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For examining the components of a signal spectrum, you can’t beat the versatility and convenience of a spectrum analyzer. It allows you to measure parameters such as power, frequency response, harmonic distortion, and the amplitudes of complex components. All those functions don’t come cheap, however—unless you build our PC-based analyzer, which costs about $300. Consisting of a single printed-circuit board, the spectrum analyzer requires a modestly configured PC to act as the host machine and display. The calibrated 0.1 ± 810-MHz analyzer provides repeatable, accurate measurements of frequency and power, and includes an array of special features. To get started, turn to page 33.

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Superconducting transistor used in electronic circuits

Made from the new high-temperature superconducting materials, a superconducting transistor developed jointly by scientists at Sandia National Laboratories (Albuquerque, NM) and the University of Wisconsin, Madison, has been used in functioning electronic circuits. Dubbed the Superconducting Flux Flow Transistor (SFFT), the device can be considered the superconducting analogue to the field effect transistor (FET), the "workhorse" semiconductor that is in wide use worldwide. A transistor is an "active device"—one that can produce a power gain—and the SFFT is the first transistor made entirely from high-temperature superconducting materials. Circuits incorporating the device can operate above 77 K, the temperature of liquid nitrogen, a widely available and inexpensive coolant.

The SFFT consists of parallel, weak superconducting links that separate two pieces of semiconductor and a control line to provide a local magnetic field. While a FET's output current is controlled by changing the input voltage, the SFFT's output voltage is controlled by changing the input current. Acting like a gate, the current in the control line alters the magnetic field in the active region of the device, which modulates the output voltage and can provide gain at very high (microwave) frequencies.

The team of scientists took the device and coupled it with passive microwave components in real circuits that represent the essential components of electronic communications and signal processing technology, including amplifiers, oscillators, phase shifters, and mixers. Microwave amplifiers built with the SFFT show a gain of 10 dB at 4 GHz. The SFFT has also been used to make mixers—devices that mix together two frequencies to produce a different output frequency—that operate at up to 35 GHz.

The SFFT can serve as an interface between conventional, low-temperature superconducting electronics and semiconductor electronics. The SFFT has a low input resistances and a reasonably high output resistance, which allows it to serve as an active link between superconducting and semiconductor circuits. In Sandia's experiments, a Josephson junction drives the input of an SFFT, which then drives the gate of a field effect transistor. Current research concentrates on developing a technology around the SFFT that includes passive and active components in a whole family of applications.

CEBus developments

CEBus, the home-automation standard being developed by the Electronic Industries Association/Consumer Electronics Group (EIA/CEG), allows communication throughout the home between a variety of electronic products over existing power lines, twisted pairs (telephone), coaxial cable, and infrared means. The infrared and twisted pair sections of the CEBus (Consumer Electronics Bus) standard have been approved as interim standards. The new interim infrared standard covers the transmission of signal to integrated CEBus products—for example, the interfacing of security devices with telephone equipment—while twisted pair standard facilitates flexible room-to-room communication. The interim standards are considered by the EIA/CEG to be a major milestone on the road to a complete, overall standard, which is expected to be announced by the end of this year.

The first public working display of CEBus technology is the Bright Home, in Indianapolis, which opened at the end of March for a six month period of public tours. The Bright Home links a variety of electronic equipment and appliances into a common intelligent-control system.

The Bright Home display is intended to demonstrate the "building-block" approach to CEBus technology, which allows consumers to integrate as many CEBus products into their new or remodeled homes that their budgets and needs dictate. Among the various companies contributing products to the Bright Home project are Panasonic, Sony, and Thomson/RCA; the CEBus products and technology are provided by Hometronics, an integrated electronics consultant that's located in Indianapolis.
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AUGUST 1981
VIDEO NEWS

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

DAVID LACHENBRUCH

• Multimedia expands. Following the introduction of CDTV by Commodore (Radio-Electronics, July 1991), several manufacturers are poised to introduce the standardized CD-I (Compact Disc Interactive) system this fall. Philips has announced that it will field Magnavox brand players in the U.S. in October, followed by a Philips brand unit a month later, and Sony, Panasonic, and others have indicated that they'll be in the market this year.

The Magnavox CD-I players will carry a suggested list price of $1,400, but are expected to sell at about $1,000. They'll play standard CD audio discs, CD + Graphics (CD + G) discs, and the forthcoming Photo CD discs as well as multimedia CD-I discs. Discs will sell for around $20 to $60. Although initial discs will have animation at 15 frames per second, true full-motion video won't be available until some time in 1992. At that time, a simple plug-in adaptor (containing an MPU chip) will be offered to update players, but the original software will still be playable. When full-motion, full-screen video finally is available, the five-inch CD-I disc may well replace the 12-inch laserdisc as the preferred carrier for recorded movies.

The jury is still out on the various CD-ROM multimedia products—at least with regard to the extravagant claims that they constitute the next hot consumer-electronics product or the successor to print publishing.

• Closed captions. The FCC has accepted industry recommendations to implement the closed caption law with a relatively simple method of achieving captioning for the hearing impaired. Congress passed a law requiring caption reception capability in all sets 13 inches and larger manufactured or imported after June 30, 1993 (Radio-Electronics, May 1991). An EIA task force recommended a system that uses on-screen graphics capabilities already employed by many TV set manufacturers. Some features that are now mandatory in the captioning rules will be made optional, and other features will be added. Zenith has indicated that it will introduce closed-caption receivers well in advance of the deadline, with the first sets to appear this year at moderate prices, starting at around the $299 area. The captions, when generally adopted by the industry, are expected to be useful in areas other than assisting hard-of-hearing consumers, and could even lead to some kind of program identification system—such as display of the name of the program or episode—or even a possible automatic system that would permit viewers to program their VCR's by the name of the program to be recorded.

• Widescreen VHS. JVC and Thomson Consumer Electronics (whose U.S. brands are RCA and GE) are working together on a compatible system to record widescreen 16.9 images on standard VHS video recorders. According to JVC, the system would involve "identification signals" for automatic switching between 16.9 and standard 4:3 aspect ratios. The system presumably would be a version of Super VHS recording. In Europe, widescreen enhanced-definition programming is already being transmitted by satellite, and in the U.S. Thomson and Philips are pushing ACTV, an enhanced widescreen system, as an intermediate step before HDTV. Thomson and Philips are consulting with other manufacturers on the proposed parameters, and JVC says it hopes to commercialize the system within a year.

• Video compression. All of a sudden, everybody's talking about compression technology. From satellites to multimedia to HDTV, bandwidth compression is now regarded as the biggest breakthrough since color TV. A cable system in Queens, N.Y. is now planning to offer 150 channels through a combination of compression and optical fiber. HBO will soon be offering a three-channel service to cable systems which can take advantage of compression to let viewers choose the starting time of the movies they want to watch. SkyBox pay-TV service is squashing six channels into one on a satellite transponder. Multimedia services, such as CD-I, are now talking about full-motion video on 5-inch optical discs through the use of compression. The computer has changed the nature of television. Soon there will no longer be a scarcity of spectrum because of the ability to squeeze many channels into one.

• Big-screen sets gain. In spite of an 8% decline in total sales of color TV sets in the first three months of 1991 (as compared with the same period in 1990), direct-view sets between 27 inches and up rose by 13%, and projection set sales were up 15%—indicating a growing move to larger sets. Sets 27 inches and larger, including projection, rose to 16.8% of total sales from 12.2% in the similar year-earlier period. Direct-view sets with sizes 30 inches and larger jumped by 43.6%.

• VCR popularity contest. What's the biggest-selling brand of camcorder? Why Sony, by a large margin. The latest survey by Television Digest newsletter gives Sony an 18% share of the camcorder market, followed by Panasonic with 14%, RCA with 13%, and Sears and JVC with 7.5% each. Runners-up to that top five were Sharp, Magnavox, GE, Hitachi, and Canon, in that order. The same survey which produced those rankings showed manufacturers think 8mm will be 1991's leading format, accounting for 44% of camcorder sales, followed by full-size VHS with 40%, and VHS-C with 16%.

In video decks, RCA was the undisputed leader with 11% of the market, with Panasonic second at 8%, Emerson, Sharp and Magnavox each, followed by JVC, Zenith, Sears, and Goldstar. The survey reflects shares and rankings for the full year of 1990.

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I've never had a problem like this so I can't give you a ready-to-wear answer to the problem. There are some things about your predicament that surprise me however, and I have a few suggestions about what you can do.

The first thing that struck me is that you're getting channel crosstalk and interference on only one TV—and a new one at that. If this had been a problem on every TV in your house I would have called it an unavoidable problem but, since it happens on only one TV, it's logical to suspect the tuner in that TV.

I called Heathkit to ask them about your problem and everyone that I spoke to went on at length about the circuitry in your TV.

If you don't want to do that, or if you don't have any access to a signal-strength meter, you can accept the crosstalk as a feature (?) of your TV and, as you asked in your letter, do something to attenuate the channel-58 signal before it gets to your TV.

There are several companies around that specialize in making traps to remove either individual channels or a range of channels and you'll find that a bunch of them advertise in Radio-Electronics. I called Star Circuits of Las Vegas (1-800-433-6319), a Radio-Electronics advertiser who makes channel traps. The people there were extremely helpful and, when I explained the problem, they were sure they could come up with something that would do the job.

They sell their traps for about twenty-five bucks and, even though I still think the problem is in your TV's tuner, it's probably a lot less of a hassle to add an attenuator to the antenna input than it is to start fooling around with the circuitry in your TV.

MOTORCYCLE REBUILD
I'm rebuilding a 1970's era motorcycle and am stuck on how to go about setting up a power-management system. I have an alternator and am now looking for a voltage regulator. In the best of all possible worlds I would have a redundant system so that if one fails I could switch over to the other one. Can you help?—G. Perry, Barrington, NH

Every once in while a letter comes in that I can take a particular pleasure in answering. You couldn't have sent your letter to a better person—I own a 1968 Jaguar and recently finished rebuilding a 1968 Triumph Bonneville. For my money, that's the best bike ever made.

I had a similar problem to yours when it came to the electrical system. All the original stuff was made by Lucas (why do the British drink warm beer?—because they use Lucas refrigerators), and I had no desire to use the original parts. And when I found out that the original Lucas regulator cost eighty-five bucks, I was doubly sure I wanted to do something of my own. After all, a voltage regulator is an electronic thing and I know about that stuff.

The circuit shown in Fig. 1 is the voltage regulator I've been using in both my car and the bike. It's been working in my car for about eight years and I've never had any trouble with it. As you can see, it uses standard parts that can be gotten almost anywhere.

Before you go out and get everything you need to build the circuit there are some things you have to know about an alternator. Different bike and car manufacturers use different techniques to handle all the alternator connections and you have to know how your bike is set up before you get started. Since you're rebuilding everything anyway, it may be possible to set things up in a manner different than what was done originally by the manufacturer.

Even though an alternator produces three-phase AC, as far as the external world is concerned it's a DC machine. There are usually six diodes on two D-ring heat sinks that rectify the AC before it leaves the alternator. What sets an alternator apart from a generator is not only the need to rectify the output of the windings (a generator will produce DC directly), but also the presence of the field coil.

Alternators have a working sim-

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A class of one.
Since 1934.
ularity to transformers. You can think of the main three-phase windings as the secondary and the field windings as the primary. Like a transformer, the more voltage you have across the primary, the more you’ll get out of the secondary. A voltage regulator for an alternator is essentially a controller that monitors the system voltage and tries to keep it at a certain level by adjusting the amount of current (and hence the voltage) present in the field windings.

Given all that, a standard alternator has four terminals that have to be connected to the electrical system. The secondary windings (the main alternator windings) are usually sent to power and ground, but the connections made to the field windings vary with the manufacturer of the car or bike.

The field terminals can be treated in one of the following ways: Both field terminals can be brought out of the alternator and left floating for you to connect any way you want, one side can be grounded inside the alternator (called a grounded field), or one side can be tied to the DC positive inside the alternator (called a pulled-up field).

The schematic in Fig. 1 is designed to work with a system that has a grounded field. Since you’ve been fooling around with your own designs, you should be able to easily modify it to work with a pulled-up field if that’s the situation in your bike. Basically, the voltage regulator monitors the system voltage and controls the field current by modulating Q2 and Q3 (they’re set up as a Darlington pair because I found it difficult to get the Darlington I wanted to use). The output is being modulated and the transistors are being run saturated (used as a switch) because they run a lot cooler that way.

The three external connections are +V (connected to the battery), the field (connected to the free end of the field coil), and ground (connected to system ground). Let me repeat that this regulator is designed to work in a system that has a negative ground and in which one side of the field windings is grounded as well. If your system is set up for a pulled-up field and you use this circuit, you’ll blow up the regulator and possibly destroy some other electrical stuff in the bike as well.

