperatures will be equal when the DC output of A2 equals the RMS output of A1.

Although this is a simple approach, accurate measurements using this method are difficult. The main problem is the need for highly accurate thermal matching. Any difference in size, shape, contact, or insulation causes errors. Also, thermal inertia has to be optimized. It has to be slow, to average the AC waveform over its whole cycle. However, excessive inertia causes sluggish measurements.

The Linear Technology LT1088 RMS-to-DC converter has matched pairs of 50- and 250-ohm resistors and diode sensors in a thermal package. The diode has a forward-bias voltage drop temperature coefficient of −1.75 mV per °C, and the two sets of internal resistors provide flexibility.

Figure 6 shows the LT1088 in a practical circuit. V_{IN} comes from an amplifier stage, heating the 50-ohm AC resistor while A1 heats the 50-ohm DC resistor via emitter-follower Q1. The level at pin 9 is 1 volt DC per volt of RMS input, while A2 provides gain adjustment. The maximum input is 4.25 volts for 50 ohms, and 9.5 volts for 250 ohms. Accuracy is 1% up to 50 MHz, with a 3-dB bandwidth for A1 of 300 MHz, and input crest factors (peak-to-RMS ratio) up to 50:1, making this method highly suitable for RF RMS measurement.

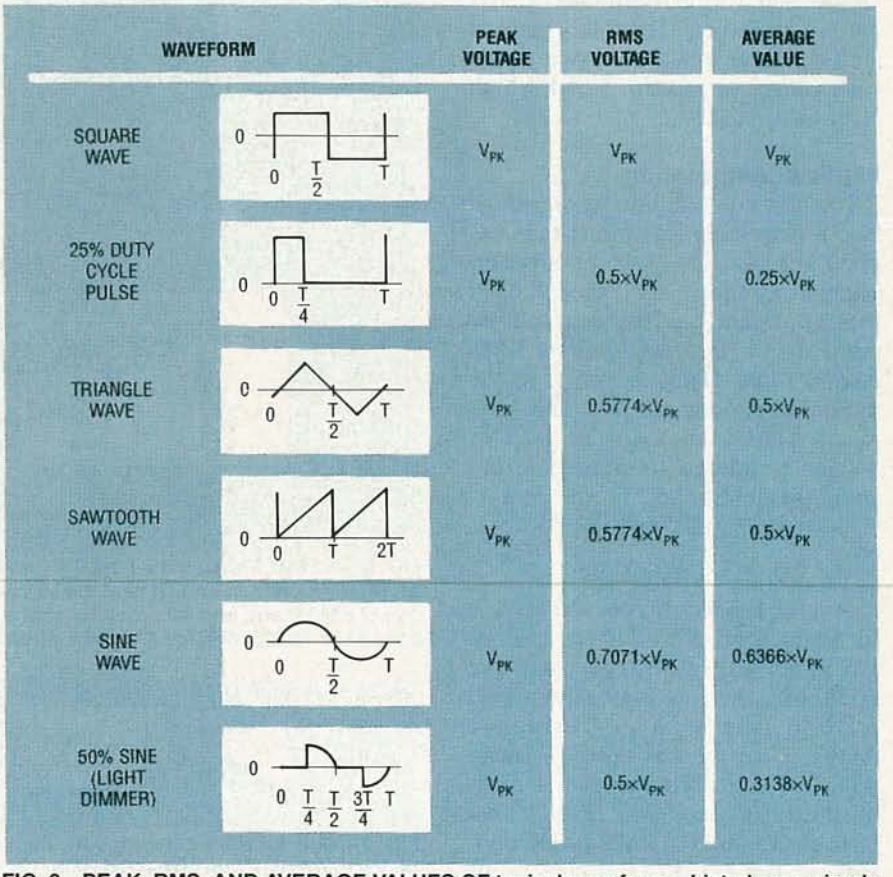


FIG. 3—PEAK, RMS, AND AVERAGE VALUES OF typical waveforms. Listed are a simple square wave (50% duty cycle, 0 volts DC), a periodic pulse train (25% duty cycle, positive-only), a triangle wave (0 volts DC), a sawtooth wave (positive-only), a sinusoid (0 volts DC), and a 50%-sine wave used in light dimmers.

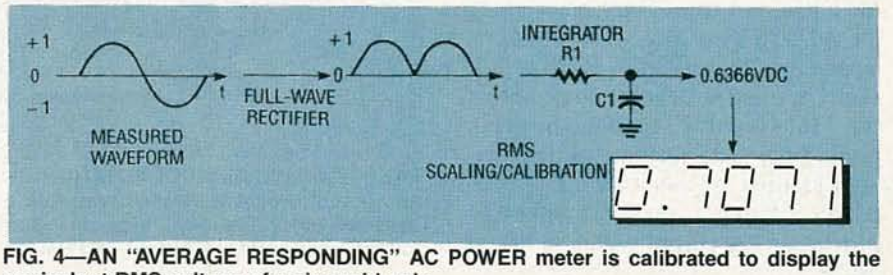


FIG. 4—AN "AVERAGE RESPONDING" AC POWER meter is calibrated to display the equivalent RMS voltage of a sinusoid only.

Direct RMS computation

Direct or explicit RMS computation solves the problem of RMS power measurement electronically. As shown in Fig. 7, the amplified or buffered AC is rectified, squared, averaged, and presented to a circuit that determines the square root of the average, giving the RMS level. The problem here is the dynamic range of the squared signal.

The squaring multiplier produces full-scale output with both X and Y at full scale. Thus, 100% inputs produce 100% output, 10% inputs produce 1%

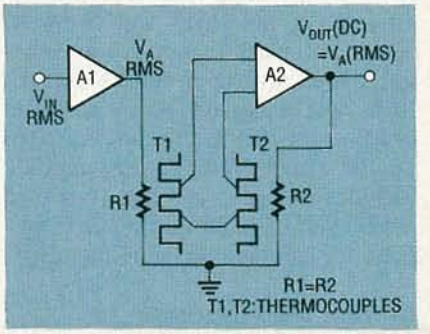


FIG. 5—THERMAL RMS VOLTAGE MEASUREMENT by the power dissipated by R1 and R2. Here, R1 = R2; matched temperature sensors contact R1 and R2, and A2 responds to the temperature difference. If R1 is hotter than R2, the A2 output increases until the resistor temperatures are equal, and the DC voltage across R1 equals the RMS voltage across R2.

output, and 5% inputs produce 0.25% output, and so on. Thus, this method isn't suited to voltages varying over a wide range, or waveforms with high crest factors.

Implicit computation

Implicit computation as shown in Fig. 8 may seem less direct than explicit computation, but it's simpler. There's no square-root needed, and this approach has better dynamic range than is the case in direct RMS computation. Here, A and B in the multiplier/divider are V_A, and C is V_{OUT}. Thus $V1 = (V_{IN})^2/V_{OUT}$. This voltage is filtered (averaged) to become the output, so

$$V_{OUT} = Avg[(V_{IN})^2/V_{OUT}],$$

or

$$V_{OUT} = \sqrt{Avg[(V_{IN})^2]}.$$

Analog Devices makes several IC's for implicit RMS-to-DC conversion, such as the general-purpose AD536A, the low-power/low-level AD636, the high-performance AD637, and the low-cost/low-power AD736/7, all used by several manufacturers of true-RMS DVM's. For an in-depth study of RMS-to-DC conversion, you can get a free copy of the *RMS-to-DC Conversion Application Guide* (see the box on page 57).

Figure 9 shows a practical circuit for a low-cost true-RMS meter using an AD536A as IC1. The input is scaled for 200 millivolts RMS at full scale, applied to a buffer amplifier on pin 7 (BUF IN) of IC1, and fed from pin 6 (BUF OUT) to an absolute value precision rectifier on pin 1 (V_{IN}). It then passes through a squarer/divider that provides a log output scaled in dB on pin 5.

The final output comes from a current mirror that produces a current of 40 μA DC per RMS volt of input. This current passes through an internal 25K resistor, to produce 1 volt DC/RMS volt of input. There's no offset or gain adjustment, since the AD2026 *D*igital *P*anel *M*eter (DPM) module includes them. If you use your own meter, you can add an output amplifier with gain and offset adjustments.

Current transformers

Electronic current measurement usually begins by passing a current through a dropping resistor to create a proportional voltage. For currents of tens, hundreds, or thousands of amps, this is impractical, requiring resistors in the milliohm range, or below. Current transformers reduce such high currents to practical levels, using a single winding of N turns on a toroidal core.

The wire carrying the current is threaded through the center of the toroid and becomes a single-turn primary. The secondary current is 1/N times the primary current, and is passed through a dropping resistor to create the proportional voltage. Current transformers generally produce 5 amps out at full-scale primary current.

Power and phase shifts

Up to this point, we've considered only true RMS measurement. Next, we'll examine the effect of phase shifts on power measurement. Our discussion will deal only with pure sinusoids. The concept of phase shift has meaning for sinusoids as well as other periodic waveforms of the general form:

$$V(t) = V_{PK} \times \sin[(2 \times \pi \times f \times t) + \theta].$$

Phase shifts are caused by capacitive or inductive reactances. In a pure capacitance, voltage lags current by 90 degrees, while in a pure inductance, current lags voltage 90 degrees. RC or RL circuits produce phase shifts other than 0 degrees or 90 degrees, while pure resistances cause no phase shift at all.

In Fig. 10-*a*, a charging current starts to flow into the capacitor as the voltage rises, stops when the voltage reaches its peak, and reverses as the voltage falls. If there were no resis-

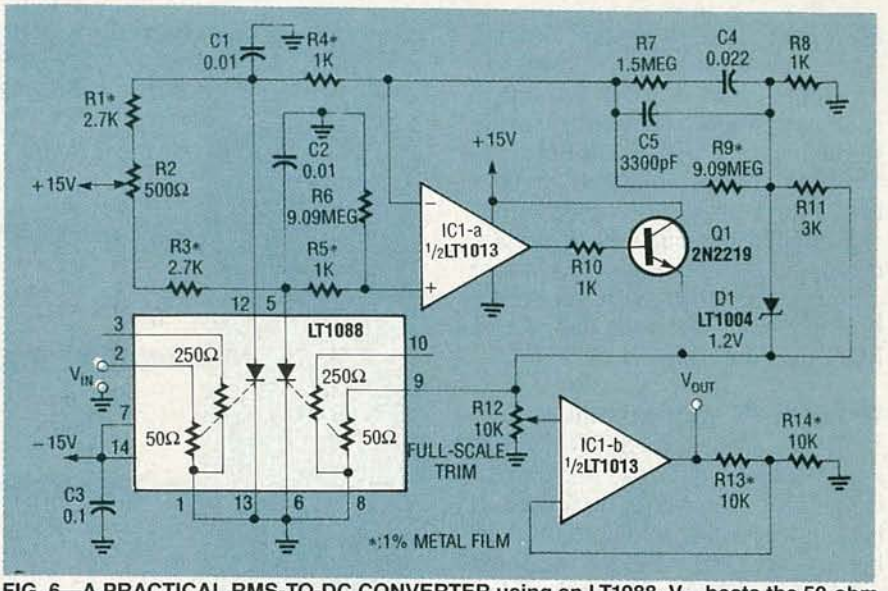


FIG. 6—A PRACTICAL RMS-TO-DC CONVERTER using an LT1088. V_{IN} heats the 50-ohm AC resistor while A1 and Q1 heat the 50-ohm DC resistor. The level at pin 9 is 1 volt DC per volt of RMS input, and A2 provides gain adjustment. Accuracy is 1% up to 50 MHz, 3-dB bandwidth is 300 MHz for A1, and input crest factors reach 50:1.

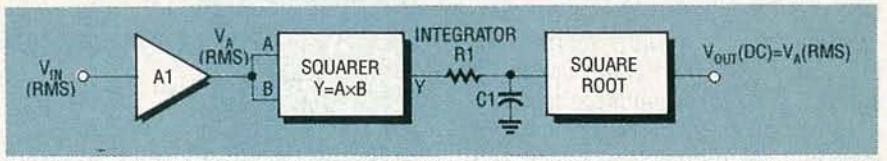


FIG. 7—DIRECT RMS computation; Amplified AC is rectified, squared, and integrated; taking the square root gives true RMS. The squaring multiplier gives full-scale output with both X and Y at full scale.

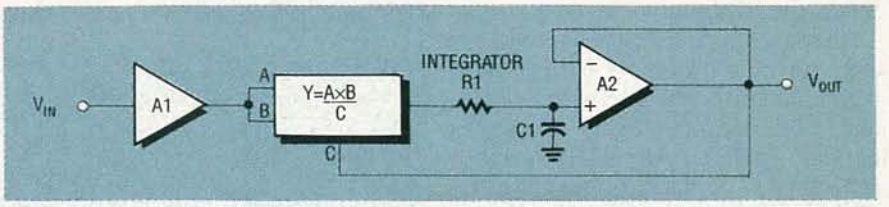


FIG. 8—IMPLICIT RMS COMPUTATION; it may seem less direct than Fig. 7, but it's simpler, as no square-root is needed, and has better dynamic range. Analog Devices makes several IC's for this role; the general-purpose AD536A, the low-power/low-level AD636, the high-performance AD637, and the low-cost/low-power AD736.

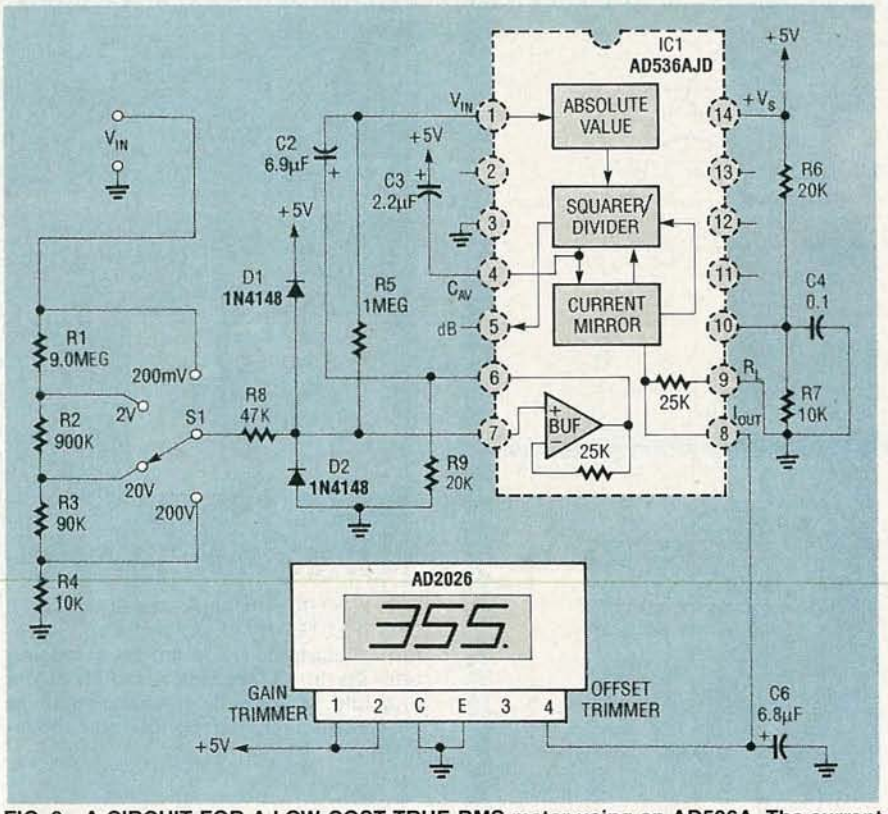


FIG. 9—A CIRCUIT FOR A LOW-COST TRUE-RMS meter using an AD536A. The current mirror sources 40 µA DC per RMS volt of input through an internal 25K resistor, producing 1 volt DC per RMS volt of input. There's no offset or gain adjustment, since the AD2026 *D*igital *P*anel *M*eter (DPM) module includes them.

tances and thus no power loss, the capacitor would store energy from the inductor part of each cycle, and feed it back the rest of each cycle, the generator acting like a motor. Looking at the waveforms, instantaneous power $E \times I$ is positive for half a cycle and negative the other half, so no net power is gained or lost.

Figure 10-*b* illustrates pure inductance. Any change in inductor current induces an EMF opposing the change, so current lags voltage by 90°. Energy is alternately stored in the magnetic field and fed back to the AC source. As in the case of the capacitor, no net power is gained or lost in an ideal inductive circuit with no resistance.

Resistances convert electrical current to heat; Fig. 10-*c* shows a pure resistance, and Fig. 10-*d* an RL circuit of under 90° phase shift. In general, power usage for purely sinusoidal circuits is $P = E \times I \times \cos(\theta)$, where E and I are RMS voltage and current, θ is the relative phase, $\cos(\theta)$ is the *P*ower *F*actor (PF), and $E \times I$ is measured in *V*olt-*A*mps (VA). Also, at $\theta = 0$ degrees, PF = 1, while at $\theta = 90$ degrees, PF = 0.

Ideal reactive loads don't consume power, but they increase total current drawn from a source, causing extra loss in the resistance of generators, transformers and power lines. Phase shifts are minimized by adding capacitance to balance inductive loads (motors and transformers). As mentioned earlier, the imaginary component of a joint resistive-reactive load corresponds to the reactive part. The fraction of the total power going into the reactive part of the load is measured in Volt-*A*mps *R*eactive (VAR), given by $VAR = E \times I \times \sin(\theta)$. Also, at $\theta = 0$ degrees, VAR = 0 VA, while at $\theta = 90$ degrees, the VAR is maximized, with no power is being resistively dissipated as heat.

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Marshall Technology
(distributor for **Linear Technology**)
336 LosCoches Road
Milpitas, CA 95035
(408) 943-4600 or (800) 877-5682

Measuring phase shift

Phase shift provides a measure of the time difference between two waveforms, by detecting the time between zero crossings; Fig. 11 gives the general layout of a circuit that can be used to measure a time difference. Each comparator flips when its input crosses 0 volts; their polarities are opposite one another. Comparator B sets the flip-flop, while comparator A resets it, both on positive-going transitions.

If the voltage and current are in phase, the transitions will be ½-cycle apart, and the flip-flop will be set 50% of the time. Lagging current delays the set, producing longer low and shorter high intervals, while leading current does the opposite. The filter averages the flip-flop output, producing a voltage proportional to phase shift, and rises or falls indicating lead or lag.

This isn't a complete working circuit, as component values depend on input levels, supply voltages, and desired output. Gain and offset adjustments will be needed for calibration; the output stage is a good place to add them. One or both inputs should be transformer-coupled for safety, but remember that transformers add phase shift. Also, the output represents *theta*, not $\sin(\theta)$.

Measuring true AC power

Now that we've covered true RMS measurement and phase shifts, we could consider a computational circuit for $E \times I \times \cos(\theta)$, but that would be complex, and inaccurate for nonsinusoidal waveforms. It's easier to go back to the basic definition of power; at any given instant, power is $P = E \times I$. Power is found by integrating (averaging) the $E \times I$ product over one or more cycles, as shown in Fig. 12-*a*.

Figure 12-*a* shows what takes place in an electromechanical wattmeter movement, while Fig. 12-*b* shows the

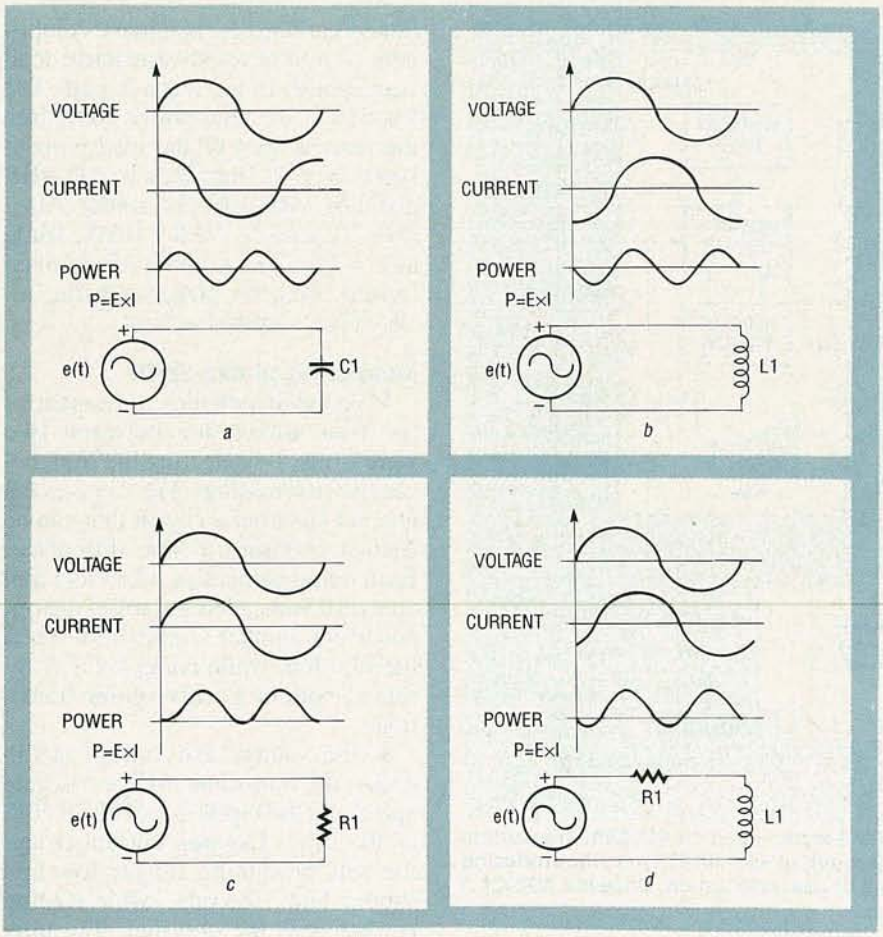


FIG. 10—A PRESENTATION OF VOLTAGE, CURRENT, and power waveforms, for capacitive, inductive, RC, and RL loads (*a–d*). With a 90° phase shift as in (*a*) and (*b*), average power consumption over a complete line cycle is zero. Voltage and current in phase, as in (*c*), produces maximum power. A 45° phase shift as in (*d*) reduces average power.

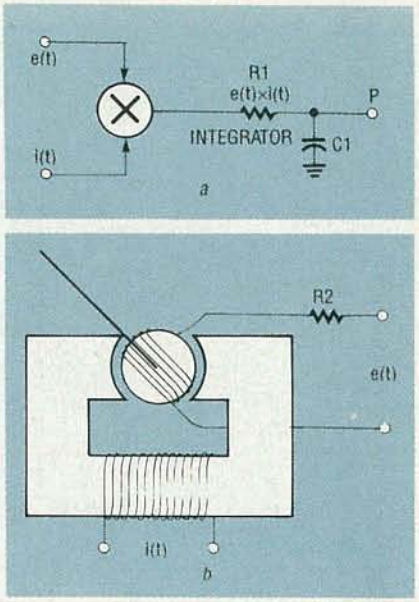


FIG. 12—TRUE POWER MEASUREMENT, UNAFFECTED by phase shifts and waveform distortions, is found by averaging e(t) × i(t). In (*a*) appears a sketch of the principle, while (*b*) displays a diagram of an electromechanical wattmeter movement.