As I said, I’ve been using this regulator in both my car and bike without any problem at all. I included LED1 in the circuit because it gives me a visual indication that the charging system (or at least the regulator) is working. You can use the potentiometer to adjust the knee of the regulator.

The setting here will determine what the steady-state voltage of the regulator will be. Moving it to one end will effectively turn off the charging system (although why you’d want to do that is beyond me), and turning it to the other extreme will cause the alternator to put out a lot of juice. That can be handy for those times when your battery is either in need of a charge or you’re putting a heavy current demand on the electrical system (lights on in stop-and-go traffic during a heat wave and rainstorm). If you’re using the regulator in a car, you can mount the potentiometer and LED inside the car so you can monitor its action and make adjustments while you’re driving. The regulator should work well regardless of the construction method you use. I designed a PC board for it and, if you’re interested, drop me a line and I’ll send you a copy of the foil pattern. Best of luck from a fellow biker.
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Letters

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Toner Cartridge Omission

We were shocked and disappointed that Chenesko Products, Inc. was not mentioned by Don Lancaster in Hardware Hacker in the May issue of Radio-Electronics. The company has been involved with toner-cartridge recharge for five years and sells to both end users and dealers engaged in the recharge business. Our catalog has been out for more than three years, and we carry the most extensive line of products in the industry.

EDWARD W. GRENZIG, PRESIDENT CHENESKO PRODUCTS, INC. 62 North Coleman Road Centeretech, NY 11720

Bring Back the Tubes

As a working audio professional, after reading his recent Audio Update columns, I think it’s fairly obvious that Larry Klein simply doesn’t know what he’s talking about. He and the other “scientific audio authorities” such as Bob Carver and the crew at McIntosh are about as scientific as pro wrestlers.

I work mainly with midwestern pop, country, and jazz recording artists. While few of them are “audiophiles” in the classic sense, very few are not capable of hearing the difference, and preferring older, simpler, and most often tube gear over modern stuff sporting superior measurements. Tube condenser microphones such as Neumanns, tube compressors (such as those from Fairchild and Pultec), and most especially, tube guitar amplifiers and effects are very popular and their value is increasing every day. Various companies are now making new tube studio hardware, which, while often expensive, seems to be selling quite well.

Recording-studio owners are not “tweaks” and faddists, but hardened and often intrinsically cheap fellows who buy gear strictly on the basis of the results generated. Producers and artists can hear the difference, and among those who care a great deal about their sound, a good deal of tube equipment is the rule, not the exception, especially for mixing vocals and for guitars.

The bottom line is that the current battery of audio tests are not even close to sufficient for “objective” analysis of what is going on inside audio amplification and processing gear compared to the limits of what even the rudimentarily trained human ear can discern—when its owner’s conscious mind has not stopped it from doing so. The “subjectivist” crowd of audio reviewers are only attempting to fill a void in the knowledge accrued on the subject, however successfully, and if Mr. Klein and friends cannot do better, I suggest they leave it to those who can.

To close, I can do no better than to paraphrase L.A. Rollin’s famous lexicon: “Spec worship: Sense of life experienced by (audio) objectivists and other breeds of dog.”

RICHARD CARYSFORTH Lenexa, KS

Easier Indicator

I would like to suggest a simpler remedy to the problem posed by T. Waller in Ask R-E in the May issue of Radio-Electronics. Mr. Waller asked for a visible indication that he is using the print-screen function of his IBM compatible. Your response points to a complicated hardware solution that would not really solve the problem. As I see it, Mr. Waller wants to know when a screen print is in progress, and not just that the print-screen key has been pressed on the keyboard.

A short software routine would provide a simple solution to the problem. The print-screen key press could be determined by intercepting either the BIOS keyboard character fetch routine or, better yet, the actual print-screen routine itself. For example, he could change the BIOS print-screen routine vector to point to his own custom patch. The first thing the patch does is to turn on some kind of indicator that shows a screen print is in progress. When that subroutine returns control to his patch, he can sim...
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I hope this is a more workable solution to the proposed problem. JEFF SCHMOYER
Colorado Springs, CO

MIND OVER MONEY

I read with interest Alex Funk's letter in the April issue questioning the "idiocy" of Charles Colby's article, "Build a Macintosh-Compatible Computer" (Radio-Electronics, January 1991). I used that article to build the SE-30, and there are a couple of points I'd like to make.

If all you want is a computer, then you are probably better off buying either a new one or a good used one from a friend or a reputable dealer. The real purpose in building your own system is to learn about its design and construction. Half the articles in Radio-Electronics are about building devices that are almost always commercially available, although at generally higher costs. But buying the finished product defeats the whole purpose of having electronics as a hobby. The idea of charging yourself 10 hours of construction time, as Mr. Funk does in his cost assessment, makes no sense to the hobbyist.

Mr. Funk also includes in his expenditures for building a Mac $50 for a motherboard and $50 for a monitor. He apparently is talking about the Mac 128K, the least powerful of the Macs. His conclusion is accurate: It just isn't cost effective to build such a low-end system. For the same price, a PC or XT cannot write back to the keyboard. If the machine is a PC or XT, an external LED indicator can be wired into an unused serial or parallel port pin.

I would like to say that I found Mr. Colby's article very enjoyable. I had the opportunity to speak with him by phone during the construction of my Mac, and both he and his company were very helpful with their advice.

KEVIN HOLLEY
Reston, VA

IBM-PC PROponent

I say "Right on!" to Jeff Holtzman in his response to Raymond Cheng (Letters, Radio-Electronics, April 1991).

My first computer was a Texas Instruments TI 99/4A. There were TI 99/4A zealots at that time. The computer served its purpose: It helped my family to better understand computers and to learn a bit about BASIC and other programming. It was treated as an educational tool, but was little more than a toy when it came to useful applications.

Several years later we bought our first MS-DOS personal computer. We delayed this purchase until there was some hint of standardization, competitive marketplace, and long-term usefulness due to its compatibility at work and at home. The entry of IBM clones provided that confidence. In less than three years, we purchased four MS-DOS computers. The second and third were for two children in college (engineering and business). The fourth was to upgrade our own computer and to pass on the first one to our oldest son.

Radio-Electronics has gauged its readership well. In my opinion, Radio-Electronics covers items that are of interest to the vast majority of its readers. I like the computer articles, but my primary interest is in new technology and explanations of how devices work. I seldom build anything anymore. However, articles on construction usually describe how the equipment functions, and why. Keep up the good work.

T. LAMAR MOORE
Alexandria, VA
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We remember the days when four-function calculators were items that cost several hundred dollars and weren't available on key chains at your local dime store. Back then, an engineer never left his home without his slide rule, and computers were used only for the toughest number crunching. The microprocessor changed everything, of course. The amount of power that can be packed into today's engineering calculator is remarkable. A good case in point is the PC-E500 from Sharp Electronics Corporation (Sharp Plaza, Mahwah, NJ 07430).

Although we normally call it a calculator, the PC-E500 is actually more of a pocket computer. It features an 8-bit CPU, a 256K system ROM (including the built-in BASIC programming language), and a 32K RAM (3.8K of system RAM, plus 312 bytes for fixed variables and 28600 bytes for programs and data).

The PC-E500 offers the operations you'd expect from an advanced calculator: Addition, subtraction, multiplication, division, trig and inverse trig functions, logarithmic and exponential functions, angle conversion, square and square-root capability, power, sign absolute, integer, coordinate conversion, and more. Although we didn't count them, Sharp claims that the calculator features 1101 functions for technical calculations (including scientific formulas, constants, and operations).

The PC-500E, at just under 8 x 4 x 9/16 inches, is larger than most calculators, even larger than most high-powered scientific calculators. However, that's not necessarily a bad thing—there are 89 keys on the front panel, including a full QWERTY keyboard. (Don't plan on touch-typing; the keys are quite small. Even so, the keyboard is quite usable.) The calculator weighs a little over one half pound, including its four "AAA" batteries and its lithium backup battery. A hard plastic slide-off cover protects the PC-E500 from damage. The display, which can handle some graphical operations, is a 4-line, 40-column LCD that measures just smaller than 1 x 4 inches.

Using the calculator

When the calculator is first powered up, the main menu is displayed so that you can select the operating mode. Five options (BASIC, CALC, MATRIX, STAT, ENG) are presented on the bottom line of the display; you choose one by pressing one of the five "soft" programmable keys below the choices. A sixth choice, AER, is seen only if you hit a menu-scroll key.

The BASIC mode actually consists of two modes: PRO, which allows you to enter or edit BASIC programs, and RUN, which lets you execute stored programs. The CALC or Calculator mode allows you to use the PC-500E as a standard calculator. The MATRIX mode, as you might expect, allows you to perform operations using matrices, while the STAT mode allows you to do statistical and regression calculations. The AER mode lets you write and solve algebraic expressions. The most interesting mode, of course, is the ENG mode, which lets you use the built-in Engineer Software.

The Engineer Software contains a wealth of built-in programs as well as physical constants. The software is accessed via a hierarchical structure. For example, once you enter the ENG mode, you are presented with five choices above the "soft" function keys: MATH, SCI, ELEC, MECH, and DISTR. While you can probably guess the first four, the last one stands for Distribution and Probability.

Expanding the PC-E500

A number of accessories are available to increase the power of the calculator. RAM cards in sizes from 8K to 64K can expand the computer's RAM memory, and can be used for non-volatile program storage thanks to the card's battery backup. A pocket disk-drive is also available, as is a thermal printer/cassette interface. The built-in serial port can also be used for expansion, although the connector is a non-standard one.

All in all, the Sharp PC-E500 is an effective computer/calculator. Despite its many capabilities—which we wish we had more room to discuss—it's surprisingly easy to use. Any functions that we couldn't use intuitively were covered clearly in Sharps excellent 350-page manual. With a suggested list price of $229, the PC-E500 is more than competitively priced in its class. We highly recommend it for any engineer who needs mathematical computing power and a formula-reference book in a pocket-sized package.

The ELEC or electrical engineering function presents you with four additional choices: COMPLX, which performs complex-number calculations, EE FRM, which displays 14 formulas ranging from Ohm's law to delta-wye transformation to electric resonance. ELEMAG displays 16 formulas for electric and magnetic fields, from Coulomb's law to Faraday's law of electromagnetic induction. Finally, LAPLAC displays 46 Laplace transform formulas.

Formula references, of course, are certainly handy, and some of the other functions present such references as the periodic table and integration formulas. The real power of the calculator is that you can program the soft keys to perform any function you want. So, for example, you could create a program that would ask for coil and capacitor values and then calculate the natural frequency of a tank circuit, and store it to appear under the electrical engineering menu.
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The Protometer 4000 ten-in-one test instrument costs $139.95.—Global Specialties, 70 Fulton Terrace, New Haven, CT 06512; Phone: 203-624-3103; Fax: 203-468-0060.

CIRCLE 18 ON FREE INFORMATION CARD
LOW-NOISE POWER SUPPLIES. Two benchtop DC power supplies from Hewlett-Packard offer high performance plus ripple and noise less than 200 mV RMS. The models HP E3610A (pictured) and HP E3611A feature dual-range outputs and CV/CC operation with automatic mode crossover. The CV mode is for devices requiring constant voltage and the CC mode is for those requiring a constant current. The E3610A's Range 1 is 8 volts/3 amps and Range 2 is 15 volts/2 amps; the E3611A's Range 1 is 20 volts/1.5 amps and Range 2 is 35 volts/0.85 amps.

For user convenience, each of the 30-watt power supplies has separate digital displays for voltage and current readout, a CC-set button for setting the current level of the supply without having to short the output, and mode-indicator LED's to show whether the unit is in CV or CC mode.

The E3610A and E3611A low-noise DC power supplies are list priced at $300 each. Hewlett-Packard Company, Inquiries, 19310 Pruneridge Avenue, Cupertino, CA 95014; Phone: 1-800-752-0900.

TELECOMMUNICATIONS WIRING TESTERS. According to Paladin Corporation, their Patch Check is the first hand-held instrument that can specifically identify the exact connection point of two connections at each end of a modular cord assembly. Designed to check telecommunication wiring tester, complete with installed battery and one-year warranty, has a list price of $49.95. - Paladin Corporation, 3543 Old Conejo Road, Suite 102, Newbury Park, CA 91320; Phone: 805-499-0318.