Three types of electronic multipliers are used; log/antilog amplifiers, duty-cycle (pulse-width) modulators, and Hall-effect devices. Figure 13 shows the first, that performs multiplication by adding logarithms, $\log(E \times I) = \log(E) + \log(I)$, and then takes the antilog, anti-

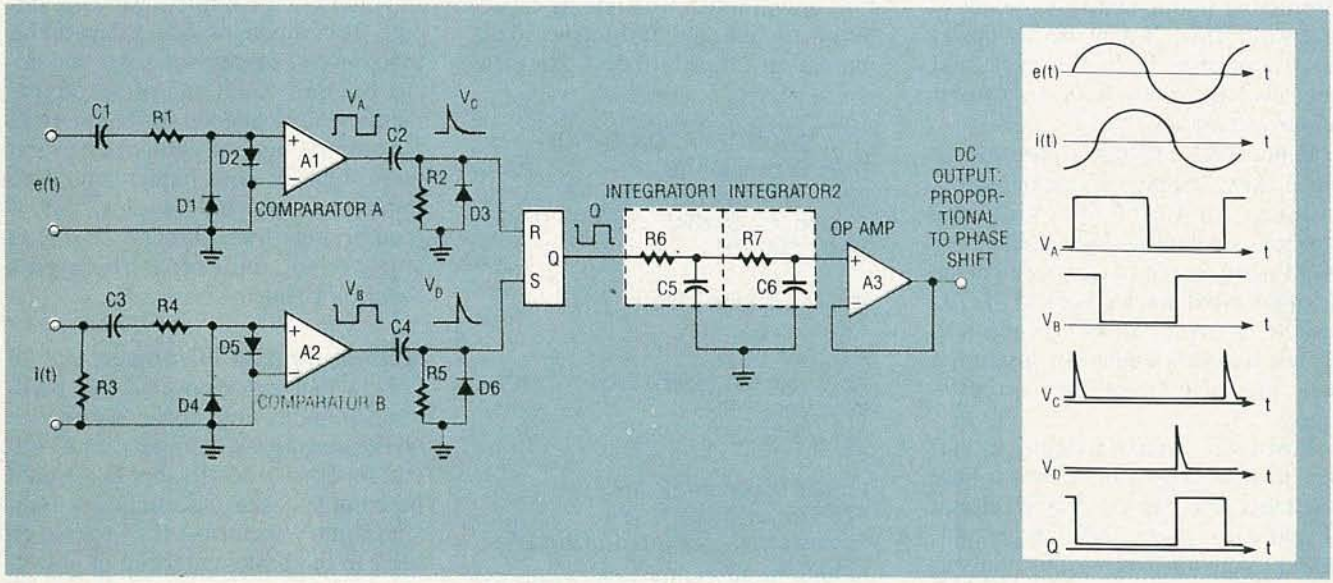


FIG. 11—AN INCOMPLETE CIRCUIT CONCEPT TO measure relative phase shift. By setting and resetting the flip-flop when the current and voltage waveforms cross 0, the relative phase shift can be measured.

movement itself. In the meter, one field is created by E, the other by I, and the attractive force between them is proportional to $E \times I$. Filtering is achieved by the inertia of the meter movement plus mechanical damping; otherwise, the pointer would vibrate rapidly with each cycle.

$\log[\log(E \times I)] = E \times I$. The final result is integrated to find average power.

The object here isn't to discuss log/antilog amplifiers; that's an article in itself. They all use the log relation

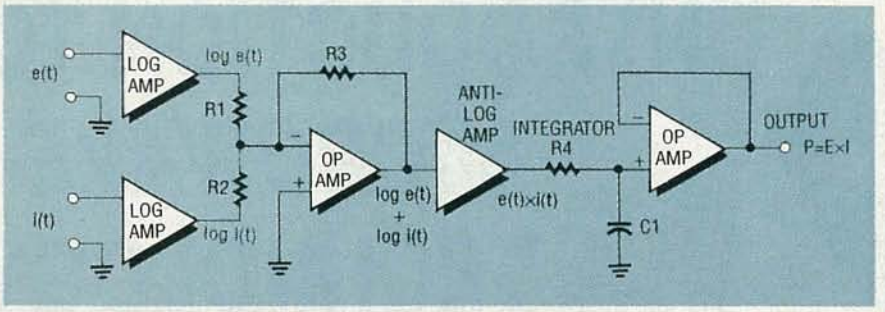


FIG. 13—MULTIPLICATION USING LOG/ANTILOG amplifiers. This circuit is also incomplete, but the log/antilog amplifier exploits the log relation between current through and voltage across the *B*ase-*E*mitter (BE) junction of a bipolar transistor to find average power.

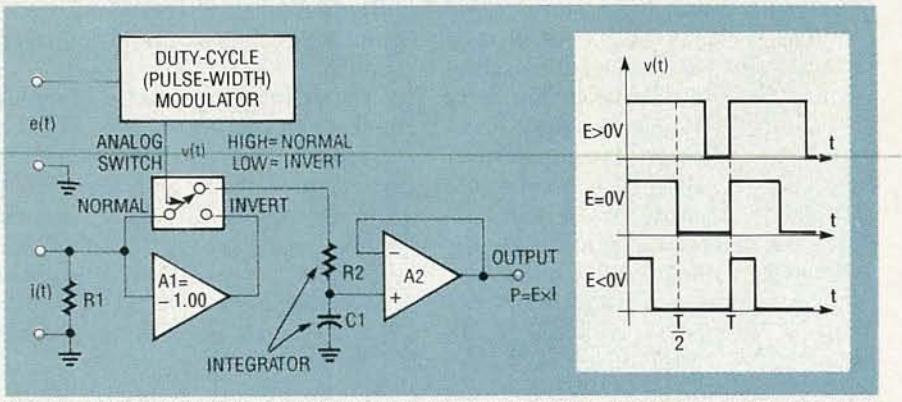


FIG. 14—AN INCOMPLETE DUTY-CYCLE (PULSE-WIDTH) modulator. The voltage input is converted to a duty cycle, modulating the current input to perform modulation.

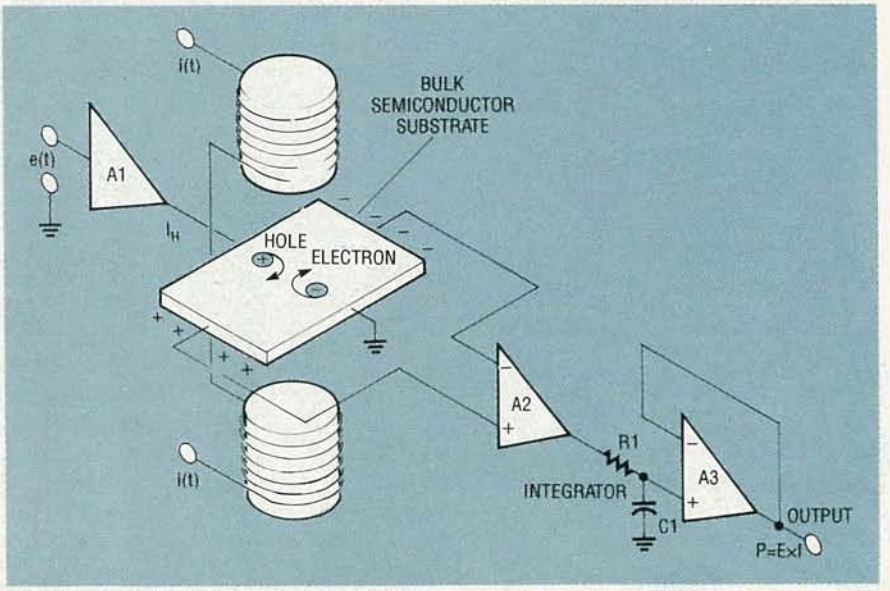


FIG. 15—A HALL-EFFECT DEVICE USED TO PERFORM multiplication, producing an EMF proportional to the product of the semiconductor's current times the magnetic flux density.

between voltage and current in the *B*ase-*E*mitter (BE) junction of a bipolar transistor. IC multipliers are available that perform the complete log-sum-antilog function internally. Examples include the Analog Devices AD530/630/830, Burr-Brown MPY100 and 4203, and Raytheon RC4200. Their prime advantages are simplicity, typical frequency response of 400 kHz or higher, accuracy of 0.25–1.0%, and temperature stability of 0.02–0.05%/deg C.

When extreme accuracy is needed at low frequencies such as 50–60 Hz, the duty-cycle (pulse-width) modulator shown in Fig. 14 gives superior performance. At 0 volts in, the pulse-width modulator produces a 50% duty cycle; its output controls an analog switch that alternately connects non-inverted or inverted inputs to the filter. At 50% duty cycle, the signal fed to the filter spends equal times positive and negative, so the filtered output is 0 volts regardless of the current input.

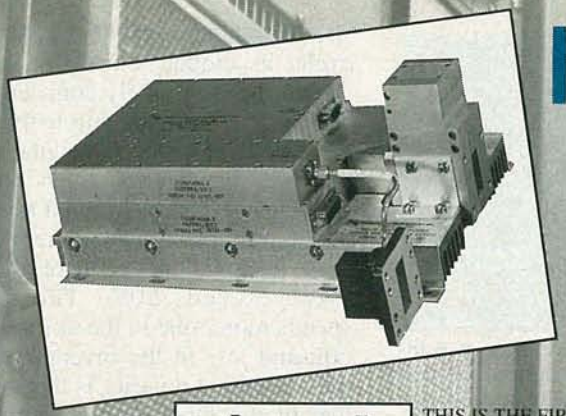
As the input goes positive, the duty cycle exceeds 50%. The switch spends more time in the normal position and less in the inverted, so the filtered output polarity is the same as that of the input current. Similarly, when the input voltage goes negative, the switch spends more time in the inverted position and the output polarity becomes opposite to that of the input current. The higher the voltage, the higher the duty cycle, and the higher the filtered output. The output is proportional to the product of duty cycle × I, or e(t) × i(t).

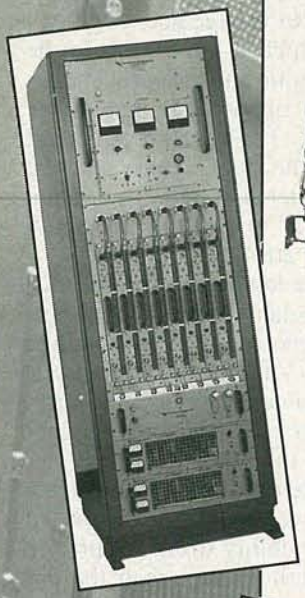
Unlike the log/antilog circuit, this one isn't available as an off-the-shelf IC, and is more complex to design and build. It's frequency response is also lower, since the duty cycle frequency must be many times higher than that of the inputs. Properly designed, however, it's capable of accuracies lower than 0.1%, limited more by the ability to obtain precise AC calibration sources than the circuitry itself.

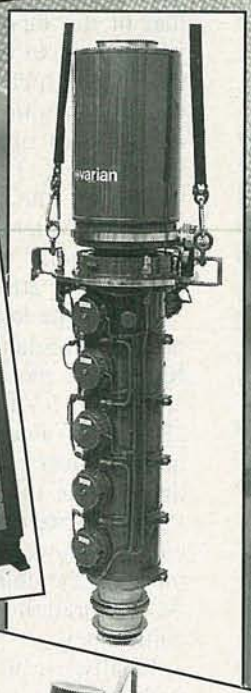
Finally, we'll examine Hall effect multipliers, as shown in Fig. 15. A Hall-effect device uses a shaped and doped semiconductor in a magnetic field. As the holes or electrons flow at right angles to the field, they're deflected in a curved path toward the semiconductor edges, inducing an EMF between two edges proportional to the product of flux density B and current i(t); reversing either reverses the EMF.

In AC power measurement, the power current controls the magnetic field, and the power voltage controls the semiconductor current. The induced EMF is amplified by a differential amplifier, filtered, and scaled. Hall effect devices are very linear, and have a wide bandwidth. Their main drawback is they need temperature compensation to achieve high stability. Clearly, AC power measurement involves much more than multiplying voltage and current. The techniques shown here make possible precise measurement of RMS voltage/current, phase shift, and true power in electronic circuits. **R-E**

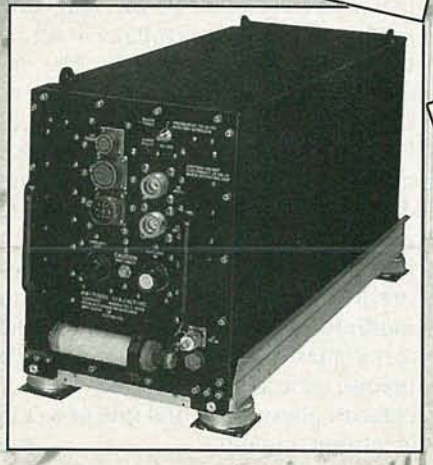
INTRODUCTION TO *MICROWAVE* TECHNOLOGY

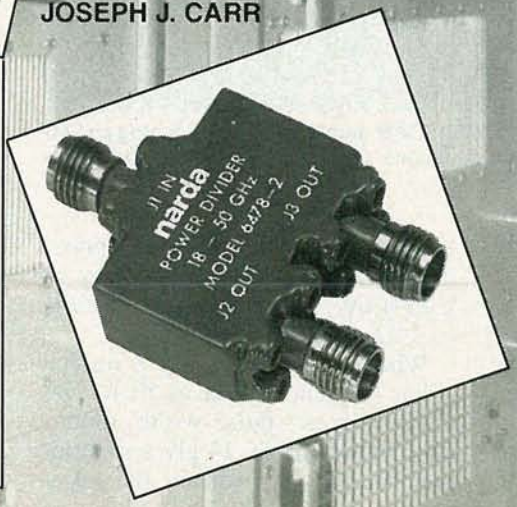












THIS IS THE FIRST IN A SERIES OF ARTICLES dealing with microwave electronics. The word microwave stems from "micro," meaning very small, and "wave," for electromagnetic oscillations; thus, microwaves are very short-wavelength electromagnetic oscillations. The electromagnetic spectrum shown in Fig. 1, is broken into such bands for purposes of both convenience and identification.

Rigorously defined, the microwave region begins above 300 MHz, occupying an upper part of the UHF (300 MHz–3 GHz) band, all of the SHF band (3 GHz–30 GHz), all of the EHF band (30 GHz–300 GHz), and a lower part of the *i*nfrared (IR) region. However, there's considerable overlap in physical properties between the UHF and microwave regions. The UHF region is nominally from 300 MHz–3 GHz, but above about 900 MHz or 1 GHz, UHF and microwave propagation and scattering are very similar.

The definition of exactly where the microwave region begins is further complicated a great deal by both historical precedent, and depends on both the application and the user. For example, the original military definition of the microwave bands for radar and communication systems (circa World War II), used letter designations to define them, as shown in Table 1.

Those definitions used the letters P, L, S, C, X, K, Q, V, and W, in that order, and were originally defined for security and technical reasons. There was no sensible partitioning of the actual frequencies involved. Whatever rationale was originally used to select these bands and labels, both are really of historical interest only.

Get to know basic microwave terminology and technology.

JOSEPH J. CARR

For that reason, the *D*ept. *O*f *D*efense (DOD) issued updated band designations on May 24, 1970, as shown in Table 2, that used a somewhat less chaotic approach. The band labels went in strict alphabetical order, from A–M, although there were still considerable jumps in the actual frequencies assigned to each. Thus, almost the same entire frequency region is considered microwave, although the new scheme reduces the lower bound by 125 MHz.

As if this weren't ambiguous enough, the *I*nstitute of *E*lectrical and *E*lectronics *E*ngineers (IEEE), the major U.S. and international electrical engineering society, has its *own* designation scheme, as shown in Table 3, now almost universally accepted, although older designations still persist out of habit. The IEEE designations use a combination of some of

the original World War II band designations, and then add their own lettering. They maintain the HF, VHF, and UHF designations, but above that, use the designations L, S, C, X, Ku, K, Ka, Millimeter, and Submillimeter.

For purposes of this series, the high end of the UHF region will be considered part of the microwave region, since there's no sharp transition in properties from the shortest non-microwave UHF wavelengths to the longest microwave wavelengths. Also, certain applications usually considered strictly in the microwave region sometimes also use UHF (such as long-range radar). For present purposes, our definition includes all frequencies above 500 MHz but below the IR region.

No doubt you're wondering how microwaves differ sufficiently from other frequency ranges of electromagnetic waves to warrant a separate series of articles. Microwave wavelengths approximate the physical size of ordinary electronic components, so components tend to behave differently when this is the case. At microwave frequencies, a half-watt metal film resistor is a complex RLC network with distributed inductance and capacitance, and a much different resistance. Certain characteristics irrelevant at lower frequencies become significant in the microwave region. Components and conductors act increasingly like transmission lines, with reflection, transmission, and cross-talk becoming critical to circuit function.

TABLE 1—OLD U.S. MILITARY MICROWAVE FREQUENCY BANDS

BAND DESIGNATION	FREQUENCY RANGE
P	225 MHz–390 MHz
L	390 MHz–1.55 GHz
S	1.55 GHz–3.9 GHz
C	3.9 GHz–6.2 GHz
X	6.2 GHz–10.9 GHz
K	10.9 GHz–36 GHz
Q	36 GHz–46 GHz
V	46 GHz–56 GHz
W	56 GHz–100 GHz

TABLE 2—NEW U.S. MILITARY MICROWAVE FREQUENCY BANDS

BAND DESIGNATION	FREQUENCY RANGE
A	100 MHz–250 MHz
B	250 MHz–500 MHz
C	500 MHz–1 GHz
D	1 GHz–2 GHz
E	2 GHz–3 GHz
F	3 GHz–4 GHz
G	4 GHz–6 GHz
H	6 GHz–8 GHz
I	8 GHz–10 GHz
J	10 GHz–20 GHz
K	20 GHz–40 GHz
L	40 GHz–60 GHz
M	60 GHz–100 GHz

TABLE 3—IEEE/INDUSTRY STANDARD MICROWAVE FREQUENCY BANDS

BAND DESIGNATION	FREQUENCY RANGE
HF	3 MHz–30 MHz
VHF	30 MHz–300 MHz
UHF	300 MHz–1 GHz
L	1 GHz–2 GHz
S	2 GHz–4 GHz
C	4 GHz–8 GHz
X	8 GHz–12 GHz
Ku	12 GHz–18 GHz
K	18 GHz–27 GHz
Ka	27 GHz–40 GHz
Millimeter	40 GHz–300 GHz
Submillimeter	>300 GHz

Microwave history

Microwave technology was relatively undeveloped until World War II, when huge investments in research and development led to rapid developments in radar and other electronics technologies used in the war. Vacuum tubes of the 1920's and 1930's wouldn't work at the UHF or microwave frequency ranges. The main problems were interelectrode capacitance and electron transit time from cathode to anode. Attempts to reduce electrode size and spacing caused other problems that proved unacceptable in practical circuits.

Interelectrode capacitance was reduced using clever geometries and closer interelectrode spacing (also a factor in transit time). By World War II, operation at 200 MHz was possible, 500–800 MHz was achieved by the end of the war, and 800 MHz by the early 1950's. In 1920, Barkhausen and Kurz of Germany achieved oscillation at 700 MHz by manipulating electron transit time. Although the Barkhausen-Kurz Oscillator achieved UHF/microwave oscillations, it was inefficient. Overheating was also a problem, because the grid glowed white hot at high power.

One solution in 1921 by A.W. Hull replaced the grid with a magnetic field, which later evolved into the magnetron, the first practical high-power microwave generator, still used in some radars and microwave ovens today. Unfortunately, it's a narrow-band device, often requiring the designer to make a trade-off, regarding available output power versus frequency agility.

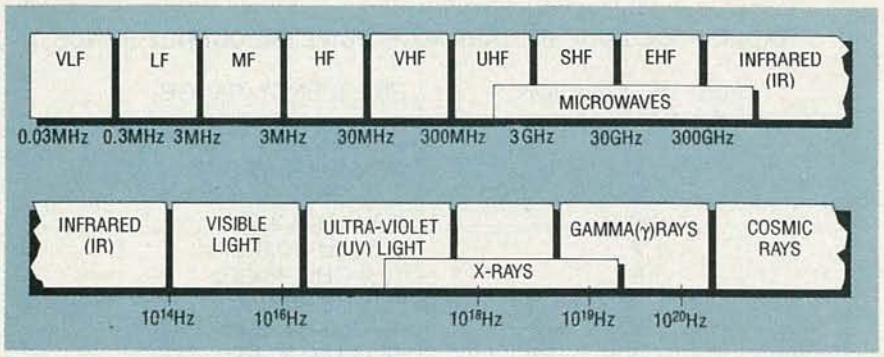


FIG. 1—THE ELECTROMAGNETIC SPECTRUM; the upper end of UHF is considered microwave. Both regions have common properties, and certain microwave applications, like long-range radar, are often UHF. Here, microwaves include all frequencies above 500 MHz and below IR.

The power-vs-frequency dilemma seemed insoluble until 1935, when W.W. Hansen of Stanford Univ., and A.A. Heil and O. Heil exploited transit time by velocity modulating an electron beam. In 1939, W.C. Hahn and G.F. Metcalf proposed the theory of velocity modulation for microwave tubes. A few months later, Russell H. and Sigurd F. Varian extended Dr. Hansen's work, producing the first two-cavity microwave vacuum tube using velocity modulation, known as a reflex klystron. And, in 1944, R. Kompfner invented the helical Traveling-Wave Tube.

Much of the really critical microwave development work during World War II was performed at the Massachusetts Institute of Technology Radiation Laboratory, known as the RadLab. Their reports are still actively used today by many working microwave engineers as references, and can be found—over 45 years later—as standard items in many technical bookstores.

In the 1950's vacuum tubes began to be replaced with bipolar transistors. Although P-N junction semiconductor diodes like the 1N23 were made for low-frequency microwaves during World War II, other solid-state devices simply refused to function at these frequencies. Semiconductor materials exhibit a phenomenon analogous to vacuum tube transit time, called electron saturation velocity.

B.K. Ridley and T.B. Watkins in 1961 and C. Hilsum in 1962 independently predicted that gallimum-arsenide (GaAs) would exhibit the transferred-electron effect. In 1963, John B. Gunn of IBM experimented with N-type gallium-arsenide (GaAs), and noted current instability that was due to negative resistance. That observation evolved into the Transferred-Electron Device, or Gunn diode.

Other solid-state microwave devices soon followed. You can now buy DC-to-2-GHz *M*onolithic *M*icrowave *I*ntegrated *C*ircuits (MMIC's) that produce about 13–20 dB of gain for about $1. Other solid-state microwave devices operate at 20 GHz or more. All such microwave solid-state devices exploit negative resistance for oscillation and amplification.

Modern electronics designers have a wide variety of solid-state devices to select from, and microwave technology is no longer the poor orphan of electronics. Radar, communications, electronic navigation, and satellite TV links all operate at microwave frequencies. Also, modern medical diathermy, or tissue heating, long ago moved from the 11-meter band to microwave frequencies.

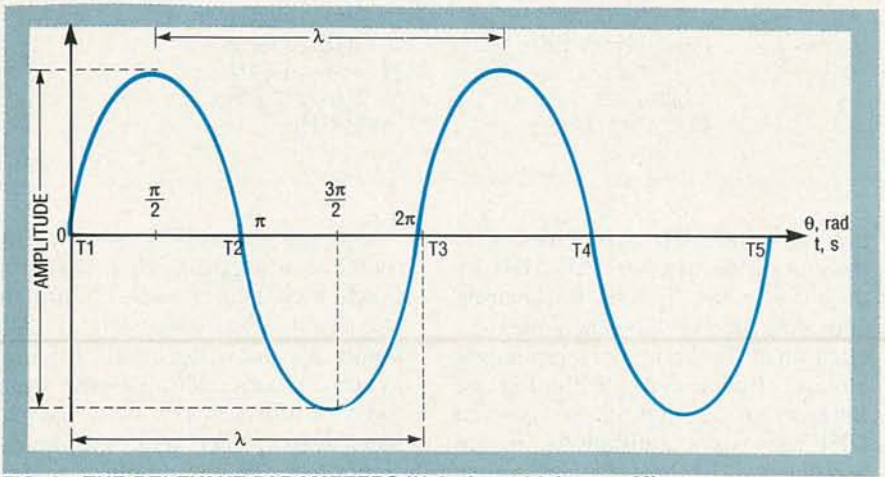


FIG. 2—THE RELEVANT PARAMETERS IN A sinusoidal wave. Microwaves, like all electromagnetic waves, exhibit the characteristics of amplitude, propagation in free space at the speed of light, frequency, wavelength, period, and phase.