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<table>
<thead>
<tr>
<th>MODEL</th>
<th>TUNING RANGE</th>
<th>FOR CHANNELS</th>
<th>PASS BAND</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>224</td>
<td>50-66 MHz</td>
<td>2(4) 6 MHz FM</td>
<td>50-100 MHz</td>
<td>$32</td>
</tr>
<tr>
<td>467M</td>
<td>66-108 MHz</td>
<td>4.5-6 MHz FM</td>
<td>50-300 MHz</td>
<td>$32</td>
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<td>120-144 MHz</td>
<td>4(4) 15(4)</td>
<td>50-400 MHz</td>
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<tr>
<td>1622</td>
<td>144-174 MHz</td>
<td>18(3) 19(2) 29(3) 21(4) 22(2)</td>
<td>50-400 MHz</td>
<td>$32</td>
</tr>
<tr>
<td>713</td>
<td>174-216 MHz</td>
<td>7.6 10 11 12 13</td>
<td>50-400 MHz</td>
<td>$32</td>
</tr>
</tbody>
</table>

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and full-featured VCR with tuner, timer, and wireless remote control. No problems with picture rolling are created in the conversion process, and no vertical hold control is required. The converted signal is recordable. The standard NTSC signal and the converted output are available as composite video, RF, and with S-VHS outputs in S-VHS models. The new conversion technology is compatible with previous and current Image Translator products, and owners of earlier Image Translator VCR’s can have their units retrofitted with the 50/60 digital frame standards module to allow complete compatibility with all TV’s, monitors, and projection systems, and for standards-conversion purposes.

Prices for the 50/60 Image Translator VCR’s begin at $999. —Instant Replay, 2601 South Bayshore Drive, Suite 1050, Coconut Grove, FL 33133; Phone: 305-854-8777; Fax: 305-858-9053.

CIRCLE 22 ON FREE INFORMATION CARD

SCANNER Antenna. Designed to provide great reception at a low price—and be rugged enough to withstand wind and weather—the Super Scanner Stick from Electron Processing receives all scanner frequencies between 25 and 1200 MHz. Its unique internal multipole construction allows the compact antenna to cover such a wide range of frequencies, and an internal 15-dB “Signal Intensifier” amplifier ensures strong signals, even from distant stations. Completely encased in a PVC tube, the Super Scanner Stick withstands weather conditions that routinely destroy other scanner antennas. The 35-inch-long antenna comes completely assembled with mounting clamps for masts up to 2-inches in diameter, so installation is easy. To connect the antenna to its 115-VAC power unit, a 25-foot coaxial cable is included: longer lengths are available. The power unit connects to a scanner via a supplied jumper cable.

The Super Scanner Stick costs $80; a 12-VDC version is available for $84. —Electron Processing, Inc., P.O. Box 68, Cedar, MI 49621; Phone: 816-226-7020.

CIRCLE 23 ON FREE INFORMATION CARD

UV EPROM Eraser. According to Logical Devices, their Palm-Erase is the industry’s smallest UV EPROM eraser. It is particularly designed for field service and engineering applications where space is at a premium. The Palm-Erase can erase EPROM’s in less than three minutes. It incorporates a small tray that can accommodate a single 24-, 28-, 32-, or 40-pin DIP IC’s.

ChipShip packages are priced from $2.95 to $4.95 each, and are shipped in cartons of 10. —IT01 Enterprises, P.O. Box 59, Newton Highlands, MA 02161; Phone: 617-332-1010.

CIRCLE 24 ON FREE INFORMATION CARD

PC-Compatible Circut Breadboard. With a unique bus-grid design that allows easy access to power and ground hook-up points, Radio Shack’s Archer Experimenter’s Plug-In Card (Cat. No. 276-1598) can be used by technicians, students, and hobbyists to breadboard digital and analog circuits. The board is made of sturdy epoxy-glass-composite material and has a card-edge that is compatible with XT-style microcomputer expansion bus connectors. In addition, the Experimenter’s Plug-In Card has an input/output port designed to hold a right-angle DB25 connector. Board holes are plated-thru for electrical continuity and measure 0.042 inches spaced 0.100 inches on centers. The board itself measures 3½ × 10½ × ¼ inches.

The Archer Experimenter’s Plug-In Card sells for $49.95. —Logical Devices, Inc., 1201 NW 65th Place, Fort Lauderdale, FL 33309; Phone: 1-800-EE1-PROM; Fax: 305-974-8531.
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WIRING GUIDE; from Car Audio Specialists Association/Vehicle Security Association (CASA/VSA), 2101 L Street, NW, Washington, DC 20037; Phone: 202-828-2270; $14.95 (members), $24.95 (non-members).

Originally presented as a series of articles in CASA/VSA's monthly publication, the Mobile Electronics Monitor, the "Wiring Guide Series" has been released as a set of 12 leaflets complete with an index identifying all vehicles featured and a binder to which additional guides can be added. The guides feature wiring diagrams that identify various OEM radio plugs, color codes, pin positions, and related information. Available separately are individual binders with index and single copies of guides in the ongoing series. To date, 17 guides have been published.

TEST INSTRUMENTS
BK-91; from B&K-PRECISION, Maxtec International Corp., 6470 West Cortland Street, Chicago, IL 60635; Phone: 312-889-1448; free.

B&K-PRECISION's full line of electronic test instruments—oscilloscopes, IC comparators, digital multimeters, signal and function generators, video test instruments, component testers, power supplies, probes, and accessories—is covered in this 68-page catalog. With a glossary of terms for each major project category, as well as summaries of key product features and selected product applications, the catalog helps purchasers identify the right instrument for a given task.

Complete specifications are provided both in the detailed product listings and in easy-to-use comparison charts. A complete line of accessories, designed to enhance the functionality of many different test instruments, also is described.


This hobbyist's guide to radio-frequency circuit theory and experimentation is written to demystify that part of the electromagnetic spectrum. Aimed at amateur experimenters, ham-radio operators, shortwave listeners, and electronics students, the book explains in clear, nontechnical language what RF is, how it works, and how it differs from other electromagnetic frequencies.

Broad in scope, with hundreds of helpful diagrams and equations to clarify the text, the book explains how to repair variable circuits, align RF circuits, and cope with electromagnetic interference. With an emphasis on practical applications, the book also shows how to design and wind inductor coils; design and build simple wire antennas with ten BASIC programs, RF amplifier circuits, and preselector circuits; and build a digital frequency-counter module. Also covered in the guide are the basics of receiver operation, the proper use and repair of components in RF circuits, and the principles of radio propagation from low frequencies to microwave.

BUILDING POWER SUPPLIES; by David Lines. Master Publishing Inc., available at Radio Shack stores nationwide (Cat. No. 276-5025); $4.95.

This book has two main goals: to provide a thorough understanding of how power supplies work, and to explain how the reader can build their own power supplies. Covering both regulated and unregulated power supplies, the book describes the basic function of each of the components in a power supply and how those components work together to form a functioning unit. Opening with a discussion of the fundamentals of AC and DC energy sources, the book provides in-depth looks at unregulated power-supply systems—including transformation, rectification, and filtering to produce a DC voltage from an AC source—and regulated power supplies—including the basics of how to control a DC voltage to close limits as input or output varies. Complete construction plans are included for three linear regulated power supplies and two switching regulated supplies.

Using easy-to-understand text and clear illustrations, the book guides the reader through the design and construction steps. A chapter on measurements, calibration, and troubleshooting closes the book.
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THE PC-BASED SPECTRUM ANALYZER WE PRESENT IN THIS ARTICLE OFFERS FEATURES NORMALy FOUND ONLY IN INSTRUMENTS COSTING MANY TIMES MORE.

ALTHOUGH THE "GUTS" OF THE ANALYZER RESIDES ON A SINGLE PC BOARD, AN IBM XT OR COMPATIBLE COMPUTER IS REQUIRED TO ACT AS A DISPLAY, AS WELL AS TO PRECISELY POSITION PHASE-LOCKED LOOPS (PLL's) FOR FREQUENCY CONTROL AND TO PROVIDE LOOK-UP TABLES FOR POWER CALIBRATION. USING A PC ALLOWS US TO INCLUDE SUCH FEATURES AS MARKER AND DELTA-MARKER READOUT OF FREQUENCY AND POWER, HARDCOPY PRINTER OUTPUT, INSTRUMENT-SETTING MEMORY SO THAT "FRONT-PANEL" SETTINGS CAN BE Saved AND RECALLED, AND TUNABLE FM DEMODULATION.

REFER TO TABLE 1 FOR COMPLETE INSTRUMENT SPECIFICATIONS.

A MODESTLY CONFIGURED PC IS REQUIRED TO WORK WITH THE SPECTRUM ANALYZER: A SINGLE 360K FLOPPY DRIVE, CGA OR EGA VIDEO ADAPTERS, AND 512K RAM ARE ALL THAT'S REQUIRED. THE CARD EITHER PLUGS DIRECTLY INTO AN 8-BIT SLOT OR, WITH AN EXTERNAL POWER SUPPLY, RUNS OFF THE PARALLEL PRINTER PORT. THAT DUAL INTERFACE ALLOWS THE USER A WIDE CHOICE OF HOST MACHINES—FROM BASIC LAPTOPS TO HIGH-END MACHINES.

A SPECTRUM ANALYZER IS USED TO DISPLAY THE POWER DISTRIBUTION OF A SIGNAL AS A FUNCTION OF FREQUENCY, AS SHOWN IN THE RIGHT SIDE OF FIG. 1. IT IS BASICALLY A TUNED RECEIVER WITH SELECTABLE FREQUENCY RANGES AND INTERMEDIATE-FREQUENCY (IF) BANDWIDTHS. A SPECTRUM ANALYZER SEPARATES AN INPUT SIGNAL INTO ITS VARIOUS FREQUENCY COMPONENTS AND DISPLAYS EACH COMPONENT AS A VERTICAL LINE ON A CRT. THE HEIGHT OF EACH VERTICAL LINE ON THE DISPLAY REPRESENTS THE AMPLITUDE OF EACH FREQUENCY COMPONENT, THE HORIZONTAL POSITION OF EACH LINE INDICATES THE FREQUENCY LOCATION.

FIGURE 1 SHOWS THREE EXAMPLES OF INPUT SIGNALS REPRESENTED IN...

...side of Fig. 1. All time-domain plots have an associated spectrum that can be graphically described in a frequency-domain plot where the amplitude of the signal is a function of frequency. (Mathematically, that's done using the Fourier transform.) It is in the frequency-domain where the spectrum analyzer draws a picture, so that you can analyze the signal spectra in question.

BEFORE WE GO INTO THE THEORY BEHIND OUR SPECTRUM ANALYZER, LET'S BRIEFLY DISCUSS WHAT THIS INSTRUMENT ACTUALLY DOES, AND HOW IT OPERATES.

SPECTRUM ANALYZER DISPLAYS

ELECTRONIC SIGNALS, WHETHER THEY ARE PERIODIC, APERIODIC, OR TRANSIENT, CAN BE SHOWN IN A TIME-DOMAIN PLOT WHERE THE AMPLITUDE IS A FUNCTION OF TIME (LEFT
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Highband</th>
<th>Lowband</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>50-810 MHz</td>
<td>0.1-100 MHz</td>
<td></td>
</tr>
<tr>
<td>Available Spans</td>
<td>0.625, 1.25, 2.5, 5, 10, 25, 50, 100, 200, 300, 400, 500, 600, 800 MHz</td>
<td>0.625, 1.25, 2.5, 5, 10, 25, 50, 100 MHz</td>
<td>0.625 MHz to 800 MHz</td>
</tr>
<tr>
<td>Resolution Bandwidths (RBW)</td>
<td>10 KHz, 280 kHz</td>
<td>10 kHz, 280 KHz</td>
<td>Maximum frequency resolution is 10 kHz</td>
</tr>
<tr>
<td>Power Accuracy*</td>
<td>±3 dB</td>
<td>±3 dB from 4-100 MHz</td>
<td>With min. 6-dB (50-ohm) pad on input.</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>&gt; -98 dBm</td>
<td>&gt; -92 dBm</td>
<td>With internal attenuation set to 0 dB and 50-ohm source.</td>
</tr>
<tr>
<td>VSWR Input (50 ohms)</td>
<td>&lt;1.2 (6 dB)</td>
<td>&lt;1.3 (10 dB)</td>
<td>50-ohm pad on input.</td>
</tr>
<tr>
<td>Spurious Response (Birdies)</td>
<td>&lt; -95 dBm</td>
<td>&lt; -92 dBm</td>
<td>Unit outside of PC case, 50-ohm terminal on input.</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>&gt;58 dB (all bands and RBWs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Attenuation</td>
<td>0, 10, and 20 dB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Input Power</td>
<td>+10 dBm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Accuracy</td>
<td>&lt;10 kHz</td>
<td></td>
<td>Limited by 10-kHz RBW.</td>
</tr>
<tr>
<td>Reference Oscillator</td>
<td>4.000 MHz crystal, ±100ppm</td>
<td></td>
<td>All VCO's phase-locked to this reference.</td>
</tr>
<tr>
<td>FM Demodulator</td>
<td>280-kHz bandwidth, quadrature detection, manual volume control. Tuning stepsizes 125 kHz at 280 kHz RBW, 62.5 kHz at 10 kHz RBW.</td>
<td>FM demodulator is for wideband FM. Narrowband FM is demodulated, but because of the 10-kHz RBW, it cannot be seen on the display.</td>
<td></td>
</tr>
<tr>
<td>Power Requirements</td>
<td>+5VDC at 0.45A, +12VDC at 0.12A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interfaces</td>
<td>PC bus or parallel interface (Centronics)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Requirements</td>
<td>360K disk drive, EGA or CGA graphics adapter, 512K Ram, DOS 3.0 or higher.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
oscillators (VCO's) are used for that purpose.

There are problems, however, with the heterodyne type. In the mixing process, unwanted frequencies can appear in the fixed-filter bandwidth—additional noise is added and there is a reduction in dynamic range (the difference between the smallest signal detectable and the largest signal allowed).

One way to help eliminate the unwanted heterodyne frequencies is to use tracking filters (Fig. 2-c). A tracking filter is a filter that is tuned by voltage. In practice, tracking filters are used ahead of the mixer stage to reduce the number of frequencies that are mixed with the oscillator. A tracking filter is just a swept filter used in different way. It is designed to follow the oscillator (usually a VCO) so that some protection from the unwanted frequencies is provided.

Our analyzer uses the heterodyne principle in combination with tracking filters. Fixed ceramic 10-kHz and 280-kHz bandpass filters provide the two resolution bandwidths.

**Phase locking**

Phase locking a VCO takes an otherwise unpredictable beast and nails down its frequency. VCO’s, if left on their own, wander in frequency due to temperature, vibration, and a host of other causes. Frequency calibration is impossible with such variations. Frequency wandering can be greatly reduced by phase-locking the VCO with a highly stable source, such as a quartz crystal oscillator. The VCO’s in our analyzer can wander as much as 1 to 5 MHz. When phase-locked to the 4.000-MHz reference, the frequency drift is only a few hundred hertz.

That accuracy does not come without a price. Phase locking to a given frequency takes a significant amount of time. That results in longer sweep times when compared to sweeping an unlocked VCO. Also, phase-locking forces frequency steps on the VCO, whereas the unlocked VCO can be put at any frequency, at least in theory. For our design, the advantages of PLL's far outweigh the disadvantages.

**The big picture**

Figure 3 shows the overall block diagram of the spectrum analyzer. At the heart of the unit is a Zenith tuner module (IC17). The tuner takes highband inputs from 50 to 810 MHz and converts them to a 45-MHz IF, which is the first IF stage. After that conversion, the first of two Signetics NE615 receiver IC’s (IC16) down-converts the 45-MHz IF to a 10.7-MHz IF, which is the second IF stage. The 10.7-MHz IF is tapped off and sent to another NE615 (IC13) where the 10.7-MHz is downconverted to the standard 455-kHz IF, which is the third IF stage.

Figure 4 shows the circuit of the first 45-MHz IF stage. Of the four local oscillator’s (LO’s) used, three are phase-locked using Motorola’s MC44802 IC (IC14, IC15, and IC23). The LO for the 10.7-MHz IF is crystal-controlled by XTAL1. The PLL’s used for the tuner IC also perform band switching, which will be discussed in more detail below. Those PLL’s are self contained and have a serial interface. A 4-MHz crystal oscillator (XTAL2, Fig. 5) is used as a common reference for all the PLL’s, as indicated in the block diagram (Fig. 3).

The circuit of the second and third IF is shown in Fig. 5. FM demodulation is provided by IC13 and IC16. The output of the 10.7-MHz IF is suitable for wide-band FM such as standard FM radio broadcast. The FM output of the 455-kHz IF is not very clean but can be used for narrow-band FM signals such as voice-only broadcasts. However, only the FM from the 10.7-MHz IF is sent to the audio amp (IC22).

The NE615 receiver IC’s (IC13 and IC16) have a received-signal strength indicator (RSSI) out-

---

**FIG. 1—TIME AND FREQUENCY DOMAINS of input signals.** Two different signals applied at the same time results in two separate frequency components (a). An AM signal is displayed with its carrier and two sideband frequencies (b). A sine wave that appears perfect on an oscilloscope may show harmonic distortion on a spectrum analyzer (c).
When the RSSI output is read by the computer using an 8-bit analog to digital converter (ADC) (IC12, an ADC0834), raw data is provided for the spectrum display. Extensive use was made of serial interfaces in our analyzer to cut down on computer interface requirements.

The analyzer has two resolution bandwidths that are provided by a combination of ceramic filters. The 10.7-MHz filters (FL1 and FL2) are used for the 280-kHz RBW. Pretuned filters (FL3 and FL4) are used to provide the 10-kHz RBW.

In order to see frequencies below 50 MHz (the tuner's lower limit), an additional mixer and local oscillator (LO). IC24, are used to upconvert the 0.1–100-MHz band to an IF of 145 MHz. The analyzer's lower limit has its own separate input jack, LOWBAND INPUT. The 145-MHz IF is led to the tuner where it is down converted, as before, to the 45-MHz IF. From here on, the signal is processed as in the highband case (50–810 MHz).

As shown in the block diagram (Fig. 3), an 8-bit DAC (IC7) controls the automatic gain control (AGC) input of the tuner. AGC cancels out gain variations and provides signal attenuation. An 8-bit shift register (IC8) is used to provide IC7 with a serial interface to the host PC.

The signal analyzer supports two interfaces; PC bus and the parallel printer port. Either interface may be used, but not simultaneously. There is no difference in operation between the two interfaces. All frequency, AGC, and RSSI information are communicated over those interfaces to or from the host PC.

**Signal processing**

Figure 6 shows a block diagram of the RF signal processing. Starting with the 0.1–100-MHz front end shown in Fig. 7. IC24, a Signetics NE602 oscillator/mixer, is used to provide the up-conversion to the 145-MHz IF. The oscillator of the NE602 is buffered by Q5 and sent to PLL2 (IC23) for frequency locking. A varactor diode (D4) in the oscillator of the NE602 allows for voltage control of its frequency. That oscillator is swept from 145 MHz to 245 MHz in order to cover

**FIG. 2—SPECTRUM ANALYZER TECHNIQUES.** The swept-filter analyzer sweeps, or tunes, a bandpass filter over a specific frequency range (a). The heterodyne type uses a swept oscillator in combination with a mixer to sweep over a frequency range; a fixed filter determines the resolution of the analyzer (b). A heterodyne type with tracking filter eliminates undesired heterodyne frequencies (c).

**FIG. 3—A BLOCK DIAGRAM OF THE SPECTRUM ANALYZER shows the tuner module, phase-locked loops, receiver blocks, DAC, ADC, and the PC bus connection.**
the 0.1 to 100-MHz band. A lowpass filter, consisting of L5, C68, and C69, with a 100-MHz bandwidth is used on the input to the mixer to reduce unwanted frequency products at the output. The tuner is set up to receive the 145-MHz IF from the NE602 mixer. The NE602 is turned off for the highband mode using Q7 as an on/off switch, which is controlled from a PLL1 band-switching output.

The input is fed directly into the tuner module (IC17) in the higband case. The tracking filters are internal to the tuner, as previously described. Two bandpass trackers are used with a buffer amp between them. The output of the second filter is fed to the mixer for downconversion to the 45-MHz IF. A 45-MHz bandpass filter, with a 6-MHz bandwidth, follows the mixer. The local oscillator (LO) must be 45 MHz above the input signal to mix to the 45-MHz IF. For the 50 to 810-MHz bandwidth, the tuner VCO must have a range of 95 to 855 MHz. The LO from the tuner is internally buffered and is sent to PLL1 (IC15, Fig. 4) for frequency locking.

The 45-MHz IF is fed through a 6-dB attenuation pad (R16–R18, Fig. 4) and a tuned circuit to the mixer for the 10.7-MHz IF. The attenuation pad is used to reduce signal gain from the tuner and to provide a wide-band termination for the output of the tuner mixer. The tuned circuit, consisting of L1, C8, and C7 (as seen in Fig. 5), acts to match impedance, filter, and to adjust the voltage gain. The tuning of L1 (Fig. 5) affects the overall gain and noise floor of the instrument.

The 10.7-MHz IF is produced by mixing the 45-MHz IF with a 34.3-MHz third overtone crystal-controlled oscillator, which is tuned by L2. The 10.7-MHz output of the mixer is bandpass filtered by two 10.7-MHz ceramic filters (FL1 and FL2) with a buffer amp between them. The 10.7-MHz IF is fed to a limiting amp and a quadrature tank (T1) to perform FM demodulation. The functions of LO, mixing, amplification, and FM demodulation are performed by IC16. The bandwidth of the 10.7-MHz ceramic filters is 280 kHz.

With the tuner or lowband LO set to a step size of 125 kHz and swept over the frequency span, those filters provide the 280-kHz resolution bandwidth (RBW) using the received signal strength indicator (RSSI) from IC16 (Fig. 5). The RSSI is lowpass filtered by R41 and C43 and sent to the audio amp (IC22).

A sample of the 10.7-MHz IF is taken just after the first 10.7-MHz ceramic filter, passed through FL5 and sent to IC13 for downconversion to 455 kHz. The 34.3-MHz third overtone crystal-controlled oscillator is used to further reduce unwanted mixer products and to provide isolation between the 10.7-MHz IF and the 455-kHz IF. The local oscillator of IC13 has been set to a step size of 3.90625 kHz.

To produce the 455-kHz IF, a 10.245-MHz LO is needed. That LO is provided by phase-locking the oscillator of IC13 using PLL3 (IC14, Fig. 5). The oscillator of IC13 in our analyzer has been set up as a VCO using a varactor diode (D1). A sample of the LO is buffered by Q6 and sent to PLL3 (IC14) for error generation and locking. The LO is swept from 10.21375 MHz to 10.27625 MHz in step sizes of 3.90625 kHz. That is a total span of 62.5 kHz, the step size of the tuner LO, or the lowband LO when the RBW is set to 10 kHz.

It is necessary to sweep the 10.245-MHz LO because a step size of 3.90625 kHz is not possible with the tuner LO or the lowband LO phase-locked loops. Those step sizes must fall within the 10-kHz bandwidth of the 455-kHz IF.
kHz ceramic filters. That combination of dual LO sweeping with the 455 kHz ceramic filters provides the 10-kHz RBW. As with the 280-kHz RBW, the 10-kHz RSSI is lowpass filtered using R36 and C42. That forms the video bandwidth for the 10-kHz RBW. The 10.245-MHz LO is not swept in the 280-kHz RBW.

As with the 10.7-MHz IF, the 455-kHz IF is FM demodulated using quadrature detection (T2). The comb generator, shown in Fig. 8, provides a wide-band test signal. Transistor Q8 is biased to produce the harmonics of the 4.0-MHz reference, XTAL2. That signal has detectable harmonics past 500 MHz.

Now that we've gone over the operating theory in some detail,

FIG. 5—SECOND AND THIRD IF STAGE. IC16 downconverts the 45-MHz IF to a 10.7-MHz IF, which is tapped off and sent to IC13 where the second IF is again downconverted to the standard 455-kHz IF. Pretuned ceramic filters FL3 and FL4 provide the 10-kHz resolution bandwidth (RBW).
we will discuss some of the more important IC's in this design, and the reason why each of them were chosen.

**Tuner module**

The tuner is a CATV type made by Zenith. No modifications to the tuner are needed to use it in our analyzer. Along the bottom is a row of pins for the AGC input, +5 VDC, VCO tuning input, IF out and band-switching inputs. Band-switching inputs are used because LO's cannot sweep from 95 to 855 MHz. Instead of one LO, there are four that are switched in one at a time to provide the complete span. Table 2 shows the points where the LO is switched at various frequencies.

The frequencies shown in the table are with respect to the input frequency; to get the LO frequency, just add 45 MHz. Not only is the LO switched, so is the mixer! Two mixers are used: one for the VHF band and one for the UHF band. The mixers are switched by the same inputs as the LO so no additional switching logic is needed. The band switching results in two effects: a momentary delay in the sweep at the band switching points, and a slight step up or down in the noise floor at the switching points. The switching also affects the operation of the tracking filters. The tracking filters are internally tied to the VCO control voltage so that the input signal is always kept in the center of the bandpass filters.