Wavelength and frequency

Microwaves, like all other electromagnetic waves, exhibit the characteristics of amplitude, propagation at the speed of light in free space, frequency, wavelength, period, and phase (see Fig. 2). **Amplitude** is the measure of intensity, expressed in electric or magnetic field (volts/meter or amps/meter). The speed of light in free space is $c = 3 \times 10^8$ meters/second = 186,200 miles/second.

Frequency is the number of individual oscillations per unit time, as measured in Hertz (Hz), or cycles per second. Figure 2 shows a cycle as one complete reversal of the waveform, e.g., either T1-T3 or T3-T5. The GHz, or 10^9 Hz, is the frequency unit most commonly used in microwaves.

Wavelength is the interval in distance between identical points on successive cycles of a wave (see Fig. 2). It's measured between identical peaks or zero crossings in a given direction. For all propagating waves, the product of frequency and wavelength is the propagation speed, or $v = \lambda \times f\sqrt{\epsilon_r}$.

Here, λ is the wavelength in meters/cycle, f is the frequency in Hz, ϵ_r is the *magnitude* of the complex relative permittivity or dielectric constant of the propagation medium relative to vacuum (unitless), and v is the propagation speed.

Solving for wavelength:

$$\lambda = c/f\sqrt{\epsilon}$$

or frequency:

$$f = c/\lambda\sqrt{\epsilon}.$$

For microwave signals in air, wavelengths vary from 10 centimeters at 3 GHz to 1 millimeter at 300 GHz. Microwave frequencies above 20 GHz are also called millimeter waves due to their extremely short wavelengths (under 1.5 centimeters). In media

other than dry air or vacuum, propagation speed decreases. To maintain constant propagation speed, the wavelength must decrease if frequency is held constant.

The only characteristic quantity that remains perfectly constant in a propagating wave is frequency. When microwave energy passes through a piece of plastic, for example, its speed decreases because $\epsilon > 1$, but λ must also decrease to produce the same number of cycles in a given time interval.

Any waveform can be described either temporally (in time) or angularly. As is shown in Fig. 3-*a*, period is shown to be the reciprocal of frequency $T = 1/f$, where T is the period (in s/cyc), and f is frequency (in Hz).

The angular description of a sinusoid stems from the fact that it's mathematically generated from a circle, arbitrarily defined as containing 360°. The true, non-arbitrary angular unit is the radian (or rad); to define it, consider a circle. If, as is shown in Fig. 3-*b*, you bend a line segment one radius long to fit along a sector of the corresponding circle, it subtends a 57.3° angle. If you repeat this as many times as possible over the entire circumference, you'll fit 6.28 radii on the circle in all, or 3.14 radii along a semicircle.

By definition, the number 6.28 is twice the constant pi (π), or $2 \times \pi$ radians = 6.28 rad, so $\pi = 3.14$. Since $2 \times \pi$ radians = 360°, then π radians = 180°, or 1 radian = 57.3°. The term phase denotes either *A*bsolute or *R*elative *P*hase *A*ngle (APA or RPA). The APA refers to the number of degrees or radians into a given cycle where the instantaneous point of interest is located. In Fig. 3-*a*, for example, point A' has an APA of $\pi/2$ radians or 90°.

Relative phase angle (RPA) refers to the phase angle between two signals, whether two voltage signals, two current signals, or voltage and current signals. The waveforms of Fig. 4 aren't coincident (phase angle θ isn't 0°). In this example waveform A is a cosine function, while waveform B is a sine function). These waveforms are of the same frequency, but 90° out of phase with each other. This condition is called a quadrature phase relationship.

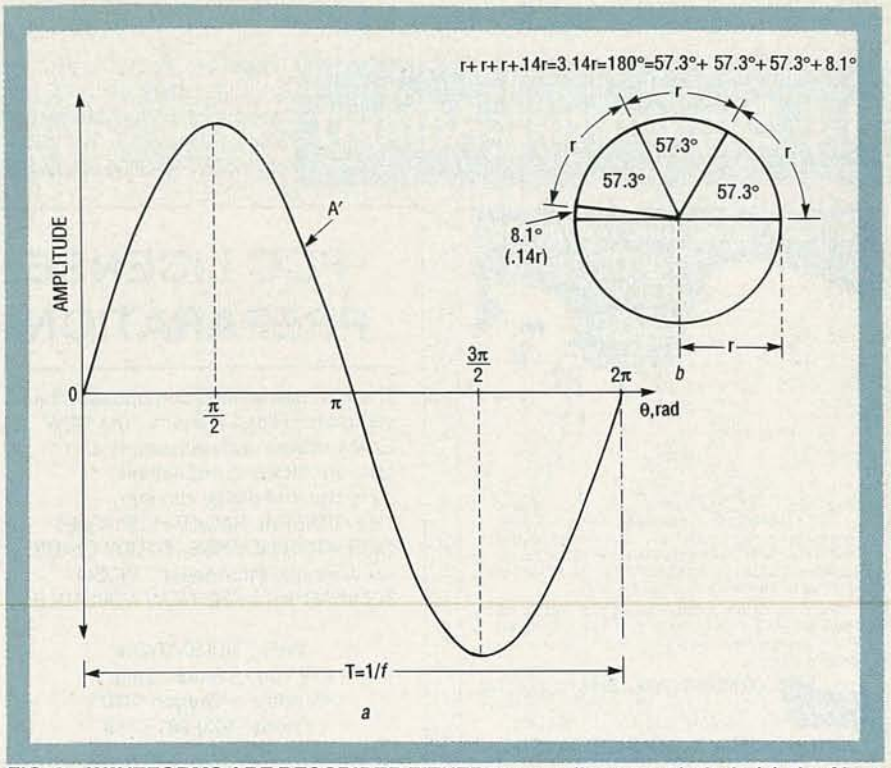


FIG. 3—WAVEFORMS ARE DESCRIBED EITHER temporally or angularly. In (*a*), the Absolute Phase Angle at A' is 90° or $\pi/2$ rads. In (*b*), a radius bent to fit on its circle subtends a 57.3° angle, so 6.28 radii fit in all. Or $2 \times \pi$ rads = 360° = 6.28 rads, π rads = 3.14 rads = 180°, or 1 rad = 57.3°, the most basic angular unit.

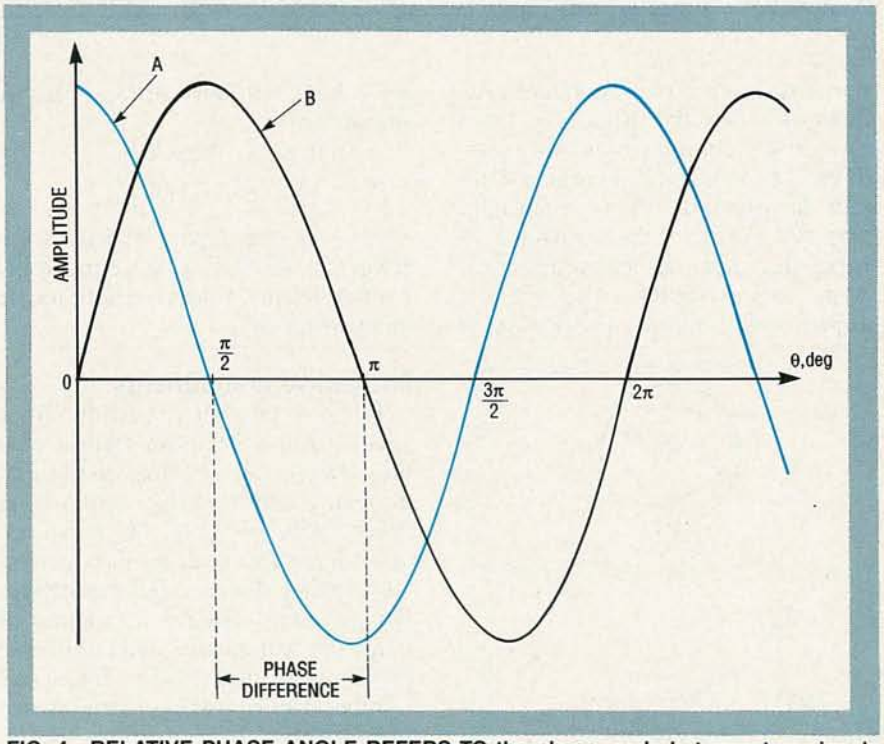


FIG. 4—RELATIVE PHASE ANGLE REFERS TO the phase angle between two signals, whether two voltage signals, two current signals, or voltage and current signals. Here, waveform A is a cosine function, while waveform B is a sine function. They have the same frequency, but are 90° out of phase, called a quadrature phase relationship.

Skin effect

There are several reasons why ordinary lumped components don't work well at microwave frequencies. As mentioned earlier, component size and lead lengths approximate microwave wavelengths. Also, distributed values of inductance and capacitance become significant here. Finally, there's the skin effect, which occurs when AC tends to flow on the surface of a conductor.

While DC flows throughout the en-

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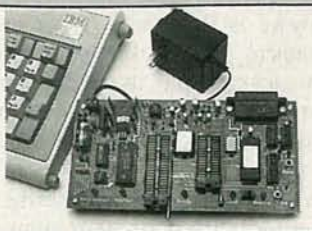
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tire cross-section of a conductor, AC flows only near the surface, in a narrow cross-sectional band that gets thinner as frequency increases. Current density falls off exponentially from the surface of the conductor towards the center, as shown in Fig. 5. At the critical depth δ, called the skin depth, the current density is 1/e = 1/2.718 = 0.368 = 36.8%, that of the surface.

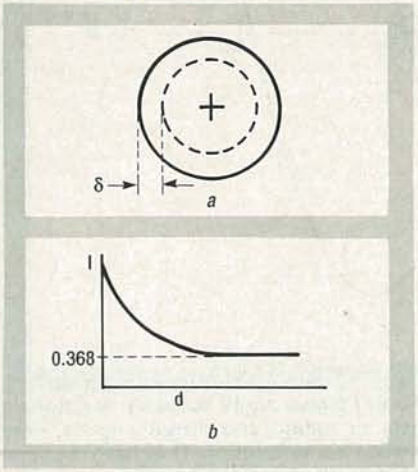


FIG. 5—THE SKIN EFFECT CAUSES AC TO flow near the surface of a conductor. While DC flows through the cross-section, AC flows only in a narrow band near the surface (*a*). Current density falls off exponentially toward the center; at the critical (skin) depth δ, the current density is 1/e = 36.8%, of that of the surface (*b*).

Skin depth is defined as

$$\delta = 1/\sqrt{\pi \times f \times \mu\sigma},$$

where δ is skin depth (in meters), f is frequency (in Hz), μ is permeability (in henries/m), σ is conductivity (in siemens/meter).

Microwave components

Because current only flows in a small part of the cross-section of a microwave conductor, instead of through its entire cross-section as at lower frequencies, the AC resistance of a microwave conductor is considerably higher than its DC resistance. Because skin effect is a function of frequency, conductors will perform as they do at DC for very low frequency AC, but may be useless in the microwave range.

For these reasons, microwave circuit design must consider the distributed resistance, inductance, and capacitance for components. In addition, specially designed lumped constant components like thin-film inductors, and chip resistors and capacitors, are necessary. For example, Fig. 6 shows how an inductor might be formed in a microwave circuit built onto a PC board. Capacitors are also made similarly, but with the conductors separated from one another.

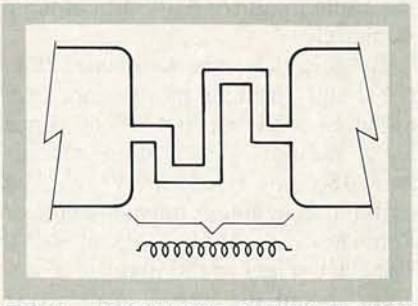
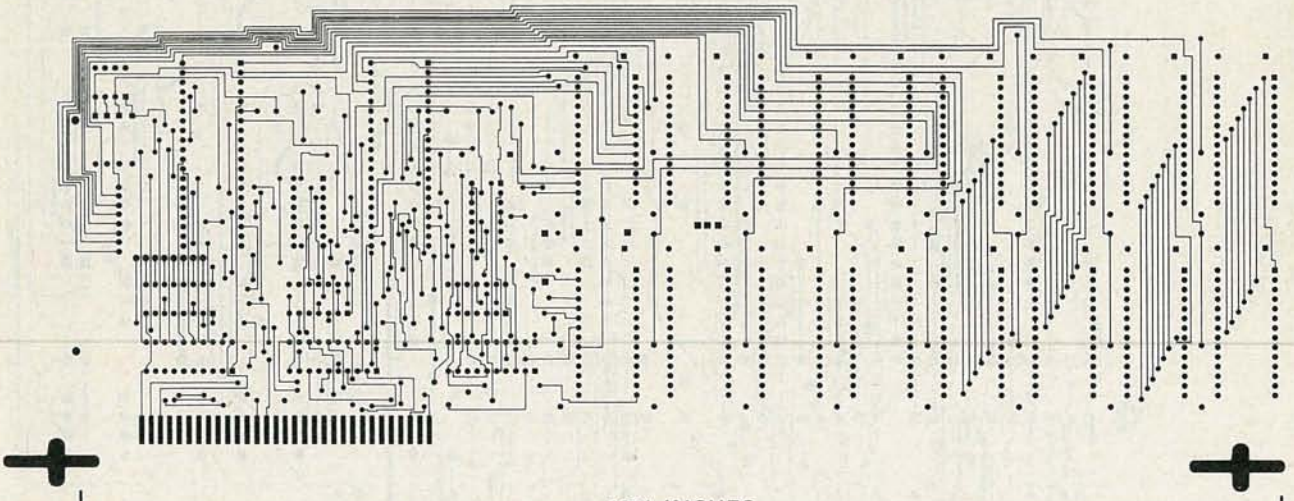


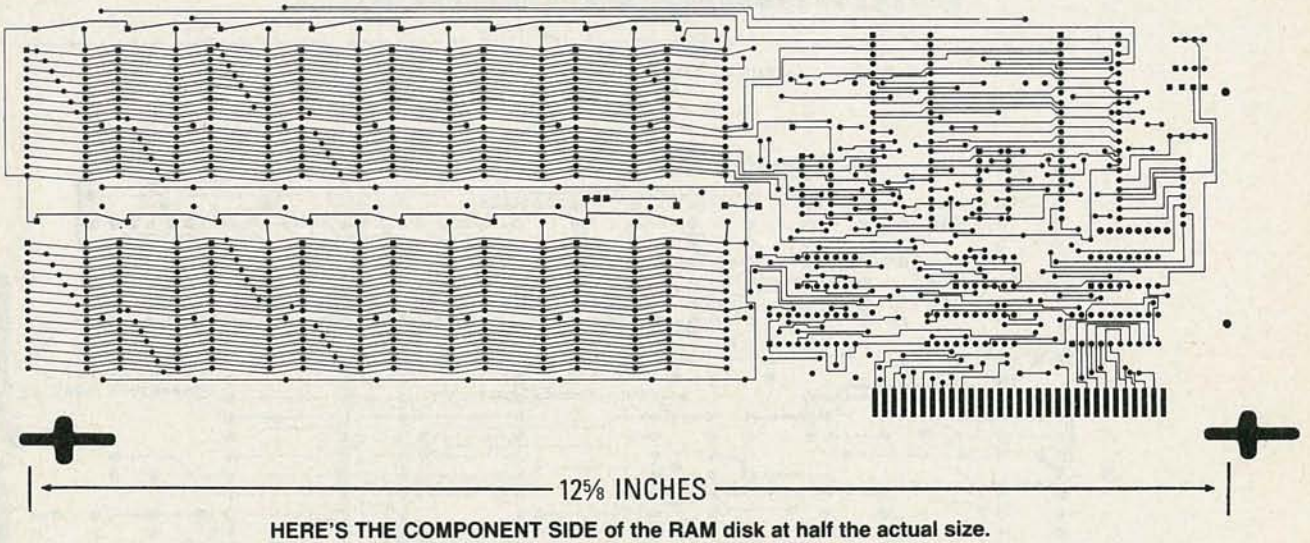
FIG. 6—MICROWAVE CIRCUIT DESIGN MUST consider distributed resistance, inductance, and capacitance of components. Also, special lumped-parameter parts are used, like thin-film inductors, and chip resistors and capacitors. Here's how an inductor might appear in a microwave circuit on a PC board. Capacitors are similar, but the conductors are separated from one another.

In our next installment, we'll consider traditional methods of generating RF power. While not specifically microwave technology, that little history lesson will set the stage for your understanding of why vacuum tubes and other early generators fared so poorly at microwaves. **R-E**

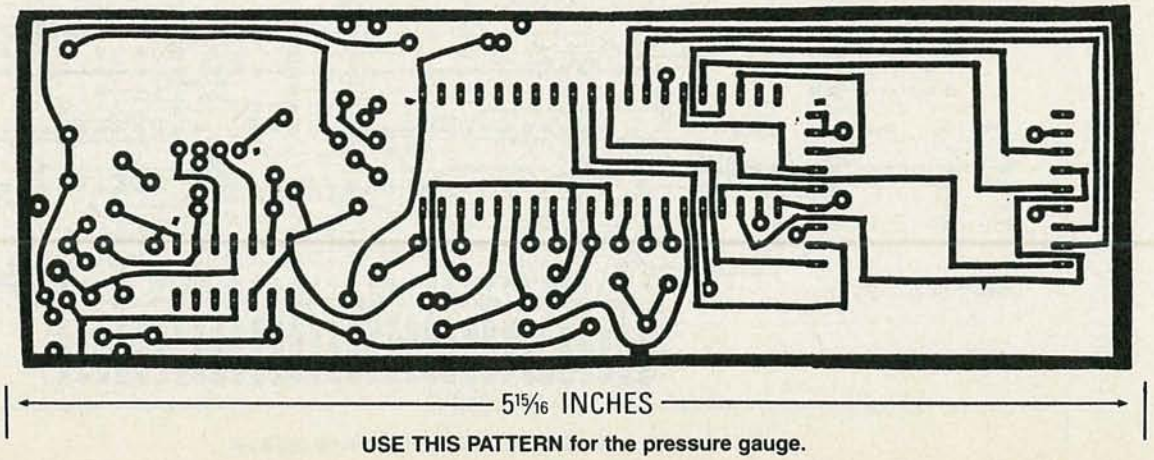
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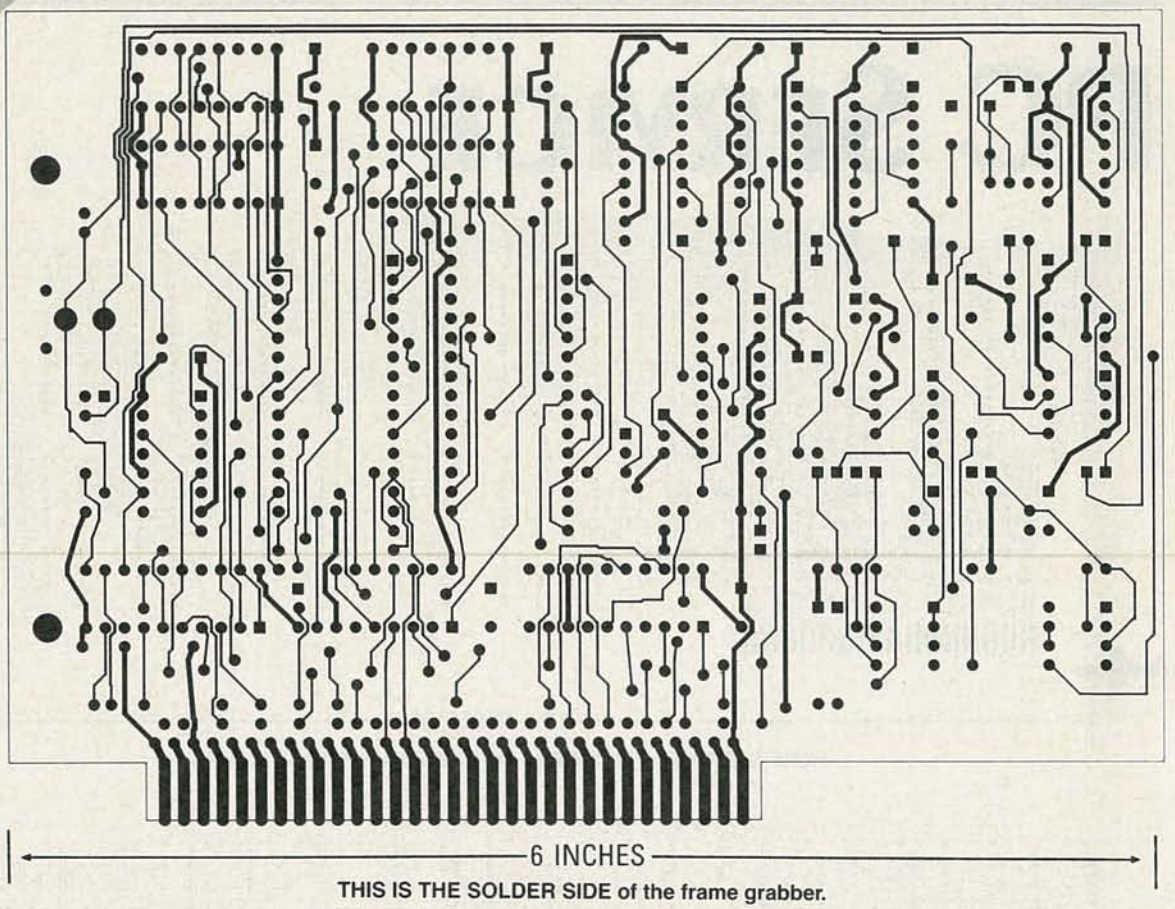
HERE'S THE SOLDER SIDE of the RAM disk at half the actual size.



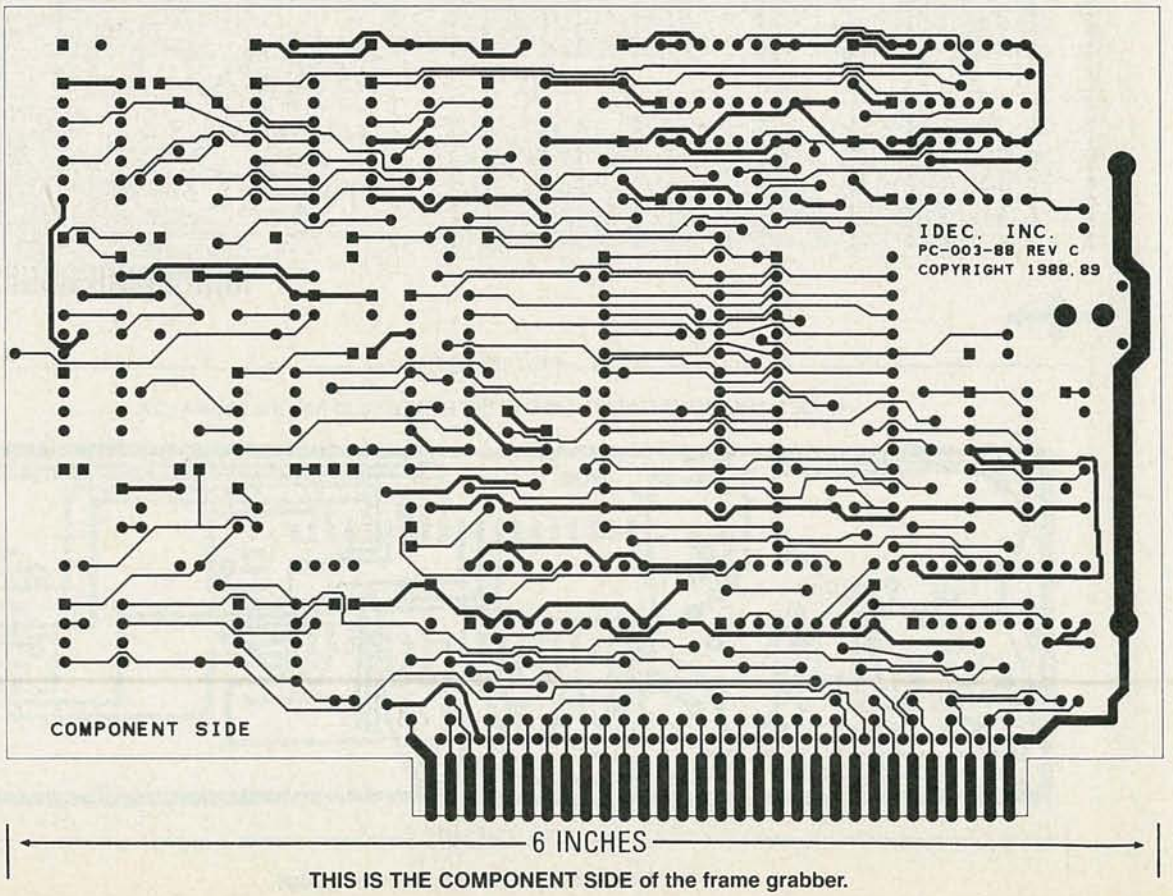
HERE'S THE COMPONENT SIDE of the RAM disk at half the actual size.



USE THIS PATTERN for the pressure gauge.



THIS IS THE SOLDER SIDE of the frame grabber.



THIS IS THE COMPONENT SIDE of the frame grabber.

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Data compression

THERE'S A PAIR OF STUPENDOUS NEW high-end compaction breakthroughs for this month, so I thought it might be a good time to go over some of the fundamentals of...

Data and image compression

You can compact data or an image whenever you want to store it in less space or else transmit it in less time. The process of compaction is sometimes called *compression*, while the reverse process is called *restoration*, *expansion*, or *regeneration*.

A compression scheme is *noiseless* if it does not add anything in the way of artifacts to the output data string. A scheme is *lossless* if nothing gets removed and if the recovered data is *exactly* the same as the input data. Being both lossless and noiseless is obviously important if you're dealing with electronic funds transfer. On the other hand, slight video-image quality variations to that tapioca pudding scene in *Godzilla versus the Night Nurses* will usually not be noticeable. Even to the critical reviewers of this cross-genre classic.

A data compression scheme functions in *real time* if it keeps up with TV frames or movie film, or else if less than one second of delay is needed for a user interaction. The compression is *symmetric* if the same amount of time and hardware is needed for either data compaction or regeneration.

The *compression ratio* is simply how much compaction you gain. If you reduce a 100K textfile to 12.5K, your compression ratio is a big 8:1. Similarly, a 20 percent compression reduces your file size by 5:4.

As you might suspect, a modest amount of compaction, say 30 percent, is easy to do. Things get sticky fast after that. The higher the compression ratio, the more time and effort that is required to do the job.

Naturally, there is a fundamental limit to the ultimate achievable compression, based upon information theory and on entropy constraints. Because both the English language and typical pictures are extremely *redundant*, these limits are often surprisingly generous.

But do note that the less redundant your information, the more intolerable any errors will become. Further, any simple errors tend to become far more destructive.

For instance, any uncompressed error that misspells a single word can instead totally trash the entire message in your compacted file. This error intolerance, along with the long processing times, are the two serious tradeoffs that get involved in extreme compaction.

Compression schemes which are *content dependent* are often (but not always) more effective than schemes that can accept anything as an input. In general, the more you know about what you want to compress, the more you can squash it. For instance, the compacted data string *alincgburgadd* should not take you four score and seven years to expand into its full text version, especially if you have got a library handy.

Or, as a second example, you could use a city, state, and a zip code consisting of the single digit 0 for your own town in a local mailing list.

Several popular areas of compression interest include ASCII text strings, fax printouts, delta modulation, disk data formats and full color HDTV video images.

Text compression

Eight-bit bytes of 256 states are a wasteful way of showing ASCII text letters, which at the most needs 127 characters, and often require only 26. Early *Infocom* text adventures used a scheme that crammed three ASCII characters into a pair of 8-bit bytes, a compression to 67 percent. Which also made snooping for hints real tough. The *Adams* adventures instead used character pairs. The most commonly used occurrences of two characters got placed in unused code slots, again giving you something like a 3:2 compression on the average.

In spelling checkers, the words are usually arranged alphabetically. Since each new word will share many of the initial characters with a previous one, you can provide a leading number instead. For instance, to get from *fixation* to *fixative*, the second word could be coded as *6ve*. You can also use character pairs as well as a trailing byte that could represent the 256 most popular combined ways of ending words, *s, ing, ly, ed*, and so on. When all is said and done, it takes only slightly over 9 bits to represent an average English word in a

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spelling checker.

Advanced data compaction schemes often are first described in the *Communications of the ACM* from the *Association for Computer Machinery*.

Going to a non-ASCII interpretive code can also help you bunches. For instance, to describe a single curved portion of a PostScript character, six signed integers, seven spaces, and the word *curveto* get involved. For a total of around 42 characters.

In Adobe's Type I Fonts, a special *character string* code gets used, of which 32 entries are commands, and the rest signed numerics of one or two self-spacing bytes. Typically, only six bytes will be needed for the same *curveto* example, giving you a compaction of 6:1 or so. There are more details in Adobe's Type I Font black book. I do have a few of these in stock.

The ASCII letter "e" usually needs eight bytes for transmission. So does an ASCII "z." But the "e" gets used far more often. So, why not set up a code where an "e" needs four bits, while a "z" needs fourteen? On the average, all of your text messages will end up somewhat shorter.

Such a scheme is called *Huffman* coding. The original horse's mouth document is *A Method for the Construction of Minimum-Redundancy codes*, as found in the September 1952 *Proceedings of the IRE*. An example of a Huffman code appears in Fig. 1.

Symbol "A" that is 20% likely codes as 10
Symbol "B" that is 18% likely codes as 000
Symbol "C" that is 10% likely codes as 011
Symbol "D" that is 10% likely codes as 110
Symbol "E" that is 10% likely codes as 111

Symbol "F" that is 6% likely codes as 0101
Symbol "G" that is 6% likely codes as 00100
Symbol "H" that is 4% likely codes as 00101
Symbol "I" that is 4% likely codes as 01000
Symbol "J" that is 4% likely codes as 01001

Symbol "K" that is 4% likely codes as 00110
Symbol "L" that is 3% likely codes as 001110
Symbol "M" that is 1% likely codes as 001111

FIG. 1—A HUFFMAN COMPRESSION USES SHORT CODES for often-occurring letters or symbols, and longer codes for those less often used. On the average, your overall message will end up shorter. Here's a simple example code which involves thirteen symbols.

Huffman codes are based upon making the length of a character code inversely proportional to the popularity of that character's use. The good news here is that a Huffman coding is fairly fast and simple, and often can be applied in combination with other compaction techniques. The bad news is that a variable bit length word can be awkward to handle in an 8-bit or 16-bit micro, and that the total compaction you get is often rather modest and typically in the 20-percent range. Worse, errors under a Huffman coding do tend to trash the entire message, rather than a single word or two.

Variations and improvements on this scheme are known as *modified Huffman codes*. These are in no way limited to ASCII. Any place you have symbols with different probabilities, you can use variable-length codes to your advantage. Often, your message will first get analyzed, and a set of rules in dictionary form will get sent as a prolog. Matching the coding to the message usually gives you the optimum compaction.

Fax and the printed page

Most fax images and most printer output consists of little bits of black buried in a sea of white. Obviously, a bitmap that sets aside one bit for each black or white dot is horrendously inefficient most of the time.

One popular way around that which works exceptionally well with black-and-white images is called *run length encoding*. With run length encoding, each successive byte represents *how many* black dots or how many white dots are to follow. For instance, four bytes in a bitmap could only represent 32 pixels. But those same four bytes coded -18- -56- -9- -143- could now represent a string of 226 pixels, a 7:1 compaction. In this case, the first 18 pixels would be black, followed by 56 white ones, followed by 9 black ones, and a final 143 white ones. Figure 2 shows you a simple example of run length encoding.

Should you have lots of picture detail, popular run length encoding schemes will automatically switch back to a bitmap whenever bitmaps are more efficient. The code can also be extended to allow for identical sequential lines.

In PostScript, the first time your descriptive font character is used, that character gets converted into a bitmap and placed into a *font cache*. Repeated use of the same character becomes much faster, since you are now only moving a bitmap using a *BitBlt* operator, rather than generating fancy paths. On up to a certain size, "real" bitmaps are used. Above that size, run length encoding is used to minimize the storage needs. While run length encoding in PostScript is typically six times slower than using a real bitmap, the method is still many hundreds of times faster than using the original character description.

Most modern fax machines use what is known as a *Group III* compression, which is based largely upon run length encoding. One source of circuits and information on Group III compression is *American Micro Devices*, especially their AM95C71 video compression-expansion chip set.

But the best way to compress a fax image is to flush it and use PostScript instead. Besides offering you a ridiculously better image quality, most PostScript superfax images transmit in one-tenth the time and will store in one-tenth the space.

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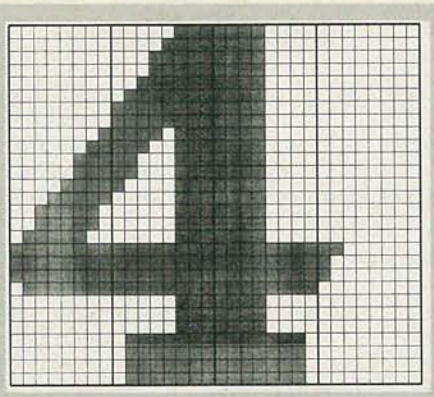
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HORIZONTAL BITMAP CODING:

```
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00 3F F0 00 00 7F F0 00 00 FF C0 00 00 FF C0 00
01 F7 C0 00 03 E7 C0 00 07 C7 C0 00 07 C7 C0 00
0F 87 C0 00 1F 07 C0 00 3E 07 C0 00 3E 07 C0 00
7C 07 C0 00 FF FF FF C0 FF FF FF 80 FF FF FF 80
7F FF FF 00 00 07 F0 00 00 07 F0 00 00 07 F0 00
00 7F FE 00 00 7F FE 00 00 7F FE 00 00 7F FE 00
```

RUN LENGTH ENCODING:

```
D7 CC 8C B9 CA 9C 8A C9 BC 8C C8 CC 75 17 C6 52
7C 55 37 C5 53 7C 45 47 C3 55 7C 26 57 C2 65 7C
15 77 C0 F0 A6 0F 09 70 F0 97 01 F0 78 D8 CD 8C
D8 C9 DB 9D B9 DB 9D B0
```

(A zero value means "don't change" unless at the line end.)

FIG. 2—RUN LENGTH ENCODING IS AN EFFECTIVE compression scheme for black-and-white images. In this example, four-bit bytes representing how many white or black pixels replace the bitmap for a 2:1 compaction.

Doing the obvious

One obvious way to compress files is to not send what you don't need. Eliminating all comments and REM statements from programs at run time is a typical example. So is getting rid of any extra spaces used for pretty printing. In PostScript, careful use of persistent downloads and common dictionaries will very much reduce your individual file sizes.

Another way to really compact certain types of images goes by the name of *delta modulation*. With delta modulation, you transmit only the *changes* between what you have now and what went by previously.

Animation is one obvious example. I've had one of my students do some incredible 4-stroke engine animation on the Apple IIe simply by brute force coding only frame-by-frame changes in successive pictures.

But delta modulation really shines in sound synthesizers. To compact voice or music, you try to anticipate where the sound is going to be in the next sample, and then transmit only the *difference* between the predicted and exact value.

This is known as *linear predictive coding*, and the sound toolkits on the Macintosh and the Apple IIgs include lots more detail. A typical compression is 2:1 or 8:3, depending on the acceptable quality.

I use an even sneakier form of delta modulation to speed up PostScript. Say you have a shipping label or a business letter with a fancy letterhead and a digitized signature. Instead of retransmitting the entire image each time, you simply place the total image into your PostScript printer *once* and then print the first name and address. You then erase *only the name and address*, and then print up your second name and address, repeating the process until your entire mail list or whatever is finished. The same idea works well with forms, or anywhere else a long makeready time can be shared among many different output copies.

The disk breakthrough

Most floppy- and hard-disk formats are surprisingly wasteful of space. So there are lots of possibilities here, over and above the obvious of trying to increase the number of tracks or the number of bytes per track.

Knowing exactly how your disk space is organized can often save

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you bunches of room. As one ancient example, leaving off those last eight invisible bytes of an Apple II HIRES image saved you an entire DOS disk sector per picture.

In ProDOS, a 511-character textfile needs only one sector, while a 513-character one needs *three* sectors; one for the first 512 characters, a second for the new index block now required in your switch from a *seedling* to a *sapling* file, and a third for the final data byte.

In fact, you can save at least one sector anytime you can get your file size just under a multiple of 512. Full details in the *Beneath Apple ProDOS* from *Quality Software*.

On the Mac, removing unused resources from your System files can often free up surprising amounts of disk space. This becomes especially critical on earlier Mac versions with limited RAM.

Similarly, knowing how your disk files are arranged and stored on any system can sometimes save you quite a bit of space. Especially on a disk that is nearly full and needs room for one or two more short files.

Our first major compression chip breakthrough for this month is the IC-105 co-processor from *Infochip Systems*. This one is initially intended for the MS/DOS world and gives you an average of a 3:1 or higher compaction of disk files. And does so while remaining fully noiseless and lossless, and still allowing a full random access. Compression is real time up to 2 megabytes per second, and the decompression blazes along at a 5-megabyte per second rate.

An adaptive algorithm is used that senses the type of data and creates optimum data dictionaries for each type. A *Markoff* scheme is used.

Interestingly enough, you do not have to store these data dictionaries. They will automatically build themselves up during the decompression process. Image compression can go as high as 15:1. The initial cost is in the $200 range.

The obvious first use for this chip is for tripling the amount of disk storage space on any laptop computer. It will be interesting to see how error-tolerable this new technique is. It should be a real winner if it works reliably enough under real-world noise conditions.

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The image breakthrough

But the really big development this month is the CL550A chip by *C-Cube*. This beauty does a full-color video compression from any source to 33:1 and beyond *in real time*, up to and including 60-frame-per-second HDTV! A massive 300:1 parallel pipelining is provided through an unusual architecture. The action in this chip takes place at a previously unheard of ten *billion* operations per second.

The compression is done by making what are known as *Discrete Cosine Transforms*, that involve blocks of 64 pixels. It turns out that certain spatial frequencies and some color shifts are nearly invisible to the human eye, so a careful filtering throws out anything that you aren't going to be able to see anyway.

Best of all, this chip implements what is soon to be an international JPEG (*J*oint *P*hotographic *E*xperts *G*roup) image standard, so it is in no way proprietary.

The obvious uses include genuine multimedia on personal computers, compact full animation on CD-ROM and for squashing the bandwidths needed for HDTV broadcasts to well *under* those currently being used for plain old TV.

C-Cube does have a free technical information packet for you on their products, along with demo boards and software emulators. Projected pricing of their chip is in the $95 range.

Video distribution amplifiers

There are lots of times when you might like to drive more than one video monitor from a single source. Unless you are very careful, you will get disappointing results. Fortunately, there's a brand-new low-cost MAX457 chip from *Maxim* which greatly simplifies this task.

Video is normally routed through shielded cables with a *characteristic impedance*, of 75 ohms or so.

If you do intentionally open or short-circuit a cable, whenever a pulse or other signal gets to the end, it will reflect and bounce back to the source and cause *standing waves*—unless the cable is terminated at both ends by a load equal to its characteristic impedance.

At baseband video frequencies, reflections off a short cable may not be all that bad. As a crude rule, if the cable is ten feet long or less, you can often get away without terminating it. Longer than that, and you will want resistive terminations at both ends, or you will get character smearing and other loss of quality.

Figure 3 shows you the correct way to tie several monitors to a single source. You can use a daisy-chain connection. The monitors inside the chain should all be set to their *high impedance* termination stage. The last monitor in the string should get load terminated.

Note that you cannot simply put a bunch of monitors in parallel, since all their loads will gang up and swamp your source, leaving you with a very washed out picture, poor sync, or even nothing at all.

Figure 4 shows you a dual video driver using the MAX457. Each out-

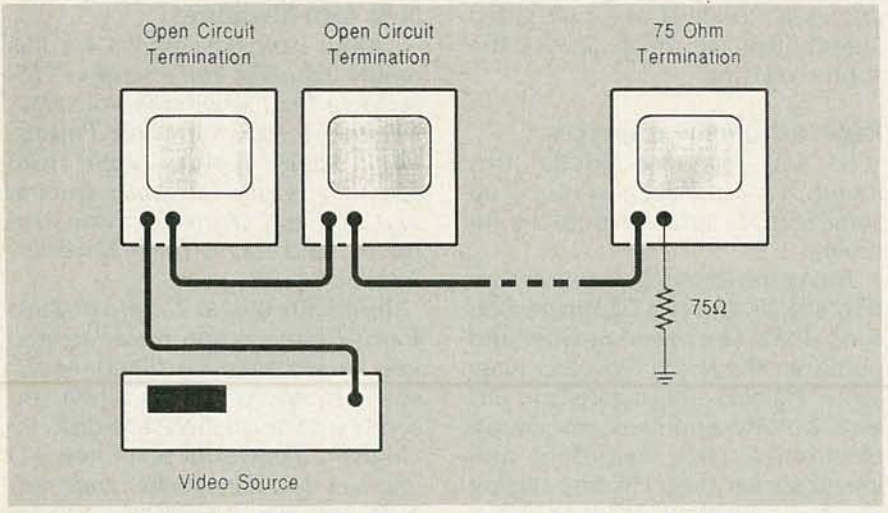
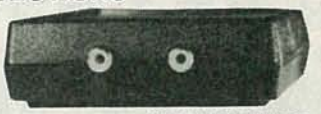


FIG. 3—THE CORRECT WAY TO CONNECT several video monitors to a single source is to daisy chain them. Only the last monitor input should be terminated with a 75-ohm resistor. Never connect cables in parallel!

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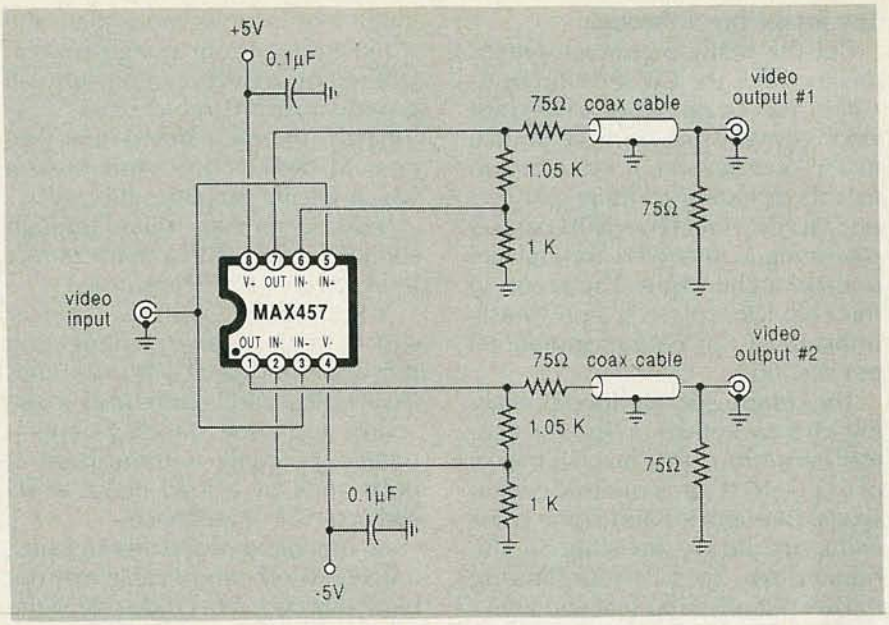


FIG. 4—THIS DUAL VIDEO DRIVER is handy any time you want to use more than one monitor with a VCR or a computer, especially with long cables.

put is an independent 75-ohm source. You can cascade as many of these as you need to.

To make up for the drop across the 75-ohm source resistance, the video gain is set to precisely two. Half of that develops across the source, and half across your terminating load. At a gain of two, the bandwidth is around 30 megahertz, so high-definition stuff can be handled as well as ordinary video.

A split +5, −5 supply is required. Sorry about that, but you do have to somehow suck out current on all your grounded sync tips. Supply current is under 40 mils for the pair of drivers. The normal output level is adjusted to a white level of 2 volts and grounded sync tips. That becomes a standard one-volt video signal after the drop across the source resistor.

Radio astronomy resources

For our resource sidebar this month, I have chosen to round up some stuff for amateur radio astronomers.

Two of the foremost resources are Bob Sickels and Jeff Lichtman. Bob runs *Bob's Electronic Service* and publishes the *Radio Observer* magazine. He also stocks parts and kits for low-noise amplifiers, microwave electronics, chart recorders, and lots of similar stuff. His free catalog also has a good no-nonsense intro.

Jeff has published three classics in the field which include his fine *Radio Astronomy Handbook*, his *Solar Radio Astronomy*, and his *Microwave Radio Astronomy*.

A leading amateur astronomy club is apparently the *Society of Amateur Radio Astronomers*. Their $20 yearly membership includes a newsletter.

Publications providing radio astronomy information in them include *Science*, the *Astrophysical Journal*, *NASA Tech Briefs*, and their discontinued *IEEE Transactions on Radio Astronomy*.

Two radio astronomy sites which welcome visitors are the *NRAO* observatory located in Greenbank, West Virginia, and that *VLA* site in New Mexico.

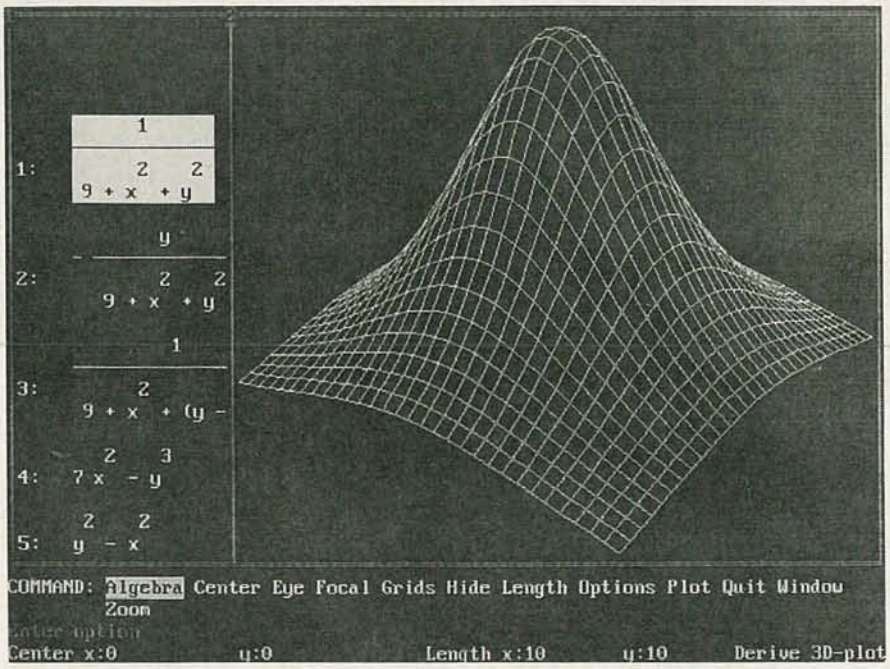
New tech literature

Useful new data books for this month include a *Voice Synthesis LSI* and *Telecom LSI* volumes from *OKI*; *Microwave Transistors* from *Phillips*, *High Speed CMOS Logic* from *Samsung*; *Optoelectronics and Image Sensors* from *Texas Instruments*; and *A/D & D/A Converters* from *Sony*.