**PLL IC MC44802**

The Motorola MC44802 IC, used in IC14, IC15, and IC23, is tailor made to interface to a band-switching tuner. Figure 9 shows a block diagram of that IC. All the switching logic is provided in the IC for band switching. An on-board prescaler with associated divide counters enables the MC44802 to directly sense and control VCO's up to 1.3 GHz. An error/driver amp is also included that is used to provide VCO tuning voltages from 0 to 35 volts. Programmable reference dividers are also present in the IC. All of the internal settings of the MC44802 are controlled via a three-wire interface.

You can continually change the contents of the VCO divide counter by sweeping the VCO being controlled by the step size selected. You can control tuner band-switching by writing to the band-switching register of PLL1 (IC15). Transistors Q1—Q4 are used as drivers for the tuner band-switching inputs.

To set the PLL to a particular frequency, divide the frequency by the step size, truncate, and insert the resulting number into the divide counter. For example, if you want to set the tuner VCO frequency to 400 MHz using a step size of 125 kHz, the divide

---

**TABLE 2—BAND SWITCHING**

<table>
<thead>
<tr>
<th>BANDS</th>
<th>VHF B+</th>
<th>Highband</th>
<th>Superband</th>
<th>UHF B+</th>
<th>Lowband</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF Low (50 to 100 MHz)</td>
<td>+12</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>VHF High (100 to 200 MHz)</td>
<td>+12</td>
<td>+12</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>Super Band (200 to 372 MHz)</td>
<td>+12</td>
<td>+12</td>
<td>+12</td>
<td>Open</td>
<td>Open</td>
</tr>
<tr>
<td>UHF Band (372 to 810 MHz)</td>
<td>Open</td>
<td>Open</td>
<td>Open</td>
<td>+12</td>
<td>Open</td>
</tr>
<tr>
<td>Lowband (0.1 to 100 MHz)</td>
<td>+12</td>
<td>+12</td>
<td>Open</td>
<td>+12</td>
<td>Open</td>
</tr>
</tbody>
</table>
counter should be loaded with $400/0.125 = 3200$ counts, of course you would also have to set the band switches accordingly. All of that programming is done by the host PC. A complete discussion of the details of programming this IC is too long to be presented here. You can refer to the Motorola Linear and Interface Data Book if you would like more information on programming the MC44802. Because of the high frequencies involved, the use of sockets is not recommended for these ICs.

**Receiver IC NE615**

The Signetics NE615 IC contains all the necessary components to do frequency conversion. The RSSI output has a 90-dB dynamic range, although our analyzer only has a 60–70-dB dynamic range due to compression in the tuner. The oscillator can be either crystal controlled or LC-tank controlled. If a varactor diode is added to the LC tank, you have a VCO.

One feature of the NE615 that is not used in our unit is the audio mute. That input allows for killing the audio output when no signal is present. The IF section has a total gain of 90 dB. The high gain can cause stability problems and consequently performance of this IC is greatly affected by circuit board layout. If you build a kit, do not put a normal socket on this chip! Individual, high-frequency, pin-type sockets can be used, but those are hard to come by.

**ADC0834**

The only thing that is unique about this ADC used for IC12 is its serial interface. Just four wires are needed to interface this IC to a processor. The ADC is used to convert the analog RSSI voltages to 8-bit digital information which is read by the PC. Diode D2 provides the reference voltage of 4.3 volts. This ADC has
In our case it is used to convert up or down DC-to-DC converter. (IC3) can be configured as a step-spans used. Motorola's MC34063 to control the VCO's over the DC to DC converter voltage output. It also needs only the DAC.

The shift register and load it into the DAC. Three lines, a clock, a 74164 8-bit shift register, and with the serial interface kept in line with the supply voltage, +12 VDC. In keeping with the self-contained reference and its self contained reference and voltage output. It also needs only one supply voltage, +12 VDC. In keeping with the serial interface approach, a 74164 8-bit shift register (IC8) is tied to the input data of the DAC. Three lines, a clock, data, and strobe, are used to insert the shift register and load it into the DAC.

Four channels, all of which are programmable. Channels 0 and 1 are used for the two RSSI voltages from the NE615's. Channel 2 is unused. Channel 3 is connected to the DAC and is used for self testing. As with the MC44802, the details of programming this IC are too lengthy to be presented here and the reader is referred to National Semiconductor's Databook.

8-bit DAC AD558
This Analog Device's DAC was chosen for IC7 primarily because of its self contained reference and voltage output. It also needs only one supply voltage, +12 VDC. In keeping with the serial interface approach, a 74164 8-bit shift register (IC8) is tied to the input data of the DAC. Three lines, a clock, data, and strobe, are used to insert the shift register and load it into the DAC.

DC to DC converter
The PLLs used need +33 VDC to control the VCO's over the spans used. Motorola's MC34063 (IC3) can be configured as a step-up or -down DC-to-DC converter. In our case it is used to convert +12 VDC to +33 VDC. Only 3 mA are needed to drive the three PLLs. The input and output voltages are heavily filtered by C57, C100, R24, C55, C99, and R62, as any ripple on the supply will show up as unwanted FM on the LOs.

Interfaces
As already stated, the analyzer can communicate via the PC bus or the parallel port LPT1 through LPT4. A header is provided on the board for a ribbon cable to connect to a Centronics-type adapter cable. If the card is operated external to the PC, an external power supply must be provided. The supply plugs into a 3-pin, Molex-type connector toward the back of the board.

A good quality DC supply with +5 volts at 1.0 amp and +12 volts at 0.4 amps is adequate. None of the DIP switches need to be set to select PC or LPT interface. When the Centronics cable is attached to the computer, it pulls pin 30 of the connector low which selects the LPT interface. The software, however, must be instructed by the user which interface is going to be used. That is done using the setup program, which will be discussed in our next issue. You can actually operate the card plugged into the PC bus using the LPT interface. In that configuration, the PC interface is used just for power.

Figure 10 shows the PC bus interface circuitry. The entire LPT interface is accomplished by using two 74LS244's (IC4 and IC5) and one 74LS04 (IC6). The 74LS244's are three-state octal drivers, which are used to buffer the signals to and from the LPT interface. The PC bus interface is considerably more complex. It consists of one 74LS688 comparator (IC20), two 74LS138's 3-to-8 decoders (IC18 and IC19), two 74LS374 8-bit latches (IC9 and IC10), one 74LS245 bidirectional buffer (IC21), and one DIP switch (S1). The DIP switch is used to select the PC bus address. The default address is 768 decimal. The default DIP switch setting for S1 is: positions 1–5 on, positions 6 and 7 off.

If another address is desired you will have to use setup to change the address used by the software and of course set the DIP switches to the new address. Details of setting the address switches are included in the README.DOC file contained in the SPECAN.ARC file. SPECAN.ARC can be copied from the Radio-Electronics BBS (516-293-2283, modem settings: 1200/2400, 8N1). If you never intend to operate the analyzer from the PC bus IC9, IC10, IC18, IC19, IC20, IC21, and IC11 can be removed from the circuit.

The PC interface does a comparison of the address bits A3 through A8 to determine where a block of eight decoded addresses will fall. Although eight read/write addresses are decoded, only two of the eight write addresses are used, and one of the read addresses. That is modeled after the LPT interface, which has two write registers and one read register.

Operation
The PC host controls all aspects of the spectrum analyzer's control and data collection. After the user selects a start or center frequency and a span frequency, computations are performed to set up the various LOs that need...
FIG. 10—PC BUS INTERFACE CIRCUITRY. The entire LPT interface is performed by IC4 and IC5. Those two 74LS244's buffer the signals to and from the LPT interface.
The steps are determined by the ADC data from the RSSI appropriate LO's and collecting data computer starts sweeping the ap-}

\[ \text{...} \]

everything is properly set up, the steps used for the tuner are 125 MHz RBW is 10 kHz, the 455-kHz RSSI output is read. If the

\[ \text{...} \]

continuously, but rather in steps. The LO's are not swept to be swept using the PLL's. Once the computer starts sweeping the appro-

\[ \text{...} \]

appropriate LO's and collecting data via the ADC data from the RSSI outputs.

If the RBW is 280 kHz, the 10.7-MHz RSSI output is read. If the RBW is 10 kHz, the 455-kHz RSSI is read. The LO's are not swept continuously, but rather in steps. The steps are determined by the internal settings of the PLL's. The steps used for the tuner are 125 kHz and 62.5 kHz. Steps for the 455-kHz IF are 3.90625 kHz. Those different step sizes are needed to accommodate the two filter bandwidths of 280 kHz and 10 kHz. As the computer is sweeping the LO's, it is also con-

\[ \text{...} \]

trolling the AGC via the DAC, which is there to keep the gain flat.

The overall basic sequence is

\[ \text{...} \]

1. Command LO's to the next fre-

\[ \text{...} \]

2. Set AGC level from the look-up table.

3. Allow adequate time for set-

\[ \text{...} \]

ting of PLL's.

4. Read RSSI voltage.

5. Calibrate RSSI data to Power in dBm.

6. Display the power/frequency pair on the screen.

7. Repeat.

Those operations are performed continuously by the computer until interrupted by the user.

In our next edition, we'll go over the software, kit con-

\[ \text{...} \]

struction, tuning, power calibration, and troubleshooting of the spectrum analyzer.
ELECTROCARDIOGRAPH

Keep an eye on your health and learn about medical electronics with the Radio-Electronics electrocardiograph.

H. EDWARD ROBERTS, M.D.

LAST MONTH WE DISCUSSED THE OPERATION OF THE CIRCUITRY for our electrocardiograph, or ECG. This month we'll build the unit and explain how to use it.

ECG construction

The ECG is relatively simple to build. Double-sided plated-through, silk screened, and solder masked PC boards, as well as all of the necessary components, are available from the supplier listed in the sources box. Software for checkout, data-acquisition, and display are also available. However, we are providing foil patterns so you can make your own PC boards, and we'll post the software on the RE-BBS (516-293-2283, 1200/2400, 8N1) as ECG.ARC.

Mount the components according to the part-placement diagrams—Fig. 1 for the controller board and Fig. 2 for the front-end board. Most of the ICs are CMOS, and must be handled accordingly. A grounded work bench and soldering iron are strongly recommended, and a static wrist strap is also a good idea. We also recommend you use IC sockets for all the ICs.

Install the IC sockets first, making sure they are flush with the PC board. Then solder in the remaining components on both boards. Make sure the polarized components are properly oriented before you solder them. Inspect the finished boards thoroughly before beginning the system checkout. Do not insert the ICs in their sockets just yet, and don't wire the two boards together until instructed to do so. The finished controller board is shown in Fig. 3 and the finished front-end board is shown in Fig. 4.

Checkout

Begin the system checkout by attaching an RS-232 cable between your PC and the DB25 connector on the controller board. The cable should be wired as shown in Fig. 5 if your PC has a 9-pin communications port, or as shown in Fig. 6 if your PC has a 25-pin communications port. Apply power to the PC and measure the voltage at pins 1 and 8 of IC19. Pin 1 should read about +12V and pin 8 about -12V. Also, check pin 14 of IC26 for 5 volts. If those voltages are correct, install the ICs in the controller board and proceed with the checkout.

Install an unused battery in the B3 battery clip and insert the battery in the holder. Press the reset button on the controller board and measure the output of voltage-regulator IC32 at pin 3. If the output is about 5 volts, the power-on circuitry is working. Remove the battery from the circuit.

The remainder of the checkout will be accomplished by running a checkout program that provides a step-by-step procedure to verify each section of the controller and the front end. Some of the checkout software resides in the ECG program EPROM, IC9, on the controller board. The remainder of the checkout software runs on your PC.

When the checkout process is complete, install the two boards in the case and prepare to take your first ECG.

Take an ECG

Skin electrodes with a conductive adhesive back-
FIG. 1—MOUNT THE COMPONENTS for the controller board as shown here, and use IC sockets for all the IC's to reduce the risk of component damage during assembly.

are recommended to attach the leads from the ECG to the body. The electrodes are available from the source listed in the sources box. Stick one electrode on each wrist and ankle and at each of the six torso locations shown last month in Fig. 3. Use alcohol to clean the area where

COMPONENT SIDE of the controller board.

SOLDER SIDE of the controller board.
FIG. 2—MOUNT THE COMPONENTS for the front-end board as shown here. Most of the IC's are CMOS, so care must be used in handling them.

the adhesive electrodes will be placed to improve the connection and the signal, and place the electrode in an area with minimal body hair. Using the alligator clips, attach the appropriate lead to each skin electrode.