Toni Patti of the *Cryptosystems Journal* offers some newly revised free Lorenz attractor "Owl's Mask" chaos theory programs when you send him a formatted IBM disk. Included is a powerful set of new 3-D graphics routines. Other free software includes a *Selectrim* trimpot selector from *Bourns*, and a

continued on page 90

COMPUTER DIGEST



Last time we outlined the hardware and software comprising the static RAM disk. Unlike a RAM disk allocated from system memory (whether conventional, extended, or expanded), our RAM disk occupies only a few I/O port addresses. And because it contains its own CMOS memory subsystem, our RAM disk can be immunized against power failures.

Now let's talk about how the circuit works, and about how to build and use the SRAM disk.

Hardware details

The circuit consists of three main sections: a bus interface, a battery backup circuit, and the static RAM array. Figure 1 shows the complete schematic diagram.

The PC bus interface consists of IC3, IC4, and IC5. The latter are a pair of 74LS244's (three-state octal bus drivers) that buffer the address lines. A bi-directional three-state octal buffer (IC3, a 74LS245) buffers the data lines.

The $\overline{IOR}$ (I/O Read) line from the expansion bus drives the data direction input of IC3; the decoding circuitry discussed below drives IC3's gate input (pin 19).

The decoding circuitry consists of IC6, IC7, and several gates in IC9 and IC10. Two outputs from IC6, a 74LS138 3-to-8 line decoder, drive the $\overline{CS}$ inputs of the parallel ports (IC1 and IC2). In a multi-board system, the first board uses the two low-order outputs ($\overline{Y0}$, $\overline{Y1}$) of IC6; subsequent boards use higher-order outputs. Address lines A0 and A1 select one of four registers (three data ports and one control port) in the selected port (IC1 or IC2). Address lines A2–A4 drive IC6, which provides an output select every four addresses.

For IC6 to be enabled, its $\overline{G2A}$ must be driven low. For that to happen, several conditions must be met. First, AEN from the bus

EDITOR'S WORK-BENCH

Low-cost Logic Analyzer

Logic analyzers can inspire fear. They're usually expensive, conceptually difficult, and hard to use. To counteract that trend, Photronics has introduced the LA1 Logic Analyzer, a $100 device that plugs into your PC. The LA1 is not going to put Tektronix out of business, but it's not even trying to compete. The LA1 is really an educational tool that provides a low-cost, easy-to-use introduction to logic analyzers. It keeps cost down by limiting operating speed to about 100 kHz, and by relying on the PC for its intelligence.

The LA1 consists of a half-length card that plugs into any 8- or 16-bit slot. As shown in Fig. 1, A connector is accessible to the user through the rear bracket; a supplied ten-conductor ribbon cable plugs into the connector. The cable is terminated with color-coded mini-clips that you attach to the circuit under test. Eight lines are for data, one is ground, and the other is for an external clock.

(Continued on page 78)

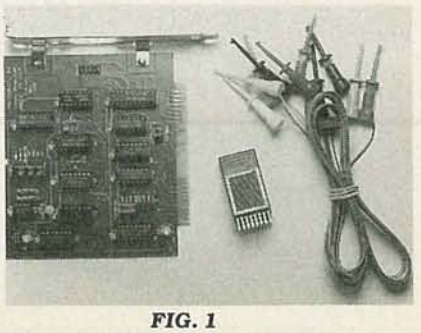


FIG. 1

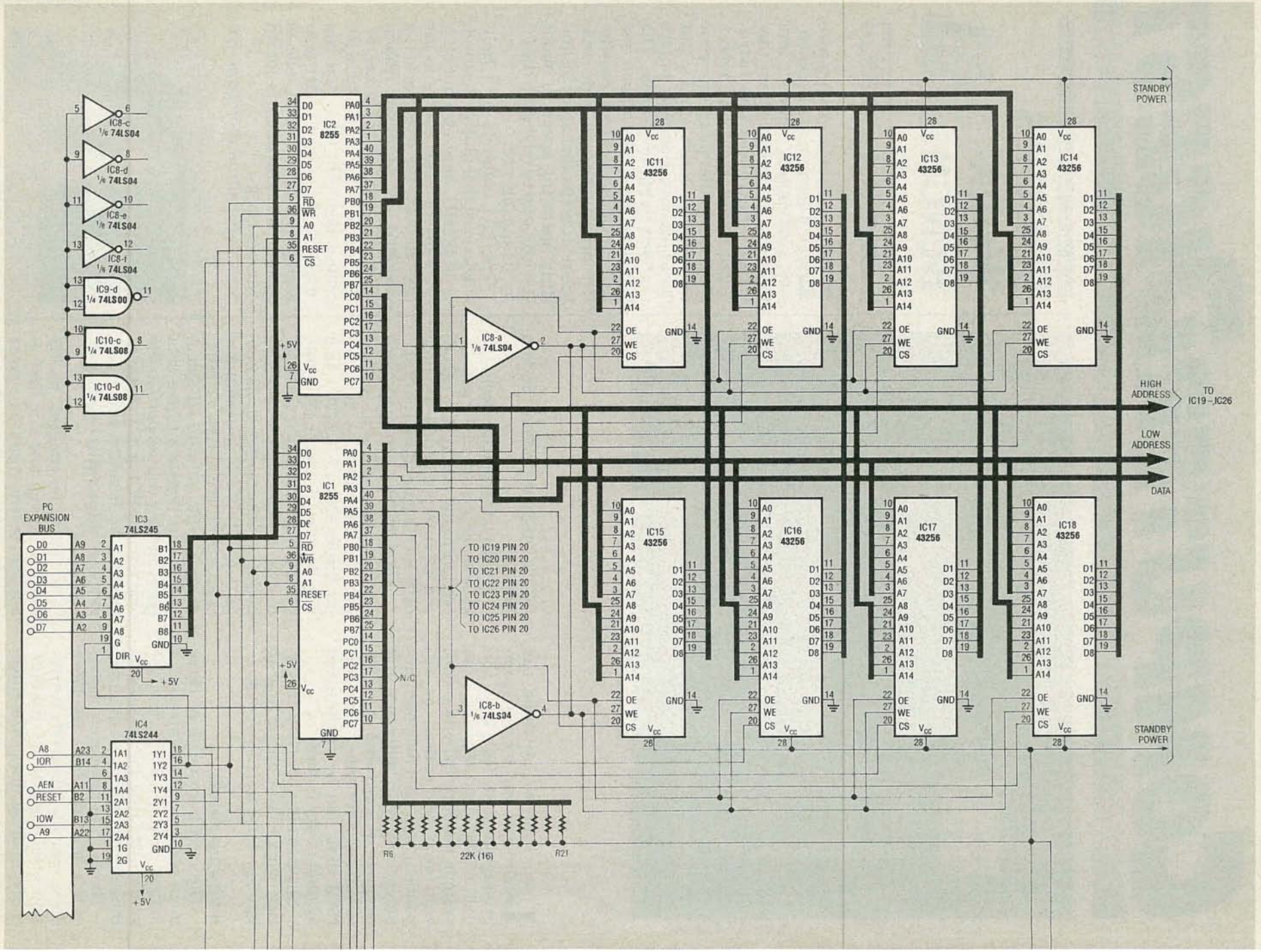
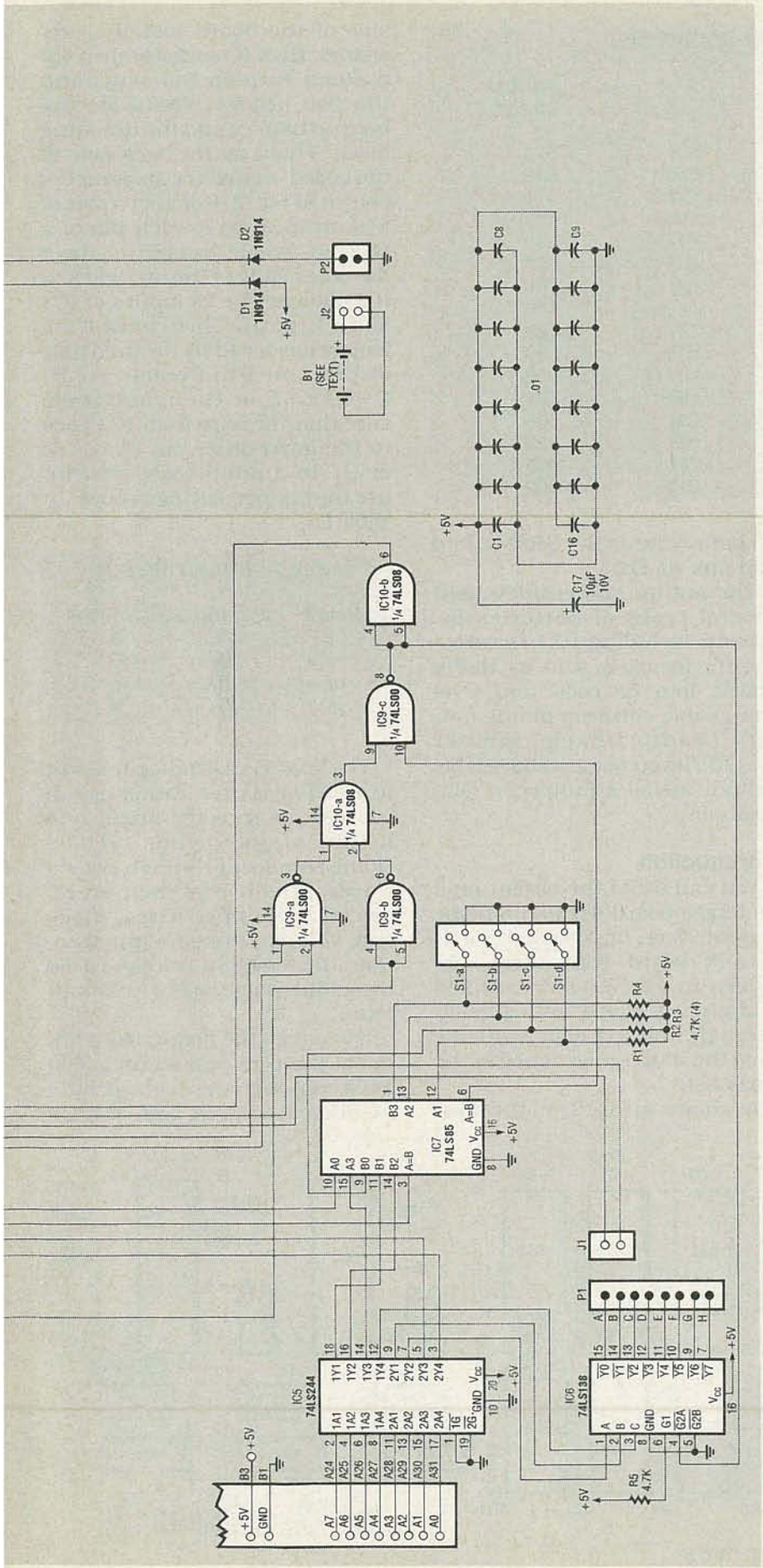


FIG. 1. THE SRAMDISK'S COMPLETE SCHEMATIC.



must be low. If it is not low, a DMA operation is taking place. Second, either $\overline{\text{IOR}}$ or $\overline{\text{IOW}}$ must be active (low). When those conditions are met, pin 3 of IC10 will go high.

Another necessary condition is that the A=B output of IC7 be high. That IC is a four-bit magnitude comparator; it has three outputs that reflect the state of two four-bit sets of inputs. If the binary-weighted A inputs are less than the binary-weighted B inputs, the A=B output goes high. The A=B and AB outputs function similarly. To compare more than four bits, you can cascade IC's by connecting outputs of one stage to corresponding inputs of the next. The lowest-order stage requires its A=B input to be high.

In our circuit, A9 from the bus drives the A=B input, and A5–A8 drive the comparison inputs. DIP switch S1 is connected to the other group of comparison inputs. The A5 and A8 address lines actually drive the A3 and A0 inputs, and A6 and A7 drive the B2 and B1 inputs respectively. The other A and B inputs are connected to the poles of S1. The net effect is that pin 6 goes high when A9 is high and when A5–A8 match the DIP-switch settings.

Table 1 shows the switch settings for various I/O port addresses. In each line of the table, the address shown is 512 more than the sum of the binary switch weights. The reason is that A9 is also decoded, so the minimum address is 512.

When pin 6 of IC7 and pin 3 of IC10 go high, pin 8 of IC9 goes low, thus enabling IC6-d, one of the port IC's. In addition, after inversion by IC10-b, the pin-8 output also enables IC3, the data-bus buffer. At that point a byte will be read or written (depending on the states of $\overline{\text{IOR}}$ and $\overline{\text{IOW}}$) to the appropriate port of the selected port IC.

SRAM array

Each SRAM has fifteen address lines, eight data lines, an output-enable (OE) line, a write-enable ($\overline{\text{WE}}$) line, and a read/write (R/$\overline{\text{W}}$) line. Port A of IC1 drives the low-order address lines of all SRAM's; the lower seven bits of port B

TABLE 1—I/O PORT ADDRESSES

S1-d (256)	S1-c (128)	S1-a (64)	S1-b (32)	Address (decimal)
ON	ON	ON	ON	512
ON	ON	ON	OFF	544
ON	ON	OFF	ON	576
ON	ON	OFF	OFF	608
ON	OFF	ON	ON	640
ON	OFF	ON	OFF	672
ON	OFF	OFF	ON	704
ON	OFF	OFF	OFF	736
OFF	ON	ON	ON	768
OFF	ON	ON	OFF	800
OFF	ON	OFF	ON	832
OFF	ON	OFF	OFF	864
OFF	OFF	ON	ON	896
OFF	OFF	ON	OFF	928
OFF	OFF	OFF	ON	960
OFF	OFF	OFF	OFF	992

drive the high-order address lines; and port C drives the data lines. The high bit of port B (PB7) functions as a pseudo read/write line that drives the $\overline{OE}$ lines, and, after inversion by IC8-a and IC8-b, also the $\overline{WE}$ lines. Last, the A and B ports of IC2 drive the chip-select inputs of the SRAM's, one bit per SRAM. Port C of IC2 is not used in the present design; you could modify our circuit to decode an additional 8 SRAM's or use the port for other things.

Data retention

The battery-backup circuitry is quite simple. Five volts from the bus feeds all of the logic and parallel ports. In addition, bus power also feeds the SRAM's and associated chip-select pull-up resistors (R6–R21) via diode D1. When bus power is off, the backup battery feeds the SRAM's and pull-ups via D2.

The author successfully used several types of batteries for backup, including a 0.1-Farad capacitor formerly sold by Radio Shack, four AA cells, and a rechargeable cordless phone battery (Radio Shack number 32-173). If you use a rechargeable battery, install a jumper in D2's position.

Construction

You can build the circuit on a prototype board with an XT-type bus interface, or you can build it on a PC board. Foil patterns are shown in PC Service; a drilled and etched board with plated-through holes is also available from the source mentioned in the parts list.

As shown in Fig. 2, on the front side of the board install all resistors, then IC sockets, then capacitors, then the DIP switch and the two header blocks for the backup battery and the decoding block. Then, on the back side of the board, install the six jumpers shown in Fig. 2. Connect a pair of wire-wrap wires to each pin of a two-pin female header; connect the other ends of the two wires to the pads by the $\overline{CS}$ inputs of IC1 and IC2 (pin 6). Then connect the female header to the desired pair of pins on P1. Choose A+B, C+D, E+F, or G+h, and make sure that the wire from IC2 goes to the lower-order pin (A, C, E, or G). In a multi-board system, use the jumper settings shown in Table 2.

TABLE 2—BOARD SELECT

Board	IC2, Pin 6	IC1, Pin 6
1	A	B
2	C	D
3	E	F
4	G	H

The board is a little too tall to fit in an XT-style case. Either use an AT case, or trim the board to a height of about four inches. Doing so will cut through several traces, which can then be replaced by jumper wires. Make sure you don't remove any more than the top eight traces to keep the additional jumpers to a minimum.

If you trim the board, the additional jumpers should be added between the correspondingly numbered pads J1...J8. For ex-

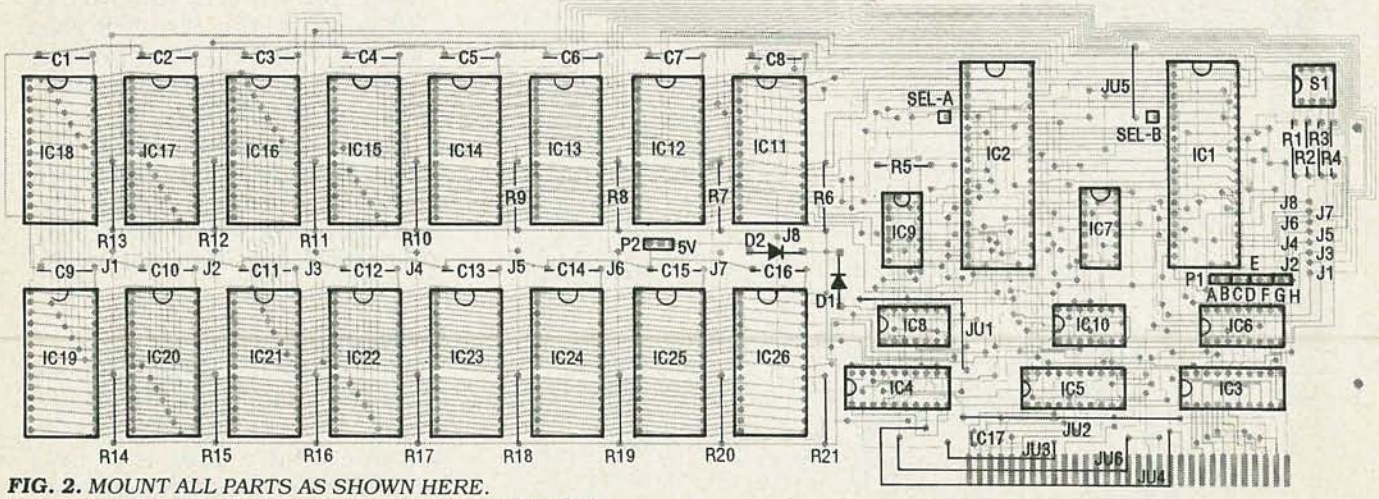


FIG. 2. MOUNT ALL PARTS AS SHOWN HERE. MAKE SURE THE FOLLOWING VERSION OF THE PARTS LIST RUNS. THERE ARE A FEW DIFFERENCES FROM PART I.

Parts List

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

R1–R5 ..... *4700 ohms*
R6–R21 ..... *22,000 ohms*

Capacitors

C1–C16 ..... *0.01 µF polyester*
C17 ..... *10 µF, 10 volts, electrolytic*

Semiconductors

D1, D2 ..... *1N914 switching diode*
IC1, IC2 ..... *8255 Programmable peripheral interface*
IC3 ..... *74LS245 Bidirectional bus buffer*
IC4, IC5 ..... *74LS244 Octal bus driver*
IC6 ..... *74LS138 Three-to-eight line decoder*
IC7 ..... *74LS85 Four-bit comparator*
IC8 ..... *74LS04 Hex inverter*
IC9 ..... *74LS00 Quad NAND gate*
IC10 ..... *74LS08 Quad AND gate*
IC11–IC26 ..... *43256-10 Static RAM*

Other Components

SW1 ..... *Four-position DIP switch*
B1 ..... *Four AA cells (with holder) (optional)*
J1 ..... *2-position, single-row, 0.1" female header*
J2 ..... *2-position, single-row, 0.1" female header*
P1 ..... *8-position, single-row, 0.1" male header*
P2 ..... *2-position, single-row, 0.1" male header*

Ordering Information

The following are available from Hatronics
145 Lincoln Street
Montclair, NJ 07042
(201) 783-7264
(201) 245-6614 (BBS, join the Hatronics conference)

Bare PC board **$50**
Kit with 0K RAM **$90**
Kit with 128K RAM **$155**
Kit with 256K RAM **$220**
Kit with 512K RAM **$322**
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Assembled and tested unit, 256K **$255**
Assembled and tested unit, 512K **$395**

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New Jersey orders add sales tax (6%).

```
5 CLS
10 PRINT"*************************************************"
20 PRINT"*                                               *"
30 PRINT"*         SRAM INITIALIZATION PROGRAM           *"
40 PRINT"*                                               *"
50 PRINT"*            COPYRIGHT HATRONICS                *"
60 PRINT"*                                               *"
70 PRINT"*************************************************"
80 PRINT" THIS PROGRAM WILL INITIALIZE THE FIRST 32K "
90 PRINT" THIS WILL SET UP THE FAT AND DIRECTORY AREAS "
95 PRINT
97 INPUT" WHAT PORT ADDRESS "; PO%
99 IF PO%=0 THEN GOTO 130
100 PRINT" ARE YOU SURE YOU WANT TO DO THIS ??? Y or N "
110 A$=INKEY$: IF A$="Y" OR A$="y" THEN GOTO 140
120 IF A$="" GOTO 110
130 PRINT" ABORTED !!!": END
140 DIM S2(16)
150 S2(1)=254:S2(2)=253:S2(3)=251:S2(4)=247
160 S2(5)=239:S2(6)=223:S2(7)=191:S2(8)=127
170 P1A=PO%:P2A=PO%+16:P1B=PO%+1:P2B=PO%+17
175 P1C=PO%+2:P2C=PO%+18:P1D=PO%+3:P2D=PO%+19
180 OUT P1D,128
190 OUT P2D,128
200 OUT P2B,255
210 OUT P2A,255
220 P%=P2A
230 PRINT" INITIALIZING FIRST 32K"
240 IF BA =2 THEN P%=P2B
250 FOR S = 0 TO 127
260 FOR T = 0 TO 255
270 OUT P1A,T:OUT P1B,S+128
280 OUT P1C,0
290 OUT P%,S2(S3):OUT P%,255
300 NEXT T
310 NEXT S
320 PRINT " END INITIALIZATION":END
```

ample, run a jumper from J1 under the DIP switch to J1 by C9, from J2 under the DIP switch to J2 by C10, etc.

If you're not going to install all sixteen SRAM's, install the SRAM's in part-number order (IC11, IC12,...IC26).

Check your work carefully for solder bridges and cold solder joints. Fix any problems, and then set S1 to a value unused by any other adapter in your system. Try 768 if you're not sure; that address is reserved by IBM for prototype boards.

Then power down your PC and insert the board into a vacant expansion slot.

Initialization

Power your PC up; if it doesn't boot normally, power down quickly, check the board again, and correct any mistakes.

Before you can use the board, you must initialize it. Run the BASIC program shown in Listing 1; that program performs a function similar to DOS's FORMAT command. If you don't keep a battery attached to the board, you'll have to run the BASIC program each time you boot. In that case, you may want to modify the program so that it automatically uses the correct port address and so that it returns to DOS after it finishes executing. In other words, change all END statements to SYSTEM statements. Then you could execute the program from your AUTOEXEC.BAT like this: GWBASIC SFORMAT.

The author is working on an enhancement that will allow the driver to optionally initialize the board each time you boot. Both the initialization program and the device driver are available from the RE-BBS, 516-293-2283, 300/1200, 8N1. The file called SRAMDISK.EXE is a self-extracting ZIP file that contains the BASIC program, the executable version of the device driver, and the source for the device driver. Run SRAMDISK.EXE on a disk with at least 150K of free disk space. Check with the author at the address given in the parts list for the latest version of the initialization program and device

(Continued on page 80)

EDITOR'S WORKBENCH

(Continued from page 73)

The card has several jumper blocks for specifying the I/O address through which data is passed to the host PC, and for selecting the clock type and rate of the clock. If you use the internal clock, you can specify a clock frequency of 1, 10, 100, 1,000, 10,000, or 100,000 Hz. The board is laid out well, has a solder mask and a silk screen indicating all component positions, and all IC's are installed using socketed connectors.