To acquire the ECG, make sure the ECG controller and your PC...
PARTS LIST—FRONT-END

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—R9, R13—20,000 ohms
R10, R24, R60, R63—30,000 ohms
R11—1800 ohms
R12, R25, R44—10,000 ohms, potentiometer
R14, R18, R26—470 ohms
R15, R17—19,200 ohms
R16—39.2 ohms, 1%
R19—200,000 ohms
R20—R22, R41—100 ohms
R23—1500 ohms
R27—910 ohms
R28, R39, R40, R43, R55, R59, R62, R65—100 ohms
R27—910 ohms
R28, R39, R40, R43, R55, R59, R62, R65—100 ohms
R29, R46, R48—15,000 ohms
R30—200,000 ohms, potentiometer
R31, R36—680,000 ohms, 1%
R32—500,000 ohms
R33—68 ohms
R34—15,000 ohms, potentiometer
R35—100 ohms
R37, R38, R43, R61—470 ohms
R42, R64—1000 ohms
R45, R51—680,000 ohms
R47—5000 ohms, potentiometer
R49—330,000 ohms
R50, R58—2200 ohms
R52, R56—1.5 meghm
R53—150 ohms
R54—150,000 ohms
R57—12,200 ohms
R65—3300 ohms
R66—1000 ohms, potentiometer

Capacitors
C1—C22, C25, C26, C28, C29, C33, C34—0.001 µF, tantalum
C1—C22, C25, C26, C28, C29, C33, C34—0.001 µF, tantalum
C1—C22, C25, C26, C28, C29, C33, C34—0.001 µF, tantalum
C16—39 pF, ceramic disk
C17—120 pF, ceramic disk
C18—0.01 µF, metal film
C19, C22, C31—0.47 µF, ceramic disk
C25—C30—1 µF, tantalum
C48, C49—47 µF, 16 volts, electrolytic

Semiconductors
IC1—IC3, IC9, IC10—LM348 op-amp
IC4—AD625 instrumentation amplifier
IC5—105, IC12—74HC245 bus transceiver
IC6, IC8—Altera EP320 PAL
IC7—Altera EP600 PAL
IC9—27C256 EPROM
IC10, IC11—55257 static RAM
IC13—74HC568 equality comparator
IC14—74HC138 1-of-8 decoder
IC15—82C55 UART
IC16, IC17—74HC573 octal latch
IC18—74HC74 dual D flip-flop
IC19—MC145406 RS232 transceiver
IC20—AD0829 A/D converter
IC21, IC22—DAC0830 D/A converter
IC23, IC24—NE5532A op-amp
IC25—74HC14 hex Schmitt inverter
IC26—74HC40 quad NAND gate
IC27—PS2501A-2 op-amp
IC28, IC31—not used
IC29—ICL7660 DC-DC converter
IC30—78L06AC voltage regulator
IC32—7805 voltage regulator
D1—D4—1N914 diode
D5—5.1-volt Zener diode
D6—6-volt Zener diode
Q1—IREFZ10 N-channel MOSFET
Other components
XTAL1—2.4576 MHz crystal
XTAL2—8 MHz crystal
S1—SPDT momentary contact switch
SO1—DB25 connector

are connected with the RS232 cable used when you checked out the system. Load and run the data collection batch file, ECG.BAT, in your PC. Input the patient information that the program requests, terminating each answer with a carriage return. After the last response, press the reset button on the ECG to initiate data collection. Make sure the patient does not move during the collection process.

You will see a message on the PC as soon as the data collection process starts. After about 30 seconds you will see a message on the PC indicating that data is being transferred between the ECG and the PC. That is an indication that the ECG has finished collecting data. After the data has been transferred, your PC will begin processing it for display. Depending upon the speed of your PC, the graphs of the ECG will appear after a few seconds of processing. In addition to the plots shown on the CRT, each of the plots may be sent to your dot-matrix printer for a permanent record.

Now let’s examine the hardware and software interactions involved with taking the ECG you just finished. First, assume the RS232 ports between the ECG and the PC have been connected, the PC has been booted, and the ECG batch file run. As soon as the ECG reset button is pressed, the microprocessor in the ECG controller boots up and enters a wait loop, waiting for the PC to announce to the ECG that it is time to begin taking data. After the initialization prompts for patient information, and the name of the file that will be used to store the ECG data has been entered through the PC keyboard, the PC

PARTS LIST—CONTROLLER BOARD

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—10 ohms
R2, R7—R10—10,000 ohms
R3—R6, R15, R16—1000 ohms
R17—7500 ohms
R12—24,000 ohms
R13—30,000 ohms
R14—10,000 ohms x 8, SIP

Capacitors
C1—C22, C25, C26, C28, C29, C33, C34—0.47 µF, ceramic disk
C23, C24—22 pF, ceramic disk
C27, C30—0.001 µF, metal film
C31—220 pF, ceramic disk
C32—10 µF, 10 volts, electrolytic
C34—C38, C39—10 µF, 10 volts, tantalum
C36, C37, C40, C41—1 µF, 10 volts, tantalum

Semiconductors
IC1—Z80 CPU
IC2—IC5, IC12—74HC245 bus transceiver
IC6, IC8—Altera EP320 PAL
IC7—Altera EP600 PAL
IC9—27C256 EPROM
IC10, IC11—55257 static RAM
C13—74HC568 equality comparator
C14—74HC138 1-of-8 decoder
C15—82C55 UART
C16, IC17—74HC573 octal latch
C18—74HC74 dual D flip-flop
C19—MC145406 RS232 transceiver
IC20—AD0829 A/D converter
IC21, IC22—DAC0830 D/A converter
IC23, IC24—NE5532A op-amp
IC25—74HC14 hex Schmitt inverter
IC26—74HC40 quad NAND gate
IC27—PS2501A-2 op-amp
IC28, IC31—not used
IC29—ICL7660 DC-DC converter
IC30—78L06AC voltage regulator
IC32—7805 voltage regulator
D1—D4—1N914 diode
D5—5.1-volt Zener diode
D6—6-volt Zener diode
Q1—IREFZ10 N-channel MOSFET
Other components
XTAL1—2.4576 MHz crystal
XTAL2—8 MHz crystal
S1—SPDT momentary contact switch
SO1—DB25 connector

ORDERING INFORMATION

Note: The following items are available from DataBlocks, Inc., Glenwood, GA 30428, (912) 588-7101.

- Design package including schematics, assembly instructions, and checkout- and plot-software design specifications (ECG-DP): $27.00.
- Front-end PC board, controller PC board, and design package from above (ECG-PC): $74.00.
- Complete kit of parts, including both PC boards, IC’s, sockets, passive components, design package, ECG software, and checkout software (ECG-KIT): $289.00.
- Lead kit consisting of 29-gauge shielded cable, 10 alligator clips, heat-shrink tubing, and instructions (ECG-LD): $53.00.
- EPROM containing ECG software, ECG resident portion of checkout software (ECG-PROG): $45.00.
- Set of four programmed PAL’s (ECG-PAL): $67.00.
- Case as shown with mounting hardware (ECG-CASE): $29.00.
- Package of 100 self-adhesive electrodes (ECG-EL): $20.00. Please include $5.00 shipping and handling for design package and electrodes, $10.00 shipping and handling for all other products. Georgia residents must add sales tax.
FIG. 3—THE FINISHED CONTROLLER BOARD will look similar to this one, although this is an early prototype board. Inspect the finished boards thoroughly before beginning the system checkout.

FIG. 4—THE FINISHED FRONT-END BOARD. This, too, is an early prototype, so your board won't look exactly like this one. Do not wire the two boards together until you are told to do so.

software transmits a control character to the ECG that causes it to start the ECG data-collection process.

The ECG turns both batteries on and enters a calibration routine. The first part of the routine determines whether the batteries are charged. That is accomplished by digitizing the output of IC10-d in the front-end electronics with the differential inputs to the instrumentation amplifier, both connected to ground through IC7. If the batteries are good, the voltage measured will be the 2.5-volt offset from the differential amplifier. If both batteries are not fully charged, the voltage from the divider formed from R31, R34, and R36 will change, causing the output of IC10-d to change from the expected 2.5 volts. If the batteries are not good, the ECG outputs a "low battery" message to the PC and stops. If the batteries are good, the channel calibration routine is entered.

The channel calibration routine determines the appropriate channel offset for each of the nine input channels. That is accomplished by sequentially connecting each of the input channels to the positive input of the differential amplifier and comparing its voltage to that of the Wilson electrode connected to the negative input of the differential amplifier. If those two voltages are equal, the digitized output of the differential amplifier will be its offset voltage, 2.5 volts. If the input lead is not equal to the Wilson electrode, a bias is added to the channel by incrementing the output of either IC21 or IC22 in the appropriate direction; IC21 is used for coarse changes, while IC22 is used for smaller increments. That change is added to the output of the other D/A converter at the summing junction of IC24-b and passed to the front-end board.

On the front-end board, the change goes through the optical isolator IC17-a and op-amp IC9-c to the summing junction of IC3-c, where it adds with the input channel being measured. After an appropriate delay to let the voltages in the loop settle, the output of the differential amplifier is sampled again. The process is continued until the difference between the input channel and the Wilson electrode voltage is within acceptable limits, at which time the system sequences to the next channel. The digital values required to adjust the analog output of IC21 and IC22 to bring the channel biases within acceptable limits are stored in the software to be used during the data-acquisition process.

The data-acquisition routine is entered immediately after the last channel bias has been determined. This routine digitizes the difference between each input lead and the Wilson electrode, in sequence, and stores the sample in memory. Prior to digitizing the sample, the channel bias values for the channel being sampled, determined during the calibration sequence, are retrieved from the software and placed in the D/A converters, as previously described. Each channel is sampled as rapidly as the processing and loop settling time will permit. The software then enters a wait period before sampling the next data set to achieve a 400-sample-per-second rate on each of the nine channels. Two thousand samples are obtained from each channel and placed in memory for subsequent transfer to the PC for display.

At the completion of the data-acquisition phase, the ECG controller turns the batteries BI and B2 off and signals the PC that the data is available for transfer. When the PC detects that it acknowledges the message and starts its transfer routine. The ECG also sets up a transfer routine and the data is passed from the ECG to the PC. At the conclusion of the transfer, the ECG powers itself down, waiting for the PC to signal that it is time to acquire another ECG. The PC begins to process the data it just received during the transfer.

The data transferred to the PC must be processed before it can be displayed as one of the twelve standard ECG leads. Remember that the digitized information is the difference between the input channel and the Wilson electrode. The first six ECG leads, however, are combinations of in-
put channels compared with one or more other input channels. For example, consider the standard ECG lead I. This lead is defined as the electrical activity from the heart measured on the left arm with respect to the right arm. Let \( S_1 \) designate a sample from the right arm with respect to the Wilson electrode, and \( S_2 \) designate a sample from the left arm with respect to the Wilson electrode. In other words:

\[
\begin{align*}
S_1 &= RA - W \\
S_2 &= LA - W
\end{align*}
\]

Now,

\[
I = LA - RA = (S_2 + W) - (S_1 + W)
\]

so that the PC must subtract Sample 1 from Sample 2 to get lead I. In an analogous manner leads II and III are derived from their definitions as:

\[
\begin{align*}
II &= S_2 - S_1 \\
III &= S_3 - S_1
\end{align*}
\]

The augmented leads are somewhat more complicated to derive from the samples. Recall that an augmented lead is defined as the electrical activity on one of the three input leads with respect to the other two leads. For example:

\[
AVR = RA - (LA + LF)
\]

Now,

\[
\begin{align*}
S_1 &= RA - W \\
S_2 &= LA - W \\
S_3 &= LF - W
\end{align*}
\]

so that

\[
AVR = S_1 - S_2 - S_3 - W
\]

Recall that \( W \), the Wilson electrode, is the sum of RA, LA and LF (\( W = RA + LA + LF \)) so that:

\[
\begin{align*}
S_1 &= RA - W = RA - RA - LA - LF \\
S_2 &= LA - W = LA - RA - LA - LF \\
S_3 &= LF - W = LF - RA - LA - LF \\
LF &= - RA - LA
\end{align*}
\]

Adding the samples:

\[
\begin{align*}
S_1 + S_2 + S_3 &= - 2RA - 2LA - 2LF = -2W \\
or \quad W &= -(S_1 + S_2 + S_3)/2
\end{align*}
\]

and

\[
\begin{align*}
AVR &= S_1 - S_2 - S_3 - W \\
&= S_1 - S_2 - S_3 + (S_1 + S_2 + S_3)/2
\end{align*}
\]

Using the same arithmetic, it can be shown that:

\[
\begin{align*}
AVL &= S_2 + (S_2 - S_1 - S_3)/2 \\
AVF &= S_3 + (S_3 - S_2 - S_1)/2
\end{align*}
\]

The chest leads V1 through V6 are defined as simply the electrical activity on the lead with respect to the Wilson electrode.