The software consists of a single executable file that uses a drop-down menu system for loading and saving files, configuring defaults, capturing data, printing the results, etc. To capture data, you first specify capture parameters using the dialog box shown in Fig. 2. The trigger byte lets you specify the byte with which capture will begin. You can specify 0, 1, or X for each bit. For capture to begin, you must receive a byte that matches the pattern of 1's and 0's in the trigger byte. (X matches either a 1 or a 0.)

The Edge Select field in the dialog box allows you to specify whether each byte will be captured on the leading (+) or the trailing (−) edge of the clock. Sampling Count specifies the number of bytes to capture: 16, 32, 64, 128, or 256.

Timeout specifies the maximum period of time to wait for the trigger byte. If it is not received in that amount of time, the capture process terminates. You can specify an infinite wait by specifying a value of 0; however, your computer will lock up if the desired byte is not received.

After capturing data, you can view a graph of the state of each of the eight captured bits at each clock cycle. The software switches to a graphics mode for this display; all standard IBM adapters (CGA, EGA, VGA, 8514, 3270) are supported, as are several others.

The program will also print the graph; most common dot-matrix and laser printers are supported. Figure 3 shows a LaserJet II printout of one sample run.

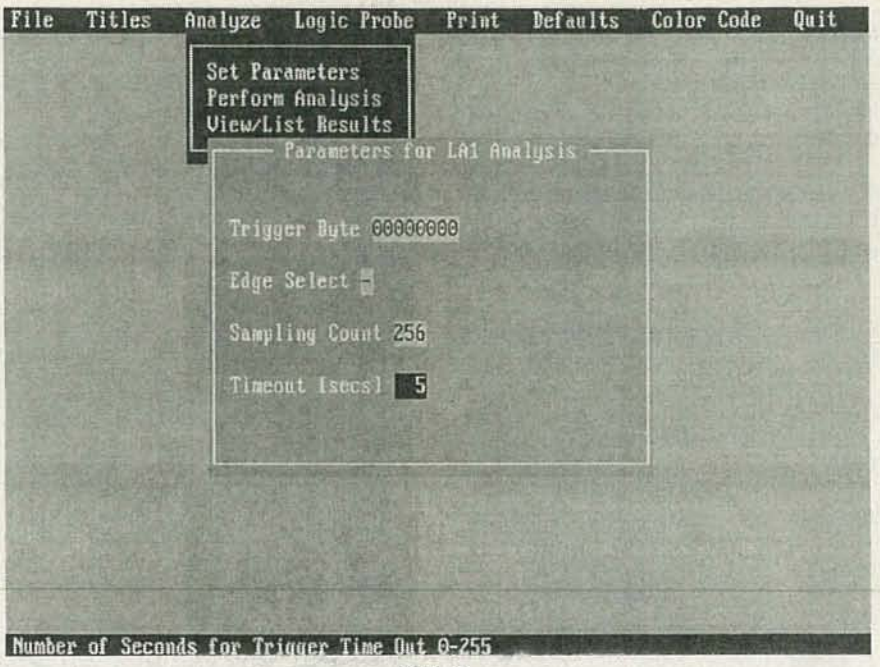


FIG. 2

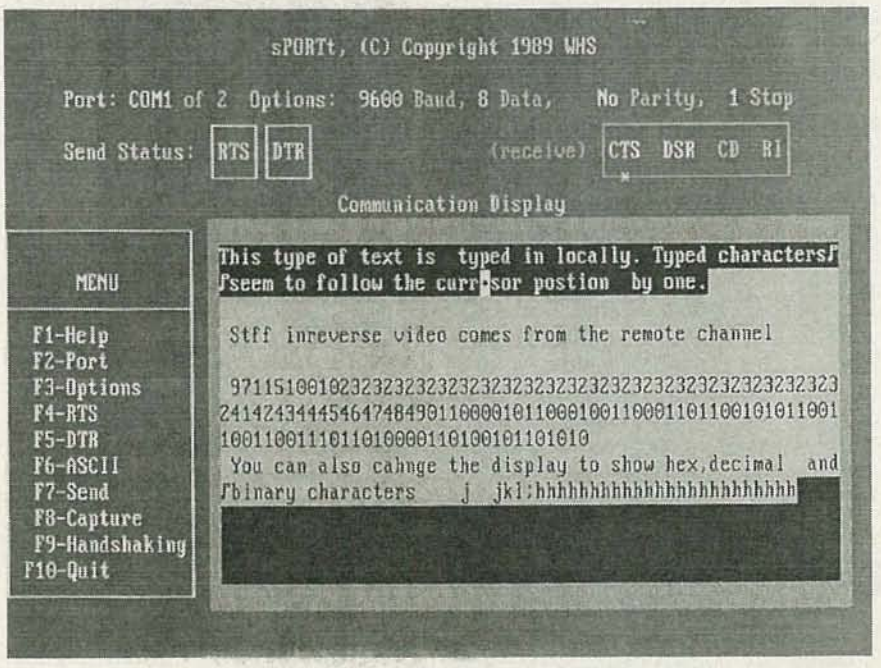


FIG. 3

The LA1 also has a special "Logic Probe" mode, in which a bit-mapped display is constantly updated to reflect the state of the input probes. For demonstration purposes, you can run the software without the card in a random mode, in which data is not captured but created by a random-number generator.

Documentation consists of a 20-page pamphlet that does a good job of explaining how to set up and use the LA1, but is weak on background information and examples. That's a weakness, because I doubt that anyone familiar with logic-analyzer operation would be interested in a product like this. Its low speed and 8-bit operation simply aren't sufficient for real-world use.

For educational use, the easy-to-use interface has a distinct advantage, but the documentation should have some sort of tutorial information. All in all, though, the LA1 would be valuable in conjunction with a beginning course in digital electronics.◆CD◆

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41256	256Kx1		120 ns	2.25
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Serial port setup with sPORTt

You can never have enough weapons in the never-ending battle with RS-232 interfaces. sPORTt is a software-only serial port tester that aids determining correct port settings for PC compatibles. It provides an interactive screen, shown in Fig. 4, in which you can change settings at will, as well as send and receive data. Whatever you type at the keyboard is sent out the current port at the current settings. You can also send a disk file, and receive to a disk file.

The nice things about sPORTt are that you can quickly and easily change settings, and that the current settings are always visible. For example, if you wonder whether that plotter requires a high on RTS, press F4 to make it high, and then send some data. If that doesn't work, press F4 to turn it back off, and try again. You can follow the same procedure with DTR. The states of the receive signals (CTS, DSR, CD, RI) are constantly displayed as well.

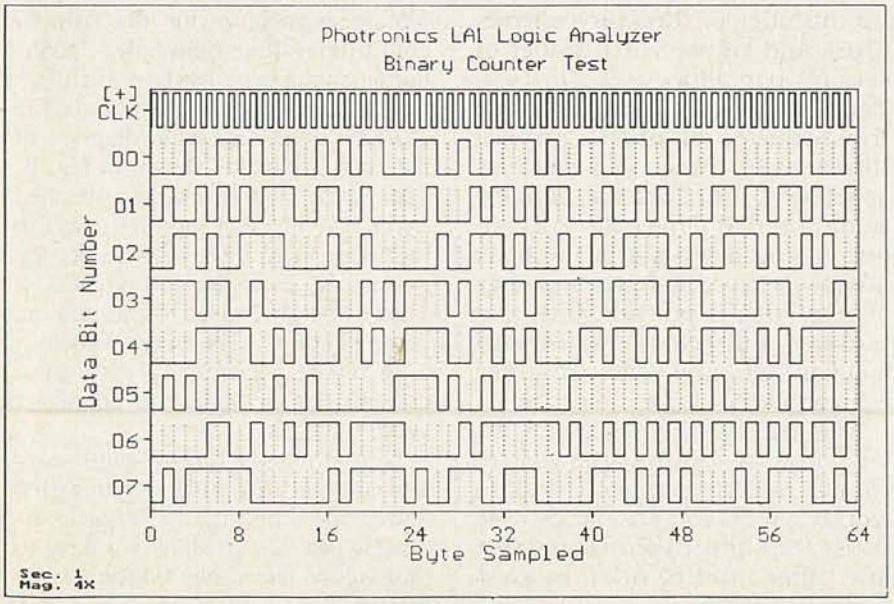


FIG. 4

The central portion of the screen contains the Communication Display, in which all sent and received characters are displayed. Each character is displayed according to the current display mode (ASCII, hex, decimal, binary), which you set with F6. Unfortunately, the numeric display modes are a little raw, with no spaces between adjacent characters, which makes the values difficult to read. I'd like to see the display formatted in a DEBUG style, with numbers on the left and ASCII on the right. A "chat" mode, in which keyboard characters (BackSpace, Tab, etc.) were interpreted intelligently would also be nice.

The program currently supports COM1 and COM2; it would be nice if the user could specify a port address, because the "standards" for COM3 and COM4 are

not universally adhered to, and multi-port serial boards use altogether different addresses.

Using the program is easy, because the single screen is self-explanatory. Printed documentation includes a 40-page three-ring notebook with background information on serial communications, 9-pin, 25-pin, and null-modem wiring diagrams, etc.

At bottom, sPORTt is a handy, easy-to-use diagnostic for PC's. It won't substitute for a fancy external serial-port analyzer, but at $90, it costs 10% of one of those devices.◗CD◖



C: The Complete Reference

C-language aficionados will appreciate McGraw-Hill's comprehensive new reference by the prolific Herbert Schildt. The book is divided into five parts. Part one includes an introduction to C that is as good as some textbooks. Part two includes complete descriptions of all standard library functions. Part three discusses data structures and algorithms common to all types of programming (searching and sorting; stacks, queues, and linked lists; arrays; etc.). Part four discusses programming problems from a higher level, and includes discussions of interfacing with assembly language; porting and debugging, and software engineering. Part five discusses C++, ANSI C, and how the latter differs from the classic K&R version of the language. At 800 pages, the book is about two inches thick, and it's filled with code examples, all of which are available on-disk directly from the author for about $25. If you're thinking about switching to C, this book will help you get up to speed quickly. If you're already there, it will serve as a valuable reference.◗CD◖

ITEMS DISCUSSED

- LA1 Logic Analyzer ($99.95), Photronics, Inc., 109 Camille St., Amite, LA 70422. (504) 748-7090.
  CIRCLE 260 ON FREE INFORMATION CARD

- sPORTt ($90), Western Hydrologic Systems, 3037 Grass Valley Hwy., #8201, Auburn, CA 95603. (916) 885-2480.
  CIRCLE 261 ON FREE INFORMATION CARD

- C: The Complete Reference, 2nd ed. ($28.95), Herbert Schildt, Osborne McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710.
  CIRCLE 262 ON FREE INFORMATION CARD

RAM DISK DRIVE

continued from page 77

driver.

The next task is to add the device driver to your CONFIG.SYS file. Until you are sure things are working the way you want, you may want to boot from floppy, not your hard disk. Later, after you arrive at the correct configuration, copy the device driver to your hard disk and edit its CONFIG.SYS.

The device driver line in CONFIG.SYS takes the form:

device = a:ramdev.sys /768 #16 $016 %2

The first parameter specifies the board's base address, in this case 768. Next comes the number of SRAM's installed (16), followed by the number of directory entries (016), and last by the number of sectors per allocation unit (2). Each parameter must contain the number of digits shown (three, two, three, and one, respectively). Add a leading zero (or leading zeros) if necessary. In addition, you must prefix the base address with a slash, the number of IC's with a pound sign, the number of directory entries with a dollar sign, and sector number with a percent sign.

Edit the CONFIG.SYS of your boot disk to add the appropriate values, and then reboot. If all is working well, you should be able to use the static ram disk just like any other kind of drive in your computer.◗CD◖

LAWN RANGER

continued from page 50

Hand-held controller

The hand-held controller allows the operator to manually steer the robot forward and backward. It contains a potentiometer and switches that interface with the electronic control system. The cable from the controller plugs into the electronic control panel located at the rear of the Lawn Ranger. Figure 7 shows a photograph of the hand-held controller, and Fig. 8 shows the schematic diagram.

Potentiometer R3 is used to steer the robot to the left or right. Microswitch S1 is hand-activated and stops and starts the forward motion of the Lawn Ranger. As the operator squeezes the hand control, S1 closes and allows the robot to move. If the operator opens his hand or drops the controller, the robot will automatically turn itself off. Switch S3 is a momentary pushbutton that is used to activate the cutting motors. An RC delay circuit formed by R2 and C1 slows the Lawn Ranger down before it goes into reverse after the operator pushes the REVERSE button. DPDT slide switch S2 allows the operator to choose either a slow or fast driving speed. As far as the contruction of the controller goes, simply install the components as shown in Fig. 8 in a suitable enclosure.

Electronic control panel

The electronic control panel is located at the rear of the Lawn Ranger. The control panel consists of a DB-25 female connector (for the manual controller), three momentary pushbutton switches, a POWER switch (ignition), and a flashing power-on LED indicator. The schematic diagram of the control panel is shown in Fig. 9. The POWER switch is a key-operated ignition switch that supplies power to the robot. The STOP button cuts the power and stops the cutting blades. The CUT button is used to energize the cutting motors. The START button is used to start the automatic cutting operation after the hand-held controller is disconnected.

Next month the Lawn Ranger story will continue. We will be covering the power board and the mechanical assembly. We'll also show you how to thoroughly test each section of the mower. R-E

AUDIO UPDATE



LARRY KLEIN,
AUDIO EDITOR

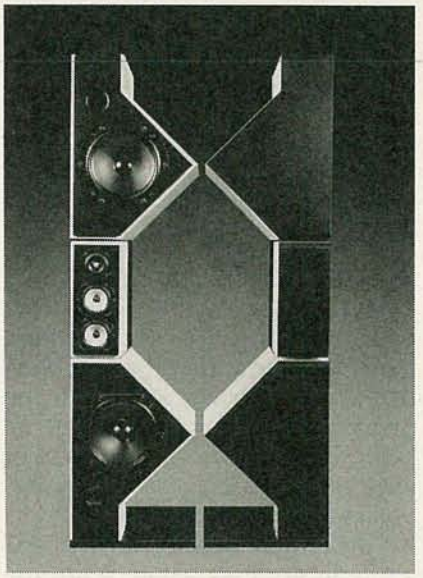
The High End Hi-Fi Show

MY BIG EVENT OF THE SEASON IN THE late 1950's was the annual Institute of High Fidelity Music Show at the New Yorker Hotel. Along with hundreds of other early audiophiles, I elbowed my way through crowded corridors for the chance to meet face-to-face such audio luminaries as Vic Brociner, Sol Marantz, Avery Fisher, Rudy Bozak, Gilbert Briggs, and Paul Klipsch. I remember a fellow audiophile who, impressed by the imposing physical and sonic presence of a dozen Klipschorns, asked timidly, "Mr. Klipsh, what would happen if you turned up all these speakers to full volume?" Without missing a beat, Klipsch replied in his characteristic drawl, "My boy, it would permanently damage the structure of the building!"

I encountered no such claims at the recent High End Hi-Fi Show sponsored by *Stereophile* magazine, a publication that caters to the needs, rational and otherwise, of dedicated audiophiles. What I did hear at the High End Show was excellent sound produced by the products of scores of high-end manufacturers.

Touring the show

A $25 admission fee covered all three days of the High End Show and included admission to the various panels, discussions, demonstrations, and live music events. I must admit that my tour of the show was far from definitive. Other commitments had limited the time I had available, but part of the blame has to be placed on the show's sprawling layout. Manufacturers' displays were scattered throughout two floors and two mezzanines, and close study of the show directory was required to locate the exhibitors of interest. It turned out that the show organizers had deliberately spaced the exhibitor's rooms both to expedite traffic flow and to prevent sonic conflicts.



TWO B&W MATRIX 800 SPEAKER systems are shown side by side, with and without their grill covers. Their brilliant sound, impressive size, and distinctive shape are matched only by their $18,000 price tag.

The products

Near the entrance to the show floor was the B&W room, featuring their new Matrix 800 speaker system pictured elsewhere on this page. Note that the photo shows *two* complete systems side by side, one with its grille cloth on, the other with it off. I was rather startled by the appearance of the speakers, each of which stands more than 6-feet tall. But I have enough confidence in B&W's engineering integrity to know that the design configuration was neither arbitrary nor specifically designed to impress by its sheer size and strange shape.

How did it sound? In a word: magnificent! Small musical groups came across with a natural quality and balance and an impressive sense of depth and space around the performers. Large orchestral performances were handled at realistic (loud!) concert-hall volumes with no sense of strain and a *substantial* bottom end. The free-field frequency-response specifications of the system are given as 23 Hz to 20 kHz ±2 dB, and I don't doubt it for a minute. Few of us would be willing to fit a pair of Matrix 800's into our listening rooms (or to accommodate their $18,000 cost) but they're a good example of how good a speaker can be when its manufacturer makes an all-out effort.

An interesting contrast to the enormous and expensive B&W Matrix 800 was provided by the diminutive Atlantic Technology Pattern woofer/satellite speaker system. The Pattern system has separate 15-watt amplifiers for each of its two satellites and a single 30-watt amplifier for the dual bass drivers. Each satellite measures 4 inches square and 7 inches high, and consists of two black cubes joined together by a pivot that allows one cube to be rotated 360 degrees relative to the other. The amplifiers are housed inside the bass module, which measures 19 inches long, 12½ inches high, and 8⅝ inches deep.

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The Pattern's amplifiers do more than simply feed a chosen signal to its drivers. The bass amplifier includes a dynamic equalizer that enhances the low-base output at reasonable volume levels, but turns it down about 5 dB when a combination of low bass and high volume would tax the 6½-inch woofers' excursion capabilities. The Pattern's highly flexible input arrangement accepts connections from up to three stereo program sources plus wires from the speaker outputs of a separate amplifier or receiver. The sound from the Pattern system was very good, although not quite up to the standard set by B&W's $18,000 Matrix 800. But for $500—built-in amplifiers and all—most people would probably consider the Pattern a better buy.

Accessories

In the past decade, the audio business has been "accessorized" to a fare-thee-well. For the dealer, accessories answer the question of what to sell the audio consumer once he's bought his basic components; for the audiophile, accessories provide an opportunity to be consistently involved in what he perceives as an evolving system. For example, for quite a while it has been possible to buy shock mounts for every component in your system—even the amplifier. Following an opposing theory, "spiking" devices are also available to ensure a firm connection between the components and the surface they are resting upon.

I don't know how many audiophiles are losing sleep over the question of whether to shock mount or to spike, or whether to apply the various clamps, weights, preservatives, and enhancing fluids, but there is one category of accessory seen at the High End Show that I can heartily endorse. Several manufacturers are selling gold-plated RCA-type phono plugs that have been redesigned and machined to provide a constant ground during insertion and withdrawal and to have a clamping action once installed. A great idea. Over the years I've probably blown hundreds of dollars worth of midranges and tweeters because of carelessness and cable problems that would have been prevented by proper plugs.

Very expensive special speaker leads and interconnect cables (we used to call them "phono" cables) were seen in profusion at the show. The manufacturer's claims and quasi-technical explanations for the superior performance of their products ranged from the vaguely possible to the definitely ridiculous—as did the prices. I was told of one speaker cable that sells for approximately $200 per *foot*!

I didn't get a chance to check out the Wadia line of outboard digital decoders meant to be connected to CD and DAT players with digital outputs. I must admit that the technical content of the impressive Wadia literature lost me in the section about LaGrangian and Spline decoding polynomials, but their basic claim is simple enough: Critical amounts of information are lost (and displeasing artifacts added) in the D/A-conversion sections of all current CD and DAT players. The Wadia 2000 decoding computer purports to restore the sound to the quality intended by the recording engineers. It's possible, but my CD players sound just fine to me as is. It would seem that I lack both the aural sensitivity and financial wherewithal ($7,700) to ever be a customer for their top-of-the-line decoder.

The final word

Consumer hi-fi shows have apparently fallen out of favor in the past decade. Whether the reason is lack of manufacturer support or loss of public interest I can't say, but the *Stereophile* Show is the only one currently scheduled. Perhaps it's just as well, because the hi-fi shows generally had deteriorated to SPL (Sound-Pressure Level) contests where it was difficult to find anyone really knowledgeable about the products shown and impossible to make critical sonic judgments because of the noise leakage from adjacent rooms.

I would guess that the 7,000-or-so attendees at the High End Show were mostly critical music listeners, and the exhibitors, by and large, respected their serious interest both by the choices of the program material and the reasonable levels at which it was played. I regret that I didn't get a chance to cover all the products played and displayed. Maybe next time. **R-E**

DIGITAL PRESSURE GAUGE

continued from page 44

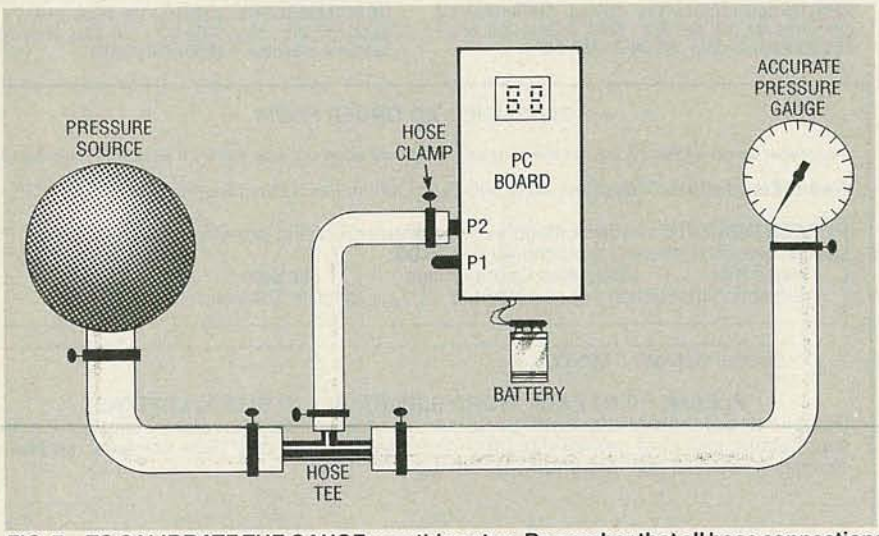


FIG. 7—TO CALIBRATE THE GAUGE, use this setup. Remember that all hose connections must be securely clamped.

Final calibration

The best way to calibrate your pressure gauge is to compare it to the reading of a known, accurate gauge. Additionally, if you plan to use the gauge to measure pressure which is normally less than full-scale capability, it would be prudent to calibrate it at this pressure level rather than at full scale. Use the setup in Fig. 7, remembering that all hose connections must be securely clamped. The setup allows the pressure source to be applied simultaneously to both gauges.

Adjust R6 so that the digital readout agrees with the reference gauge. After adjustment of R6, remove the pressure from the sensor and check the display, which should read zero. If there is some offset from zero, repeat the adjustment for R16 and R6.

Battery life should be as long as 1 or 2 years if the project is used intermittently. The display will change in appearance when the battery needs to be replaced, and it will disappear altogether when the battery is totally exhausted. **R-E**

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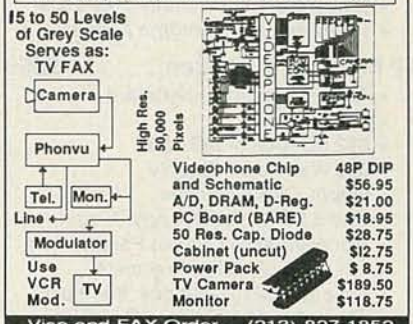
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- Wavelength: 665nm

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2716	24	2048 x 8 450ns (25v)	3.29	3.13	2.82
2716-1	24	2048 x 8 350ns (25v)	3.79	3.60	3.24
TMS2716	24	2048 x 8 450ns	6.29	5.98	5.38
27C16	24	2048 x 8 450ns (25v-CMOS)	3.99	3.79	3.41
2732	24	4096 x 8 450ns (25v)	3.79	3.60	3.24
2732A-2	24	4096 x 8 200ns (21v)	3.79	3.60	3.24
2732A	24	4096 x 8 250ns (21v)	3.69	3.51	3.16
2732A-4	24	4096 x 8 450ns (21v)	3.19	3.03	2.73
TMS2532	24	4096 x 8 450ns (25v)	5.79	5.50	4.95
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2764-20	28	8192 x 8 200ns (21v)	3.99	3.79	3.41
2764	28	8192 x 8 250ns (21v)	3.79	3.60	3.24
2764A-20	28	8192 x 8 200ns (12.5v)	3.99	3.79	3.41
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27128A	28	16,384 x 8 250ns (21v)	5.79	5.50	4.95
27C128	28	16,384 x 8 250ns (21v)	5.79	5.50	4.95
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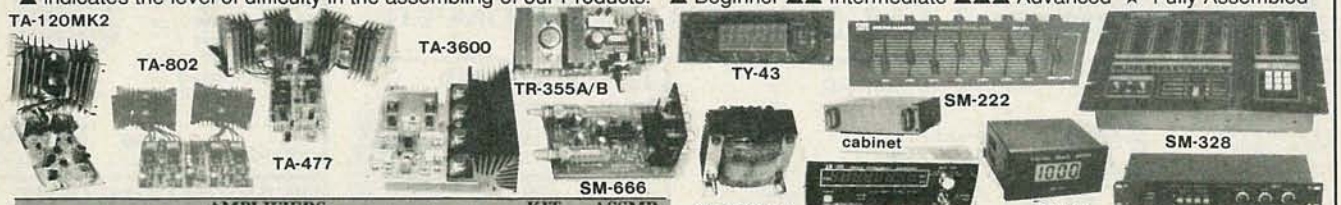
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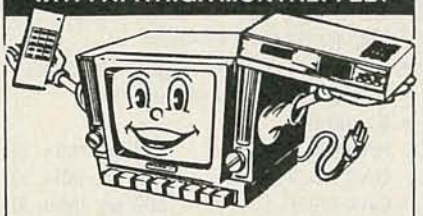
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HARDWARE HACKER

continued from page 72

PowerMOS power transistor disk from *Phillips*.

A free sample from *Tektronix*? Welcome to the nineties. They'll be happy to send you a free sample of their new SMT grabbers.

Rounding out the free samples for today are those *Bend-Flex* flexible printed circuits from *Rogers* and the *Conpad* elastomeric battery clip replacements from *Stockwell*.

A *High Current Transistor Design Guide* wall chart is available through *PowerTech*, while *Rochester Electronics* offers an inventory guide to discontinued semiconductors.

Tec Spec is an outstanding hacker newsletter chock full of easy-to-build and hands-on stuff, including Van De Graff generators, visible lasers, and do-it-yourself vacuum pumps. A free sample copy of the newsletter is available. Another special-interest newsletter is the *Tesla Coil Builder's Association* quarterly. This one is $20 per year. **R-E**

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3-WAY 100W CROSSOVER

12 dB/octave rolloff. 800Hz, 5000Hz crossover points. 8 ohm. 100 watts RMS.

#260-210 $12.50 (1-9) $9.95 (10-up)

SPEAKER CONTROL PANEL

Panel with 50 watt L-pads for tweeter and midrange and built-in LED power meter. 5"x 2 1/2" **100 watt version available**

#260-235 $14.50 (1-5) $12.90 (6-up)

12" POLY WOOFER

Super duty, 40 oz. magnet. 100 watts RMS, 145 watts max. 4 and 8 ohm compatible (6 ohm). 2" voice coil. fs = 25 Hz. QTS = .166, VAS = 10.8 cu ft. Response: 25-1500 Hz. Net weight: 9 lbs. Pioneer #A30GU40-51D

#290-125 $36.80 (1-3) $34.50 (4-up)

15" WOOFER

Original Sanyo woofer. Paper cone with vented dust cap and treated cloth surround. 12 oz. magnet. 60 watts RMS, 85 watts max. 8 ohm. Resonance: 26 Hz. Response: 25-2,500 Hz.

#291-155 $23.60 (1-5) $21.90 (6-up)

PIONEER HORN TWEETER

Mylar dome. 2.93 oz. barium ferrite magnet. 8 ohm. Response: 1800-20000 Hz. 35W RMS, 50W max. fs = 2000 Hz, SPL = 106 dB. Pioneer #AHE60-51F

#270-050 $6.50 (1-9) $5.90 (10-up)

12" SUB WOOFER

Dual voice coil sub woofer. 30 oz. magnet, 2" voice coils. 100 watts RMS, 145 watts max. fs = 25 Hz. 6 ohm (4 and 8 ohm compatible). SPL = 89 dB 1W/1M. Response: 25-700 Hz. QTS = .31, VAS = 10.3 cu. ft. Pioneer #A30GU30-55D. Net weight: 6 lbs.

#290-145 $39.80 (1-3) $36.80 (4-up)

15" THRUSTER WOOFER

Thruster by Eminence. Made in USA. Poly foam surround, 56 oz. magnet. 2-1/2", 2 layer voice coil. 150 watts RMS, 210 watts max. 4 ohm. fs = 23.5 Hz, QTS = .33, VAS = 17.9 cu ft. SPL = 94.8 dB 1W/1M. Net weight: 15 lbs.

#290-180 $43.50 (1-3) $39.80 (4-up)

GRILL FRAME KIT

With this kit you can make speaker grill frames up to 30" x 40". Kit includes 4 corner pieces, 2 "T" brackets, and 7 frame bars. Grill mounting kit included.

#260-333 $8.50 (1-9) $7.80 (10-up)

18" EMINENCE WOOFER

MADE IN USA

100 oz. magnet, 3" voice coil. 250 watts RMS, 350 watts max. 8 ohm, 30 Hz resonant frequency. 22-2700 Hz response. Efficiency: 95 dB 1W/1M. Paper cone, treated accordian surround. Net weight: 29 lbs.

#290-200 $98.90 (1-3) $89.50 (4-up)

TITANIUM COMPOSITE TWEETER

Titanium is deposited on a polymer dome to combine the advantages of both hard and soft dome technologies. 8 ohm. Ferro fluid cooled voice coil. fs = 1200 Hz, SPL = 90 dB 1W/1M. 50 watts RMS, 70 watts max. 4" round. Polydax part #DTW100T125.

#270-047 $27.50 (1-9) $24.80 (10-up)



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13TH ANNIVERSARY SEMICONDUCTOR SALE

Since 1977 we have been supplying Finest Quality components to thousands of satisfied customers worldwide. To celebrate our lucky 13th Anniversary in our new 36,000 square feet facilities, we are offering you one of the broadest lines of Semiconductor products at unbelievably low prices. All items listed below are PRIME First Run products (many with 1990 Date Codes,) obtained directly from respective manufacturers. No 'Seconds', 'Pulls' or 'Rejects'. All ICs listed are in stock, but some quantities are limited.

This sale will Absolutely end on August 31st, 1990.

74LSxxx Series

Device Type	1-99	Per 100
74LS00	$0.12	$10.20
74LS01	0.15	13.20
74LS02	0.15	13.20
74LS03	0.15	13.20
74LS04	0.15	13.20
74LS05	0.15	13.20
74LS08	0.15	13.20
74LS09	0.15	13.20
74LS10	0.15	13.20
74LS11	0.15	13.20
74LS12	0.15	13.20
74LS13	0.17	14.20
74LS14	0.18	15.20
74LS15	0.15	13.20
74LS20	0.15	13.20
74LS21	0.15	13.20
74LS22	0.15	13.20
74LS26	0.17	14.20
74LS27	0.15	13.20
74LS28	0.17	14.20
74LS30	0.15	13.20
74LS32	0.12	10.20
74LS33	0.15	13.20
74LS37	0.15	13.20
74LS38	0.15	13.20
74LS40	0.15	13.20
74LS42	0.19	16.60
74LS47	0.35	30.50
74LS48	0.35	30.50
74LS51	0.15	13.20
74LS54	0.15	13.20
74LS55	0.15	13.20
74LS73	0.18	15.20
74LS74	0.15	13.20
74LS75	0.19	16.60
74LS76	0.19	16.60
74LS78	0.19	16.60
74LS85	0.19	16.60
74LS86	0.19	16.60
74LS90	0.24	20.80
74LS91	0.28	24.00
74LS92	0.22	19.50
74LS93	0.24	20.80
74LS96	0.28	24.50
74LS107	0.19	16.60
74LS109	0.19	16.60
74LS112	0.19	16.60
74LS113	0.19	16.60
74LS114	0.19	16.60
74LS122	0.19	16.60
74LS123	0.19	16.60
74LS125	0.12	10.20
74LS126	0.19	16.60
74LS132	0.21	18.00
74LS133	0.15	13.20
74LS136	0.21	18.00
74LS138	0.22	19.50
74LS139	0.22	19.50
74LS145	0.27	23.60
74LS148	0.41	36.00
74LS151	0.22	19.50
74LS152	0.23	19.50
74LS153	0.22	19.50
74LS155	0.22	19.50
74LS156	0.23	19.50
74LS157	0.21	18.00
74LS158	0.22	19.50
74LS160	0.24	20.80
74LS161	0.24	20.80
74LS162	0.24	20.80
74LS163	0.24	20.80
74LS164	0.26	22.20
74LS165	0.24	20.80
74LS166	0.38	33.20
74LS168	0.44	38.80
74LS169	0.44	38.80
74LS170	0.40	35.00
74LS173	0.26	22.20
74LS174	0.24	20.80
74LS175	0.18	15.80
74LS190	0.27	23.60
74LS191	0.27	23.60
74LS192	0.27	23.60
74LS193	0.27	23.60
74LS194	0.27	23.60
74LS195	0.27	23.60
74LS196	0.27	23.60
74LS197	0.27	23.60
74LS221	0.32	27.70
74LS240	0.30	26.40
74LS241	0.30	26.40
74LS242	0.29	25.00
74LS243	0.29	25.00
74LS244	0.30	26.40
74LS245	0.30	26.40
74LS247	0.28	24.50
74LS248	0.28	24.50
74LS251	0.21	18.00
74LS253	0.22	19.50
74LS257	0.22	19.50
74LS258	0.27	23.60
74LS259	0.27	23.60
74LS260	0.19	16.60
74LS266	0.19	16.60
74LS273	0.30	26.40
74LS279	0.21	18.00
74LS280	0.38	33.20
74LS283	0.26	22.20
74LS290	0.22	19.20
74LS293	0.22	19.20
74LS295	0.30	26.40
74LS298	0.33	28.50
74LS299	0.74	65.10
74LS352	0.31	26.50
74LS353	0.31	26.50
74LS365	0.24	20.80
74LS366	0.24	20.80
74LS367	0.22	19.50
74LS368	0.22	19.50
74LS373	0.30	26.40
74LS374	0.30	26.40
74LS375	0.30	26.40
74LS377	0.30	26.40
74LS378	0.30	26.40
74LS379	0.30	26.40
74LS386	0.24	20.80
74LS390	0.32	27.70
74LS393	0.22	19.50
74LS395	0.32	27.70
74LS447	0.32	27.70
74LS540	0.37	31.90
74LS541	0.37	31.90
74LS640	0.54	47.10
74LS641	0.54	47.10
74LS643	0.43	37.50
74LS645	0.43	37.50
74LS670	0.37	31.90

4xxx CMOS Series

Device Type	1-99	Per 100
4001B	$0.12	$10.00
4002B	0.15	12.50
4006B	0.38	33.20
4007UB	0.15	12.50
4008B	0.33	29.10
4009UB	0.27	23.60
4010UB	0.27	23.60
4011B	0.15	12.50
4012B	0.15	12.50
4013B	0.19	16.60
4014B	0.33	29.10
4015B	0.33	29.10
4016B	0.21	18.00
4017B	0.33	29.10
4018B	0.33	29.10
4019B	0.21	18.00
4020B	0.33	29.10
4021B	0.33	29.10
4022B	0.33	29.10
4023B	0.15	12.50
4024B	0.24	20.80
4025B	0.15	12.50
4026B	0.54	47.10
4027B	0.21	18.00
4028B	0.29	25.00
4029B	0.37	31.90
4030B	0.24	20.80
4031B	0.71	62.30
4033B	0.60	52.60
4034B	1.02	90.00
4035B	0.38	33.20
4040B	0.37	31.90
4041UB	0.41	36.00
4042B	0.29	25.00
4043B	0.32	27.70
4044B	0.27	23.60
4045B	0.40	34.60
4046B	0.40	34.60
4047B	0.35	30.50
4048B	0.32	27.70
4049B	0.19	16.60
4050B	0.15	12.50
4051B	0.32	27.70
4052B	0.21	18.00
4053B	0.32	27.70
4054B	0.48	41.60
4055B	0.38	33.20
4056B	0.48	41.60
4060B	0.35	30.50
4063B	0.43	37.50
4066B	0.19	16.60
4067B	0.82	72.00
4068B	0.15	12.50
4069UB	0.12	10.00
4070B	0.12	10.00
4071B	0.15	12.50
4072B	0.15	12.50
4073B	0.15	12.50
4075B	0.15	12.50
4076B	0.27	23.60
4077B	0.15	12.50
4078B	0.15	12.50
4081B	0.15	12.50
4082B	0.15	12.50
4085B	0.19	16.60
4086B	0.19	16.60
4089B	0.43	37.50
4093B	0.21	18.00
4094B	0.37	31.90
4095B	0.26	22.20
4096B	0.26	22.20
4097B	0.80	70.60
4098B	0.37	31.90
4099B	0.37	31.90
4502B	0.37	31.90
4503B	0.27	23.60
4508B	0.84	73.50
4510B	0.38	33.20
4511B	0.40	34.60
4512B	0.30	26.40
4514B	0.74	65.10
4515B	0.74	65.10
4516B	0.35	30.50
4517B	0.66	58.20
4518B	0.37	31.90
4519B	0.24	20.80
4520B	0.33	29.10
4527B	0.40	34.60
4529B	0.43	37.50
4532B	0.35	30.50
4536B	0.58	51.20
4538B	0.35	30.50
4541B	0.33	29.10
4543B	0.33	29.10
4555B	0.30	26.40
4556B	0.30	26.40
4585B	0.35	30.50
4724B	0.41	36.00
40100B	0.48	41.60
40102B	0.48	41.60
40103B	0.48	41.60
40105B	0.52	45.70
40106B	0.24	20.80
40107B	0.24	20.80
40109B	0.37	31.90
40110B	0.58	51.20
40147B	0.40	34.60
40160B	0.40	34.60
40161B	0.40	34.60
40162B	0.40	34.60
40163B	0.40	34.60
40174B	0.29	25.00
40175B	0.29	25.00
40192B	0.41	36.00
40193B	0.41	36.00
40194B	0.41	36.00
40257B	0.46	40.20

74HCxxx Series

Device Type	1-99	Per 100
74HC00	$0.14	$11.80
74HC02	0.14	11.80
74HC03	0.14	11.80
74HC04	0.14	11.80
74HCU04	0.14	11.80
74HC08	0.14	11.80
74HC10	0.14	11.80
74HC11	0.14	11.80
74HC14	0.18	15.20
74HC20	0.14	11.80
74HC21	0.14	11.80
74HC27	0.14	11.80
74HC30	0.14	11.80
74HC32	0.14	11.80
74HC42	0.26	22.20
74HC73	0.19	16.60
74HC74	0.19	16.60
74HC75	0.19	16.60
74HC85	0.29	25.00
74HC86	0.19	16.60
74HC93	0.27	23.60
74HC107	0.21	18.00
74HC109	0.21	18.00
74HC112	0.24	20.80
74HC123	0.26	22.20
74HC125	0.22	19.50
74HC126	0.24	20.80
74HC132	0.22	19.50
74HC137	0.26	22.20
74HC138	0.21	18.00
74HC139	0.21	18.00
74HC147	0.32	27.70
74HC151	0.24	20.80
74HC153	0.24	20.80
74HC154	0.77	67.80
74HC157	0.22	19.50
74HC158	0.24	20.80
74HC160	0.29	25.00
74HC161	0.29	25.00
74HC162	0.29	25.00
74HC163	0.29	25.00
74HC164	0.24	20.80
74HC165	0.24	20.80
74HC166	0.26	22.20
74HC173	0.32	27.70
74HC174	0.26	22.20
74HC175	0.26	22.20
74HC181	0.77	67.80
74HC182	0.27	23.60
74HC190	0.29	25.00
74HC191	0.29	25.00
74HC192	0.29	25.00
74HC193	0.29	25.00
74HC194	0.26	22.20
74HC195	0.26	22.20
74HC221	0.30	26.40
74HC237	0.29	25.00
74HC238	0.27	23.60
74HC240	0.30	26.40
74HC241	0.30	26.40
74HC242	0.29	25.00
74HC243	0.29	25.00
74HC244	0.30	26.40
74HC245	0.32	27.70
74HC251	0.27	23.60
74HC253	0.26	22.20
74HC257	0.24	20.80
74HC258	0.27	23.60
74HC259	0.29	25.00
74HC266	0.22	19.50
74HC273	0.30	26.40
74HC280	0.29	25.00
74HC283	0.29	25.00
74HC297	0.66	58.20
74HC299	0.41	36.00
74HC354	0.38	33.20
74HC356	0.33	29.10
74HC365	0.30	26.40
74HC366	0.30	26.40
74HC367	0.30	26.40
74HC368	0.30	26.40
74HC373	0.30	26.40
74HC374	0.29	25.00
74HC377	0.30	26.40
74HC390	0.27	23.60
74HC393	0.27	23.60
74HC423	0.29	25.00
74HC533	0.40	34.60
74HC534	0.32	27.70
74HC540	0.30	26.40
74HC541	0.32	27.70
74HC563	0.33	29.10
74HC564	0.37	31.90
74HC573	0.33	29.10
74HC574	0.37	31.90
74HC583	0.30	26.40
74HC597	0.30	26.40
74HC640	0.40	34.60
74HC643	0.40	34.60
74HC646	1.10	97.00
74HC648	1.10	97.00
74HC670	0.37	31.90
74HC688	0.33	29.10
74HC4002	0.14	11.80
74HC4015	0.33	29.10
74HC4016	0.26	22.20
74HC4017	0.30	26.40
74HC4020	0.29	25.00
74HC4024	0.24	20.80
74HC4040	0.29	25.00
74HC4046	0.54	47.10
74HC4049	0.24	20.80
74HC4050	0.24	20.80
74HC4051	0.33	29.10
74HC4052	0.35	30.50
74HC4053	0.33	29.10
74HC4059	0.95	83.10
74HC4060	0.30	26.40
74HC4066	0.29	25.00
74HC4067	0.95	83.10
74HC4075	0.14	11.80
74HC4094	0.29	25.00
74HC4316	0.35	30.50
74HC4351	0.40	34.60
74HC4352	0.40	34.60
74HC4353	0.40	34.60
74HC4510	0.35	30.50
74HC4511	0.29	25.00
74HC4514	0.84	73.50
74HC4515	0.84	73.50
74HC4516	0.35	30.50
74HC4518	0.33	29.10
74HC4520	0.33	29.10
74HC4538	0.33	29.10
74HC4543	0.29	25.00
74HC40102	0.35	30.50
74HC40103	0.35	30.50
74HC40104	0.29	25.00
74HC40105	0.43	37.50

74HCTxxx Series

Device Type	1-99	Per 100
74HCT00	$0.12	$10.00
74HCT02	0.14	11.80
74HCT03	0.14	11.80
74HCT04	0.14	11.80
74HCT08	0.14	11.80
74HCT10	0.14	11.80
74HCT11	0.14	11.80
74HCT14	0.18	15.20
74HCT20	0.14	11.80
74HCT21	0.14	11.80
74HCT27	0.14	11.80
74HCT30	0.14	11.80
74HCT32	0.14	11.80
74HCT42	0.26	22.20
74HCT73	0.19	16.60
74HCT74	0.19	16.60
74HCT75	0.19	16.60
74HCT85	0.29	25.00
74HCT86	0.19	16.60
74HCT93	0.27	23.60
74HCT107	0.21	18.00
74HCT109	0.21	18.00
74HCT112	0.24	20.80
74HCT123	0.26	22.20
74HCT125	0.22	19.50
74HCT126	0.24	20.80
74HCT132	0.22	19.50
74HCT137	0.26	22.20
74HCT138	0.21	18.00
74HCT139	0.21	18.00
74HCT147	0.32	27.70
74HCT151	0.24	20.80
74HCT153	0.24	20.80
74HCT154	0.77	67.80
74HCT157	0.22	19.50
74HCT158	0.24	20.80
74HCT160	0.29	25.00
74HCT161	0.29	25.00
74HCT162	0.29	25.00
74HCT163	0.29	25.00
74HCT164	0.24	20.80
74HCT165	0.24	20.80
74HCT166	0.26	22.20
74HCT173	0.32	27.70
74HCT174	0.26	22.20
74HCT175	0.24	20.80
74HCT181	0.77	67.80
74HCT182	0.27	23.60
74HCT190	0.29	25.00
74HCT191	0.29	25.00
74HCT192	0.29	25.00
74HCT193	0.29	25.00
74HCT194	0.26	22.20
74HCT195	0.26	22.20
74HCT221	0.30	26.40
74HCT237	0.29	25.00
74HCT238	0.24	20.80
74HCT240	0.30	26.40
74HCT241	0.30	26.40
74HCT242	0.29	25.00
74HCT243	0.29	25.00
74HCT244	0.30	26.40
74HCT245	0.32	27.70
74HCT251	0.27	23.60
74HCT253	0.26	22.20
74HCT257	0.24	20.80
74HCT258	0.27	23.60
74HCT259	0.29	25.00
74HCT266	0.22	19.50
74HCT273	0.30	26.40
74HCT280	0.29	25.00
74HCT283	0.29	25.00
74HCT297	0.66	58.20
74HCT299	0.41	36.00
74HCT354	0.38	33.20
74HCT356	0.33	29.10
74HCT365	0.30	26.40
74HCT366	0.30	26.40
74HCT367	0.30	26.40
74HCT368	0.30	26.40
74HCT373	0.30	26.40
74HCT374	0.29	25.00
74HCT377	0.30	26.40
74HCT390	0.27	23.60
74HCT393	0.27	23.60
74HCT423	0.29	25.00
74HCT533	0.40	34.60
74HCT534	0.32	27.70
74HCT540	0.30	26.40
74HCT541	0.32	27.70
74HCT563	0.33	29.10
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74HCT573	0.33	29.10
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74HCT640	0.40	34.60
74HCT643	0.40	34.60
74HCT646	1.10	97.00
74HCT648	1.10	97.00
74HCT670	0.37	31.90
74HCT688	0.33	29.10
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74HCT4016	0.26	22.20
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74HCT4053	0.33	29.10
74HCT4059	0.95	83.10
74HCT4060	0.30	26.40
74HCT4066	0.29	25.00
74HCT4067	0.95	83.10
74HCT4075	0.14	11.80
74HCT4094	0.29	25.00
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74HCT4351	0.40	34.60
74HCT4352	0.40	34.60
74HCT4353	0.40	34.60
74HCT4510	0.35	30.50
74HCT4511	0.29	25.00
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74HCT4515	0.84	73.50
74HCT4516	0.35	30.50
74HCT4518	0.33	29.10
74HCT4520	0.33	29.10
74HCT4538	0.33	29.10
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74HCT40104	0.29	25.00
74HCT40105	0.43	37.50

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Z80A-CTC	0.85	7.50
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Z80A-SIO/1	1.99	17.50
Z80A-SIO/2	1.99	17.50
Z80A-SIO/9	1.70	15.00
Z80A-DART	1.14	10.00
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Z80B-PIO	1.70	15.00
Z80B-CTC	1.70	15.00
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Z80B-SIO/2	2.84	25.00
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UPD70116-8	8MHz, V30 Chip	$7.95
UPD70116-10	10MHz, V30 Chip	$13.49