The processed data is stored on your disk drive under the file name you entered. In addition, three traces are plotted on the CRT with each trace broken into four parts. The traces are segmented as follows:

Trace 1 = Lead I, AVL, V1, V4
Trace 2 = Lead II, AVR, V2, V5
Trace 3 = Lead III, AVF, V3, V6

You should have enough information now to use the ECG. However, if you’re not a doctor, don’t think of yourself as one—and be sure to see a medical doctor if you suspect any health problems.
BUILD THIS POWERFUL SERIAL-BUS ANALYZER FOR A FRACTION OF THE COST OF COMMERCIAL UNITS—AND LEARN ABOUT THE EVER-POPULAR 68705 MICROCONTROLLER IN THE PROCESS.

RS-232 TERMINAL/MONITOR

STEVEN AVRITCH

HAVE YOU EVER BEEN FRUSTRATED BY A PROBLEM WITH AN RS-232 LINE? INEXPENSIVE BREAKOUT BOXES WITH FIVE OR SIX LEDS SUFICE FOR SOLVING SIMPLE PROBLEMS, BUT THEY DON'T PROVIDE ENOUGH INFORMATION TO DEBUG THE SERIOUS KIND. ON THE OTHER HAND, FULL-FEATURED SERIAL BUS ANALYZERS (SBAS) GIVE YOU ALL THE DEBUGGING INFORMATION YOU NEED, BUT CAN COST CLOSE TO $1000.

However, you don't really have to spend that much. Now you can build a powerful RS-232 monitor that does most of what the expensive SBAs do, yet doesn't cost much more than a quality breakout box. In addition, this project can also be used as a portable, battery-operated terminal. Features are summarized in Table 1.

Hardware design

The heart of the project is Motorola's MC68HC705C8 single-IC microcontroller, a 40-pin DIP containing built-in PROM, RAM, serial and parallel I/O ports, timer, and clock.

The monitor requires two serial receivers: one for the TXD line and one for the RXD line. Because the microcontroller has only one built-in serial port, a second one has been implemented in software. However, the second port still requires a ±12-volt RS-232 interface. The schematic is shown in Fig. 1, and the wiring diagram is shown in Fig. 2.

A Maxim MAX232 RS-232 transceiver (IC2) provides the transmission portion of the interface; it converts TTL signals from the microcontroller to RS-232 levels. Unlike most RS-232 transceivers, which require separate +12- and -12-volt power supplies, the MAX232 has built-in charge pumps that generate the required voltages from a single 5-volt supply. A standard 1489 device (IC4) converts incoming ±12-volt signals to TTL levels.

Switch S1 is a DPDT unit that selects terminal or monitor mode. In terminal mode the CPU controls the logic levels of both lines. However, in monitor mode, all lines from the primary port (J1) are directly connected to the secondary port (J2), in which case all signals pass straight through and the device simply monitors TXD and DTR.

Other notable components include XTAL1 and the keyboard. The crystal is a standard, readily available device; it must have a frequency of exactly 2.4576 MHz in order to generate the correct baud rates. The keyboard is a surplus unit from an old TI-99/4 personal computer; the keyboard is inexpensive and readily available through many suppliers.

A beeper may be connected to pin 19 (port B7) of the microcontroller. The beeper will sound whenever the monitor detects a bell character (ASCII 07 or Ctrl-G). The beeper must be TTL-compatible (meaning that it must be powered from a 5-volt supply and draw less than 3 mA).

The low power consumption of the microcontroller allows it to operate over a wide range of input voltages (8–15 volts DC); IC3 provides voltage regulation. The output of IC3 is 6 volts; diode D2 drops voltage even further, to about 5.3 volts. D1 provides reverse-polarity input protection.

Operating modes

The RS-232 Terminal/Monitor has four basic modes of operation, as shown in Table 2. You use the keyboard to select mode, as well as a variety of operational parameters. In use, you must place S1 in the Terminal position when in terminal mode, and in the Monitor position when in any of the three display modes.
The terminal-mode display is similar to a dumb ASCII terminal, except that the display is limited to forty characters by two lines. The CPU converts keyboard characters to ASCII, then transmits them over the serial link. Conversely, received characters are displayed in ASCII on the LCD screen.

The Display Bits mode continuously displays the status of the six primary RS-232 signals, as shown in Fig. 3-a. The Display ASCII mode shows activity on the TXD and RXD lines. TXD data appears in ASCII on line one and RXD data on line two (Fig. 3-b). The Display Hex mode is similar, except that each character appears in hexadecimal format, as shown in Fig. 3-c. (A period indicates that the line was inactive when a character was received on the other line.)

---

**TABLE 1—FEATURES**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-character x 2-line LCD display</td>
<td></td>
</tr>
<tr>
<td>Full keyboard</td>
<td></td>
</tr>
<tr>
<td>Selectable baud rate (300 – 19,200)</td>
<td></td>
</tr>
<tr>
<td>Selectable protocol (number of data and parity bits)</td>
<td></td>
</tr>
<tr>
<td>Programmable scroll rate</td>
<td></td>
</tr>
<tr>
<td>Recall of last two lines displayed</td>
<td></td>
</tr>
<tr>
<td>8- to 15-volt DC power (9V battery is perfect)</td>
<td></td>
</tr>
<tr>
<td>CMOS design for low current drain and long battery life</td>
<td></td>
</tr>
</tbody>
</table>

---

**TABLE 2—MODES OF OPERATION**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>The unit acts as a simple RS-232 &quot;dumb&quot; terminal. The unit can be connected anywhere a dumb terminal is needed.</td>
</tr>
<tr>
<td>Display Bits</td>
<td>Displays status (high or low) of the six primary RS-232 lines (TXD, RXD, RTS, CTS, DSR, DTR).</td>
</tr>
<tr>
<td>Display ASCII</td>
<td>Displays TXD (line 1) and RXD (line 2) activity in ASCII format.</td>
</tr>
<tr>
<td>Display Hex</td>
<td>Like Display ASCII mode except hexadecimal display.</td>
</tr>
</tbody>
</table>

---

FIG. 1—SCHEMATIC OF THE TERMINAL MONITOR. The keyboard is a surplus unit from a TI 99/4 computer.
FIG. 2—WIRING DIAGRAM for the terminal/monitor. Connectors J4 and J5 are standard DB-25 males.

FIG. 3—DISPLAY SAMPLES. The Display Bits mode is shown in a; the ASCII mode is shown in b, with TXD on top and RXD on the bottom; and the hex mode is shown in c, again with TXD over RXD.

Table 3—Function Requests

<table>
<thead>
<tr>
<th>1st</th>
<th>Description</th>
<th>2nd</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Select mode</td>
<td>1</td>
<td>Terminal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Display Bits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Display ASCII</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Display Hex</td>
</tr>
<tr>
<td>0</td>
<td>Display current parameters</td>
<td>0</td>
<td>19,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>9600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>4800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>300</td>
</tr>
<tr>
<td>1</td>
<td>Set baud rate</td>
<td>0</td>
<td>19,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>9600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>4800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>2400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Set Protocol</td>
<td>0</td>
<td>8N1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>7N1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>7E1</td>
</tr>
<tr>
<td>3</td>
<td>Set scroll rate delay</td>
<td>0-9</td>
<td>0 = off, 9 = max</td>
</tr>
<tr>
<td>4</td>
<td>Toggle scroll/two-line mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Enable/disable linefeed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Recall last two lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Toggle local/online modes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Display help information</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

During operation in ASCII or hex mode, you can press Cntl-S to halt input temporarily and read what is displayed. Then simply press Cntl-Q when you’re ready to continue.

The monitor has several keys that can produce more than one symbol. For example, the question mark symbol is located on the front of the “I” key. To produce a question mark, press I and the FCTN key simultaneously.

Function requests

You can change several operating characteristics by pressing special key combinations, as shown in Table 3. To set a given parameter, press FCTN and the key shown in column one of the table.

Select Mode. Press FCTN-M, then press 1–4 to select mode.

Current Parameters. Press FCTN-0 to view current settings for mode (terminal), baud rate (1200), protocol (7E1), scroll rate (0), scroll mode, linefeed status (enabled), and on/off-line status (on-line). (Default values shown in parentheses.)

Set Baud Rate. Press FCTN-1 to set baud rate. The monitor runs from 300 to 19,200 bits/sec, but the maximum rate in ASCII and Hex Display modes is 9600.

Protocol. Press FCTN-2 to define the number of data bits (7, 8), parity (Even, Odd, None), and stop bits (1, 2) in each byte sent or received. The terminal currently supports three popular formats: 8N1, 7O1, and 7E1.
PARTS LIST

All resistors are 1/4-watt, 5%
R1-10,000 ohms, PC-mount potentiometer
R2—10 megohms
R3, R13—10,000 ohms
R4—R12—10,000 ohms, SIP

Capacitors
C1—1 µF, 16 volts, radial electrolytic
C2, C3—18 pF, ceramic disk
C4, C5—100 µF, 25 volts, axial electrolytic
C6—0.01 µF, ceramic disk
C7—C10—10 µF, 16 volts, radial electrolytic

Semiconductors
IC1—MC68HC705C8 CMOS microcontroller
IC2—MAX232 5-volt RS-232 transceiver
IC3—MC7806CT 6-volt regulator, TO-220 case
IC4—MC1489A RS-232 receiver
D1, D2—1N4148 switching diode

Other Components
XTAL1—2.4576 MHz
J1—16-pin 0.1” dual-row header
J2—30-pin 0.1” dual-row header
J3—8-pin 0.1” dual-row header
J4, J5—DB25 connector, male
S1—DPDT switch
BZ1—TTL-compatible beeper (Radio Shack #273-65 or equivalent)
Display—40 × 2 line LCD display module (Hitachi LM018L or equivalent)
Keyboard—Surplus TI-99/4 (48-key, 15-pin connector)

Note: The following are available from Simple Design Implementations, P.O. Box 9303, Forestville, CT 06010. (203) 582-8526:
- Complete kit including everything in parts list, IC sockets, PCB board, instructions, and schematic—$75 + $5 S/H
- Preprogrammed MC68HC705C8, instructions, and schematic—$28.00 + 2.50 S/H
- Software on 5¼-inch IBM-compatible floppy disk—$15.00 + $2.50 S/H
- PC board only—$13 + $2 S/H.
CT residents please add 8% sales tax.

Scroll Rate Delay. Press FCTN-3 to vary scroll rate. Data may scroll by faster than you can read it: variable scroll rate allows you to reduce scrolling speed by disabling the DTR line for a while after receiving each carriage return. Scroll-rate delay may vary from 0 (no delay) to 9 (maximum delay—about three seconds). The device connected to the monitor must recognize DTR and stop sending data when it is low. This works only in terminal mode.

Two-line/Scroll Mode. Press FCTN-4 to switch between the continuous scrolling and two-line modes. In scroll mode the terminal scrolls incoming data at the scroll rate set by FCTN-3. In two-line mode the terminal stops the display every time both display lines are filled. You must then press the space bar to continue. This feature works only in terminal mode.

Enable/Disable LF. Press FCTN-5 to switch between responding to and ignoring incoming linefeed characters. Some terminals, modems, and host systems issue a linefeed (LF) in addition to a carriage return (CR) at the end of every line. Extra linefeeds cause a blank line to be displayed on the screen, hence make it difficult to read. Tell the monitor to ignore extra linefeeds by selecting the LF Disabled mode. This feature works only in terminal mode.

Recall Last Two Lines. Press FCTN-6 to review the last two lines that scrolled off the screen. Press any key to return to the current two lines. Note that communication is disabled via the DTR line when displaying the last two lines. This feature works only in terminal mode.

Help. Press FCTN-H to view a brief summary of the function associated with each. You are able to view this screen from any operating mode.

Local/On-line Mode. Press FCTN-L to switch between local and on-line modes. In local mode, RS-232 communications are disabled: characters typed on the keyboard appear on the LCD display immediately. In on-line mode, RS-232 communications are enabled. Characters typed on the keyboard are transmitted over the serial link and are not displayed until they are echoed by the host system. This feature works only when used in the terminal mode.