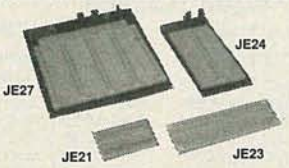
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TMS4416-12	120ns, 16Kx4	$2.25
TMS4416-15	150ns, 16Kx4	$2.00
4116-12	120ns, 16Kx1	$1.49
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4116-20	200ns, 16Kx1	$.89
4164-100	100ns, 64Kx1	$2.75
4164-120	120ns, 64Kx1	$2.39
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4164-200	200ns, 64Kx1	$1.75
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511000P-80	80ns, 1Mx1	$12.95
511000P-10	100ns, 1Mx1	$12.35
514256P-80	80ns, 256Kx4	$13.45
514256P-10	100ns, 256Kx4	$12.95

Static RAMs

6116P-3	150ns, 16Kx 1(CMOS)	$2.79
6264LP-10	100ns, 64Kx1 (CMOS)	$6.95
6264LP-15	150ns, 64Kx1 (CMOS)	$4.95
43256-10L	100ns, 256Kx1	$10.95
43256-15L	150ns, 256Kx1	$9.95
62256LP-15	150ns, 256Kx1 (CMOS)	$10.95

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Jameco Solderless Breadboards



Part No.	Dim. L" x W"	Contact Points	Binding Posts	Price
JE21	3.25 x 2.125	400	0	$4.95
JE23	6.5 x 2.125	830	0	$6.95
JE24	6.5 x 3.125	1,360	2	$12.95
JE25	6.5 x 4.25	1,660	3	$17.95
JE26	6.875 x 5.75	2,390	4	$22.95
JE27	7.25 x 7.5	3,220	4	$32.95

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

LF180 40MHz Oscilloscope Probe **$19.95**

LF210 100MHz Oscilloscope Probe **$29.95**

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- Large 6" rectangular display
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General Specs:
- Handheld, high accuracy • AC/DC voltage, AC/DC current, resistance, diodes, continuity, transistor hFE
- Manual ranging w/ overload protection

M3650, 3650B & M4650 only:
- Also measure frequency and capacitance

M4650 only: • Data hold switch • 4.5 digit

M3610	3.5 Digit Multimeter	$49.95
M3650	3.5 Digit Multimeter w/Frequency & Capacitance	$69.95
M3650B	Same as M3650 w/Bargraph	$74.95
M4650	4.5 Digit w/Frequency, Capacitance and Data Hold Switch	$99.95

Multimeter Specials

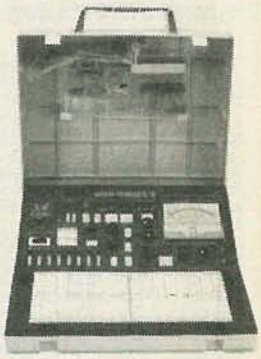
M80:
- AC/DC voltage, AC/DC current, resistance, diodes, continuity & frequency • Full auto-ranging on DC voltage • High/low semi-autoranging for AC/DC current and ohms • Data hold switch • Extra-large display

M80 3.75 Digit Multimeter **$59.95**

M3900:
- AC/DC voltage, AC/DC current, resistance, diodes, continuity, dwell angle and engine RPM • High surge voltage protection

M3900 3.5 Digit Multimeter **$59.95**

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WM2

WM1 & WM2 Features: • Removable solderless breadboard • Variable and fixed DC power supply • Multi-frequency signal generator • Analog multimeter • 8 bicolor LEDs (red & green) • 8 logic switches • Logic probe • Lighted power switch • Fuse overload protected • Sturdy ruggedized case

WM1 Special Features: • 4 potentiometers • Built-in speaker

WM2 Special Features: • Pulse Generator • Binary coded decimal (BCD) to 7-segment decoder/driver • DB25 connector • Frequency counter (1Hz to 1MHz)

WM1 Analog Prototype Station **$199.95**

WM2 Digital Prototype Station **$249.95**

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• Programs all current EPROMs in the 2716 to 27512 range plus the X2864 EEPROM • RS232 port • Software included

EPP.....$179.95

UVP EPROM Eraser



• Erases all EPROM's • Erases 1 chip in 15 Min. and 8 chips in 21 min. • UV intensity: 6800 UW/CM^2

DE4.....$69.95

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XY1683

60 Watt Analog Display Soldering Station • Electronic temperature control from 200° to 878°F • Cartridge heating element for a longer life of the soldering tip

XY1683 ..... **$59.95**

60 Watt Analog Display Soldering Station • Electronic temperature control from 200° to 878°F • Ceramic heating element for a steady temperature and long life

XY2660 ..... **$89.95**



XY999

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XY960 ..... **$99.95**

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- 7" brush and scraper
- 7" fine point probe
- 7" slotted probe
- Rosin core solder
- 30 watt soldering iron
- Desoldering pump
- Soldering stand
- Stainless steel scissors
- Utility components box
- 8 pcs. hex key wrench
- Digital Multimeter
- Round needle file
- Flat needle file
- 6" adjustable wrench
- Utility knife with extra blade
- Bent needle nose pliers
- Diagonal cutting pliers
- 5.25" needle nose pliers
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- Brush
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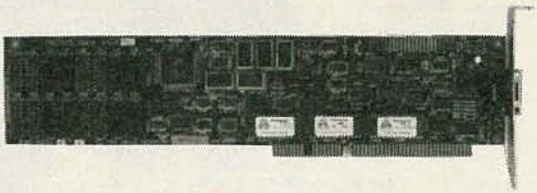
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JE3551 20MHz 80386 Compatible Kit.....**$1949.95**

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JE1055	EGA Card w/ 256KB Video RAM (PC/XT/AT)	$139.95
JE1057	8/16-Bit VGA Card w/ 256KB Video RAM (PC/XT/AT)	$199.95
JE1060	I/O Card w/ Serial, Game, Printer Port & Real Time Clock (PC/XT)	$59.95
JE1062	RS232 Serial Half Card (PC/XT/AT)	$29.95
JE1065	I/O Card w/ Serial, Game and Parallel Printer Port (AT)	$59.95
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JE2061

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- Saves an amazing 60% of the desk space used by equivalent standard keyboards

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- AutoCAD 10 template and four-button puck • Resolution: up to 1016 lines per inch • Accuracy: ±.025" • Emulates three of the worlds most popular formats: Summagraphics MM, Summagraphics Bit Pad One, Calcomp 2000 • EEPROM allows custom configuration

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- 4" Scanning Window
- 400 dpi

SCANP.....**$219.95**

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Modems



9600E Pictured

External Modems

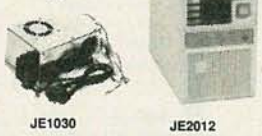
1200C	Datatronics 1200 Baud	$89.95
2400C	Datatronics 2400 Baud	$149.95
9600E	Prometheus 9600 Baud	$699.95

Internal Modems

1200B	Jameco 1200 Baud	$49.95
2400B	Jameco 2400 Baud	$99.95

Modems listed above Include ProComm Software

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JE1010	Flip-Top Standard PC/XT Case	$39.95
JE1011	Slide Standard PC/XT Case	$39.95
JE1030	150 watt PC/XT Power Supply	$59.95
JE1032	200 watt Baby AT Power Supply	$89.95
JE1035	300 watt AT Power Supply	$139.95
JE2011	Vertical Case w/300W Pwr. Supply	$269.95
JE2012	Mini-Vertical Case w/200W Pwr. Supply	$169.95
JE2019	Flip-Top Baby AT Case	$69.95

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MF353B 3.5" 720KB Internal Drive **$99.95**
Toshiba
356KU 3.5" 1.44MB Internal Drive .. **$109.95**
Teac
FD55B 5.25" 360KB Internal Drive ... **$89.95**
FD55G 5.25" 1.2MB Internal Drive.... **$99.95**

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M8425XT	20MB (68ms) 3.5"HH (Kit)	$289.95
M8425AT	20MB (68ms) 3.5"HH (Kit)	$339.95

RLL

M8438	30MB (68ms) 3.5"HH	$249.95
M8438XT	30MB (68ms) 3.5"HH (Kit)	$299.95
M8438AT	30MB (68ms) 3.5"HH (Kit)	$389.95
M8450	40MB (46ms) 3.5"HH	$329.95
M8450XT	40MB (46ms) 3.5"HH (Kit)	$369.95
M8450AT	40MB (46ms) 3.5"HH (Kit)	$429.95

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CASE-JR	MINI FLIP-TOP CASE W/150W P.S.	$149.95
FDD-360	360K 5-1/4" FLOPPY DISK DRIVE	$69.95
JDR-MONO	MONOCHROME MONITOR (GREEN)	$69.95
BTC-5060	STANDARD 84-KEY KEYBOARD	$59.95
TOTAL SYSTEM (ØK INSTALLED)		$649.65

OPTIONAL COMPONENTS

MOTHERBOARDS

MCT-TURBO-10	4.77/10MHZ SINGLE CHIP 8088	$99.95
MCT-M286-16N	8/16MHZ 286 W/NEAT CHIPSET	$289.95
MCT-M286-20N	10/20MHZ 286 W/NEAT CHIPSET	$389.95

Littlefoot™ UPRIGHT CASE $249.95



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•TURBO & RESET SWITCH
•LED SPEED DISPLAY
CASE-100
CASE-FLIP FLIP TOP CASE FOR 8088 MB'S $39.95

POWER SUPPLIES

PS-150	150 WATT SUPPLY FOR 8088'S	$59.95
PS-200X	200 WATT SUPPLY FOR 8088'S	$89.95
PS-200	200 WATT SUPPLY FOR 286/386'S	$89.95

KEYBOARDS

BTC-5339	101 KEY ENHANCED KEYBOARD	$69.95
MAX-5339	101 KEY W/TACTILE FEEDBACK (286)	$69.95

DRIVE CONTROLLERS

MCT-FDC-HD4	4-FLOPPY DISK CONTROLLER	$59.95
MCT-HDC	HARD DISK CONTROLLER	$79.95
MCT-AFH	286/386 FLOPPY/HARD CONTROL	$149.95

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MCT-RAM	576K RAM CARD (ØK)	$49.95
MCT-IO	MULTI I/O CARD	$59.95

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•READ/WRITE 720K DISKS TOO
•BLACK OR BEIGE
FDD-1.44X BLACK **FDD-1.44A** BEIGE
FDD-1.2 5-1/4" DS/HD 1.2MB FLOPPY $95.95

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21.4MB KIT $249
32.1MB KIT $279

65MS AVG. ACCESSORY KIT INCLUDES INSTRUCTIONS, XT-COMPATIBLE CONTROLLER AND CABLES. CALL FOR PRICES ON OTHER SEAGATE DRIVES

VGA COMPATIBLE PACKAGE $499.95



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•IBM STYLE MONITOR
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VGA-PKG (INCLUDES VGA CARD AND MONITOR)

JDR-RGB	14" RGB MONITOR	$239.95
JDR-AMBER	12" TTL MONOCHROME-AMBER	$69.95

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MCT-VGA-16

MCT-EGA	ENHANCED GRAPHICS ADAPTOR	$149.95
MCT-MGMIO	MONOGRAPHICS MULTI I/O	$119.95

2400 BAUD MODEM $89.95



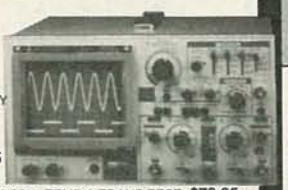
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•BUILT-IN SPEAKER • PROCOMM COMMUNICATIONS SOFTWARE
MCT-241
MCT-121 1200 BAUD INTERNAL MODEM $59.95

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PART#	SIZE	SPEED	PINS	PRICE
4164-150	65536x1	150ns	16	2.49
41256-150	262144x1	150ns	18	2.59
41256-120	262144x1	120ns	16	2.95
41256-100	262144x1	100ns	16	3.15
41256-80	262144x1	80ns	16	3.75
1 MB-80	1048576x1	80ns	18	12.95

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CAT# SWTH-9 $1.25 each
10 for $10.00
END PLATES - CAT# SW-9EC
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RG 11/U 75 OHM VIDEO CABLE



100 ft. or 200 ft. rolls of RG 11/U terminated to heavy duty F connectors. Includes 75 ohm terminator and F-61 splicer on one end. New cables manufactured for IBM PC networks. IBM P/N 1501908 COM/SCOPE.

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Panel ht.	CAT#		
2 1/4"	CAT# MB-A	$7.50 each	10 for $65.00
2 5/8"	CAT# MB-B	$7.75 each	10 for $67.50
3"	CAT# MB-C	$8.00 each	10 for $70.00

Please specify color.

SOUND ACTIVATED SWITCH



PC board with electret mike responds to sounds in immediate vicinity. Originally part of sound activated light organ. Shuts off when sound is not present. Includes hook-up diagram.

CAT# SAB-2 $2.50 each

SWITCHES

ITT PUSH BUTTON



ITT MDPL series. 3/4" X 1/2" grey rectangular key cap. S.P.S.T. N.O. Push to close. RATED: 0.1 amp switching, 0.25 amp carry current. P.C. mount.
CAT# PB-8 65¢ each • 10 for $6.00 100 for $50.00

SPDT PUSHBUTTON



Marquardt# 1843
Rated 6 amps @ 125/250 Vac. Black plastic pushbutton. Switch body: .92" X .94" X .65".
CAT# PB-18 $1.65 ea. • 10 for $15.00

PUSHBUTTON SWITCH



GC/Thornsen# 35-420
S.P.S.T. normally open momentary pushbutton switch. Red plastic actuator 0.57" diameter. Chrome bezel 0.68" diameter. Threaded bushing mounts in .50" diameter hole. Rated 3 amp @ 250Vac. Solder loop terminals.
CAT# PB-20 $1.00 each

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ALL PLUG DIRECTLY INTO 120 VAC OUTLET

12 Vdc @ 500 ma. **CAT# DCTX-125 $4.50**
9 Vdc @ 1 amp **CAT# DCXT-951 $5.00**
24 Vac @ 625 ma. **CAT# ACTX-2462 $3.25**

SERVO MOTOR



3 Vdc servo with potentiometer. Ideal for robotics or remote control model experimentation. Rotates approx. 140 degrees. Pot connected to motor varies from 500 to 3000 ohms. 1.53" X 0.95" X 1.65". 0.87" diameter rubber wheel attached to motor shaft can be used as a capstan or can be easily removed. Prepped with capacitors, chokes and wire leads. **CAT# SVO-2 2 for $1.00**

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TO-18 case with window. For wide-angle viewing applications. Spectrally and mechanically compatible with TIL-31B.
CAT# TIL-99 $1.00 each • 10 for $9.00

TIL-31B PHOTO DIODE



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AAA SIZE $1.50 each
1.2 volts 180 mAh
CAT# NCB-AAA

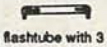
AA SIZE $2.00 each
1.25 volts 500 mAh
CAT# NCB-AA

AA SIZE $2.20 each
WITH SOLDER TABS
CAT# NCB-SAA

C SIZE $4.25 each
1.2 volts 1200 mAh
CAT# NCB-C

D SIZE $4.50 each
1.2 volts 1200 mAh
CAT# NCB-D

XENON TUBE



1" long flashtube with 3 1/2" red and black leads. Ideal for electronic flash or strobe projects.
CAT# FLT-3 2 for $1.00

RELAYS



5-6 VDC SIP REED RELAY
Electrol "Blue Boy"# BBS1A05A10
5-6 Vdc, 500 ohm coil. S.P.S.T. normally open reed relay. 0.5 amp contacts. SIP configuration. 1" X .375" X .3".
CAT# RRLY-SIP5
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5 VDC LATCHING RELAY
Aromat# RSL2D-5V
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CAT# LRLY-5DC $2.50 each



12 VOLT D.C. COIL S.P.D.T.
Omron# G2E-184P
4 amp contacts. 335 ohm coil. Sugar cube size..61" X .42" X .44 high. P.C. mount with pins on DIP spacing.
CAT# RLY-787 $1.50 each

0 - 6 HOUR AUTO SHUT-OFF TIMER



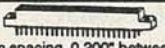
M.H. Rhodes, Inc.Mark-Time# 90007
Timer fits standard 3" deep wallbox. Rated 20 amps @ 125 Vac. Turn knob to desired time. Includes hardware, beige wallplate, and knob. UL and CSA listed. **CAT# TMC-6**
$5.75 each • 10 for $50.00

SPECIAL PURCHASE 210 MFD 330 V PHOTOFLASH CAPACITOR



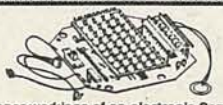
Rubicon CE photoflash capacitor. 0.79" dia. X 1.1" high. These are new capacitors that have been prepped with 1.4" black and red wire leads soldered to the terminals.
CAT# PPC-210 $2.50 each
10 for $22.50 • 100 for $200.00
Large quantities available. Call for pricing.

22/44 PIN CONNECTOR



.156" pin spacing, 0.200" between double rows, gold contacts, P.C. mounting.
SPECIAL. Same as AMP# 2-530655-6.
CAT# EBC-1G $1.00 each • 10 for $8.00

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The inner workings of an electronic Scrabble game. Operates on 6 Vdc. 8 digit alphanumeric readout, 45 button keypad, 14 transistors, 2 I.C.'s, 1 piezo element and other goodies. Top and bottom row of keypad buttons are function keys, middle 3 rows are alphabetic. No instructions available. 6" X 4.45".
CAT# ST-4 $1.75 each 10 for $15.00

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Multi Products International# A19N-HO-1D/1 Primary: 600 ohm Secondary: 600/600 ohm 0.77" X 0.61" X 0.63" high.6 p.c. pins on 0.187" centers.Primary inductance: 300 mH min., at 1kHz, 1 volt.
CAT# TCTX-1 $1.25 ea. • 10 for $11.00

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DIFFUSED T 1-3/4 size



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FLASHING LED
with built in flashing circuit operates on 5 volts...



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GREEN $1.00 each
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Many different shapes, colors, sizes. Round, rectangular, curved, etc.
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CAT# OSU-6
50¢ each
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STEPPER MOTOR



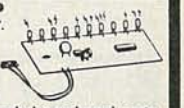
Airpax P/N C82711-M1
17 Vdc dual coil, permanent magnet stepper. 23.25 ohm coil. 7.5 degrees per step.
CAT# SMT-6 $6.00 each
10 for $50.00

L.E.D. FLASHER KIT



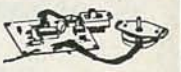
Two L.E.D.'s flash in unison when a 9 volt battery is attached. This kit includes a p.c. board, all the parts and instructions to make a simple flasher circuit. A quick and easy project for anyone with basic soldering skills.
CAT# LEDKIT $1.75 per kit

LED CHASER KIT



Build this variable speed led chaser. 10 leds flash sequentially at whatever speed you set them for. Easy to build kit includes pc board, parts and instructions. Ideal for special lighting effects, costumes, etc. Operates on 3 to 9 volts. PC board is 5" X 2.25". A great one hour project. **CAT# AEC $6.50 ea.**

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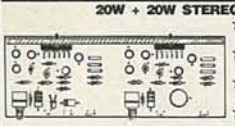
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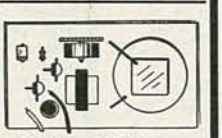


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Jumbo clear case.
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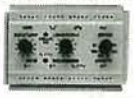
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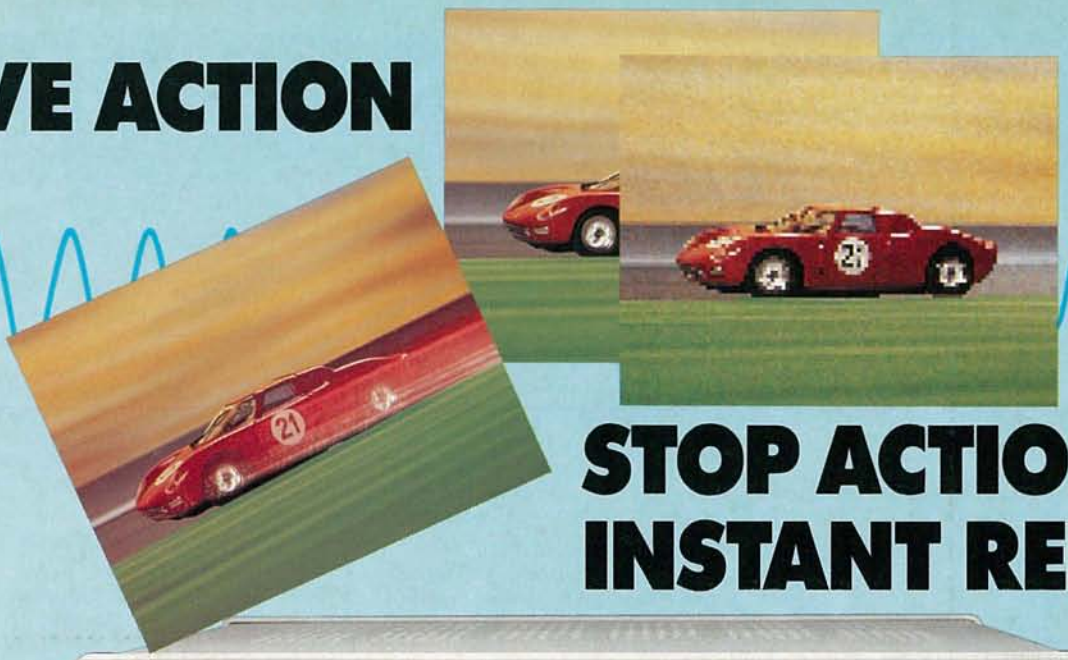
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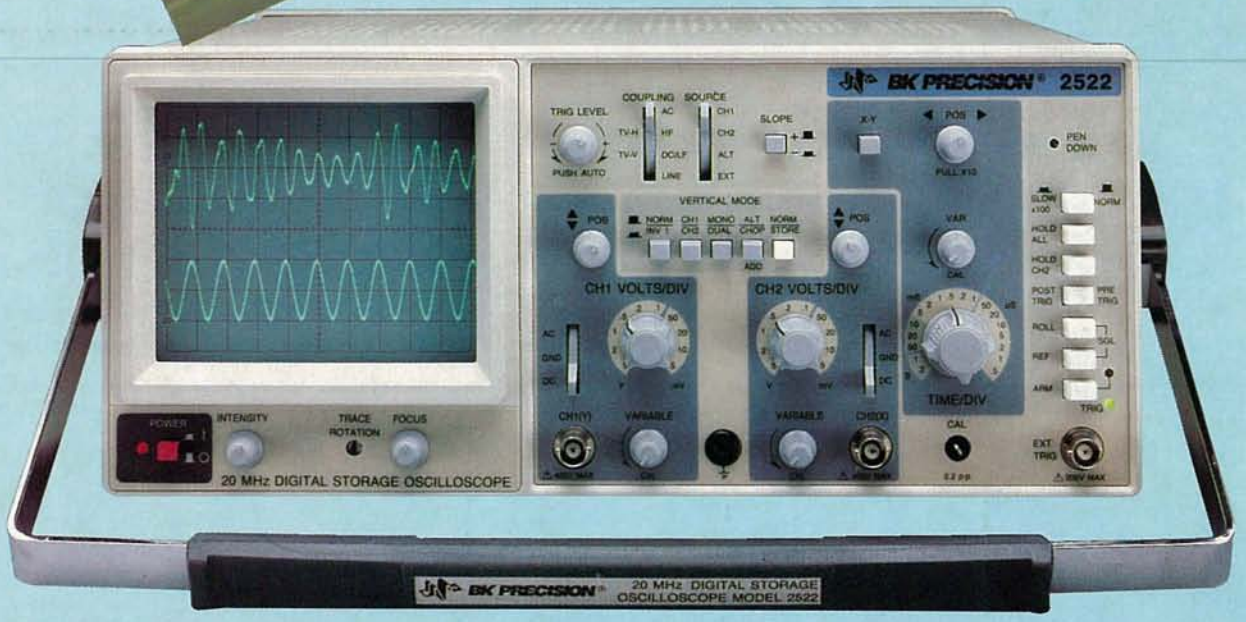
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