Interfacing
To use the device as a dumb
TABLE 4—TERMINAL VOLTAGES

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>-7 to -12 VDC</td>
</tr>
<tr>
<td>3</td>
<td>0 VDC</td>
</tr>
<tr>
<td>7</td>
<td>Check for continuity to ground</td>
</tr>
<tr>
<td>8</td>
<td>0 VDC</td>
</tr>
<tr>
<td>20</td>
<td>Press Ctrl-S and Ctrl-Q to toggle between +7 to +12 and -7 to -12 VDC</td>
</tr>
</tbody>
</table>

ASCII terminal, be sure to place switch S1 in Terminal position, then make sure that the unit is operating in terminal mode, and then enter the correct operating characteristics (baud rate, protocol, etc.). Last, connect the unit to the host system via a standard 25-conductor cable. If the unit doesn’t seem to work, you may need to reverse pins 2 and 3 using a null-modem cable or adapter.

To use the device as a monitor, connect it in series with the two devices (host and terminal, host and modem, etc.), place S1 in Monitor position, and choose one of the terminal modes. Then all you have to do is set protocol, baud rate, etc.

Software
The MC68HC705C8 software consists of an assembly-language program; unfortunately the listing is too long for publication. The program must be assembled and the resultant object code must be burned into the microcontroller’s built-in EPROM. If you don’t have facilities for assembling the program and burning it in, don’t worry—you can purchase a pre-programmed MC68HC705C8 from the author; take a look in the parts list for details.

If you wish to modify the source code (or maybe just look at it over), you can download it from the RE-BBS (516-293-2283, 1200/2400, 8N1) as a file called SMART232.SRC, or you can otherwise order it directly from the author.

Construction
You can build this project using wire-wrap or a PC board. A foil pattern is provided if you’d like to make your own board; you can also purchase a ready-to-use board from the source mentioned in the parts list if you don’t want to make your own.

Using Fig. 4 as a guide, assemble the PC board starting with the passive components. Then mount sockets for the IC’s, connectors J1–J3, and don’t forget the two jumpers. Check your work carefully, correct any mistakes, and then insert the IC’s into the sockets. Connect the cables from the keyboard and LCD module. Then make the connections between J1, J2, and the PC board. A photograph of the author’s prototype unit is shown in Fig. 5.

After verifying all wiring, apply power to the unit; a brief sign-on message should appear on the display. Adjust Contrast potentiometer R1 for best effect. Now set switch S1 to the appropriate position, and set the desired mode and operating characteristics using the Function keys. That’s all there is to it!

Troubleshooting hints
If the sign-on message does not appear on the display on power-up, the most likely cause of the problem is a wiring error. The error is probably in the power or ground lines (IC1, pins 20 and 40), the oscillator lines (IC1, pins 38 and 39), the reset line (IC1, pin 1) or the display interface lines (pins 1–6 and 11–14 of the LCD display).

If the terminal comes up with the initialization message but does not seem to communicate, check the keyboard and RS-232 driver. Check the keyboard by pressing FCTN-0 to display system parameters. If they don’t appear, check the keyboard wiring. If the terminal does display system parameters, press FCTN-L to put the terminal in local mode and then test the keyboard by pressing every key and checking for the correct letter on the display. If the keyboard checks out, the problem is probably located somewhere in the RS-232 driver, in the cabling, or in the RS-232 line itself.

Remove the connector from the terminal’s primary port, set the DPDT switch to terminal mode, and check the voltages on the terminal’s primary port. They should be close to the values shown in Table 4. If any of the values do not agree with Table 4, check the wiring of the RS-232 driver (IC2).

Wrapping up
The author housed his prototype in a custom-built enclosure that resembles a miniature RS-232 terminal. You could use an off-the-shelf metal or plastic case just as well. Just keep in mind that, however you package it, this terminal/monitor is a useful and fun project.

R-E
This simple circuit will protect your stereo speakers in the event of amplifier failure.

**MARK A. VAUGHT**

The circuit is very versatile and can be customized for many different applications. Plans for home stereo, automotive, and commercial PA/guitar amplifier applications are included.

The most common cause of speaker failure is catastrophic amplifier failure. That's in contrast to the conception that the speaker has been overdriven by an amp that’s operating normally. Most often the speaker power level has been chosen to match the driving amplifier. Semiconductors designed to handle high current, such as bipolar power transistors and MOSFET’s, usually short when they blow out. Often these devices are connected directly to an amplifier’s DC power-supply rails or through a small amount of resistance that can’t effectively limit the current when the short occurs.

The DC level of an amplifier’s power supply is designed to accommodate the peak power levels that occur when the amp is driving the speaker at full power. A 100-watt amplifier has powersupply rails of at least 40 volts. Under normal operating conditions, that level would never be applied to the speaker coil for more than a few seconds. However, if an output device in the amp shorts, the DC is applied to the speaker continuously. In the case of a 100-watt amplifier, that causes a power dissipation of:

\[ P_D = \frac{(40V/speaker resistance)40V}{speaker resistance} \]

Speaker resistance is usually one to two ohms less than the AC impedance. If a blown amplifier is connected to a 100-watt speaker with a 7-ohm DC resistance, the power being dissipated is:

\[ P_D = \frac{(40V/7\Omega)40V}{7\Omega} = 228 \text{ watts} \]
The speaker will be able to dissipate that power for only a couple of seconds before the coil is damaged due to excessive heat.

When the protector circuit senses a DC voltage on the speaker line, it activates a relay whose contacts are in series with the speaker; after two seconds the relay disconnects the speaker until the DC is removed. A fuse is inadequate for this application because the value needed to protect the speaker against DC will blow out at peak power levels during normal operation. Conversely, a fuse value chosen to allow peak power operating levels will not protect the speaker against a DC voltage. The protector circuit allows peaks to occur in the power level and also protects the speaker against DC. It should be used in conjunction with a fuse value calculated from peak power levels. The fuse should be placed as close to the amplifier as possible, if not in the same chassis, and is therefore not shown in the protector circuit’s schematic.

Circuitry

The protector circuit’s schematic is shown in Fig. 1 and the power supply is shown in Fig. 2. Up to four individual protector circuits can be powered from one supply, although most applications will require only one or two circuits per chassis. The optional 9-volt DC output jack can be used to power a footpedal or fuzzbox, eliminating the need for a DC wall transformer when the circuit is used to protect guitar-amplifier speakers. The power supply can be modified for different applications, and we’ll talk about them later.

Referring to Fig. 1, the voltage-divider resistors R3-R6 are used to bias the positive and negative inputs of the window comparator formed by IC1-a and IC1-b. The inputs are biased at plus 3 volts. The voltage divider also provides a 9-volt reference for the negative input of comparator IC1-c.

Resistors R1 and R2 form an input voltage divider fed from the speaker terminals of an audio amplifier. The input divider is referenced to analog ground, and the output of the divider is connected to the negative and positive inputs of the window comparator (IC1-a and IC1-b). The outputs of IC1-a and IC1-b are open-collector stages, wired together and pulled high through R7. That forms a wired OR function and completes the window comparator. When the output of the R1-R2 voltage divider exceeds the reference levels set by R4 and R5, the output of the window comparator goes low and removes the bias from Q1. The input voltage at which this happens is determined by the value of R1. The formulas for calculating R1 are presented later in this article. Transistor Q1 is turned off while the output of the window comparator is low, thus allowing timing-capacitor C1 to begin charging through R8.

Under normal input conditions (an AC audio signal), the output of the window comparator will return to a high level when the input returns to the plus and minus 3-volt range. That biases Q1 into conduction and immediately discharges C1. If a DC signal large enough to trigger the window comparator is present on the input, then Q1 will remain in its off state and C1 will charge until it reaches 9 volts with reference to the power-supply ground. When C1 reaches 9 volts it triggers comparator IC1-c causing its output to go high and bias Q2 into conduction via R9. When turned on, Q2 grounds one end of relay RY1 thereby activating it and disconnecting the audio passing through its contacts from the speaker. The relay contacts will remain open until the DC input is removed from the protector circuit. Diode D1 protects Q2 against reverse-bias spikes generated by the relay coil.

The circuit has two separate grounds: a speaker ground and a power-supply ground. Under no circumstances should these two grounds be connected together. If two circuits are used together, then three entirely separate grounds will exist: a power-supply ground and a speaker ground for each circuit (see Fig. 3-a).

Some stereo amplifiers, especially those used in car-radio amplifiers, have differential or floating-ground outputs for each channel and cannot be connected together. Figures 3-a, -b, and -c are AC model diagrams showing the equivalent connection paths between two circuits.
operating from a single power supply. Figure 3-a clearly shows that the current flowing in either Loop 1 or Loop 2 is not a function of the other. The speaker grounds return to the common power supply rails through the voltage-divider resistors R3–R6. Figure 3-b shows the power-supply capacitor from 3-a, which is seen as a short to AC, replaced by a wire. Finally, in Fig. 3-c, the equivalent resistance between the two speaker grounds is shown as 30K.

If the amplifier speaker grounds are connected inside the amplifier, they should NOT be connected at the speaker protection circuit’s chassis. High current is assumed to be flowing in each speaker ground lead and connection of separate ground leads anywhere except between the amplifier will degrade performance.

Calculations
To calculate the value for R1, which determines the time it takes C1 to reach nine volts, the following example analysis is presented. The first step is to calculate the RMS (average) voltage applied to the speaker terminals to obtain the rated amount of power. We'll arbitrarily use 100 watts and a speaker load of 8 ohms. From the equation:

\[ P = \frac{1}{2} V^2 \]

we can substitute values

\[ I = \frac{1}{2} V \sqrt{2} \]

100W = (1/2)8 divide by 8

The square root of both sides

\[ I = 3.53 \text{ amps} \]

From the equation:

\[ V = IR \]

we can substitute values

\[ V = 8(3.53) \]

\[ = 28.28 \text{ volts RMS} \]

As a final check use the formula

\[ P = IV \]

we can substitute values

\[ P = 3.53(28.28) \]

\[ = 99.82 \text{ watts} \]

To calculate the value for R1 we use the equation:

\[ (V_{IN}(R2))/V_{OUT} - R2 = R1 \]

and substitute values

\[ = (128.28)(4.7)/3 - 4.7 \]

\[ = 39.60K \]

To calculate the fuse value for amplifier short-circuit protection, use the equation:

\[ V_{f} = \frac{V_{RMS}}{0.707} \]

and substitute values

\[ 28.28/0.707 = 40 \text{ volts} \]

From the equation:

\[ I = \frac{V_{f}}{R} \]

we can substitute values

\[ 40/8 \text{ ohms} \]

\[ = 5 \text{ amps} \]

If you would rather avoid making all of the calculations, Table 1 shows the correct resistance values to be used for R1 for 10- to 300-watt applications. Appropriate fuse values are also provided in Table 1.

The next step is to calculate the maximum time that C1 will charge, and the voltage level it will reach before it is discharged, under normal operating conditions. This is a necessary analysis in order to prove that the circuit will not trigger falsely when peak audio power levels are reached. The lowest frequency normally associated with audio is 20 Hz. It has the longest time period (50 milliseconds) in the audio spectrum so we'll use it for analysis of the speaker protector circuit. (An actual audio signal is quite complex, but the complexity of the waveforms only decreases the time that C1 will charge, so we'll therefore use 20 Hz.)
Referring to Fig. 4-a, to calculate the time that the input waveform is between 28 and 40 volts, we’ll first assume that $e_t$ is the instantaneous voltage level (28.28 VRMS). $E_M$ is the maximum or peak voltage level (40.00Vp), the frequency is $f$ (20 Hz), $\pi$ (3.14) is equal to 3.14, $t$ is the time for sine wave to reach 28.28 VRMS, and that $2\pi$ radians equals 360 degrees (and we’ll stick to degrees from this point on). That out of the way, from the equation:

$$e_t = E_M \sin(360f)$$

we divide by $E_M$:

$$\frac{e_t}{E_M} = \sin(360f)$$

we now take the inverse sign:

$$\sin^{-1}\left(\frac{e_t}{E_M}\right) = 360f$$

and divide by 360:

$$\left(\sin^{-1}\left(\frac{e_t}{E_M}\right)\right)/360f = t$$

now we substitute values:

$$\left(\sin^{-1}\left(\frac{28.28}{40}\right)\right)/360(20Hz) = 0.457200 = 6.25\text{ ms}$$

From those equations we can conclude that, for the sine wave of Fig. 4-a to travel from 0 to 28 volts (0.707 x peak value), it takes 6.25 ms, or one eighth of the total period (50 ms) of the waveform. 6.25 ms is also the time it takes the sine wave to return to zero volts. Therefore:

$$6.25\text{ ms}(2) = 12.5\text{ ms}$$

12.5 ms is the total time $C_1$ will charge (4-c). The last step is to calculate the voltage level of $C_1$ at $t = 12.5\text{ ms}$, and we’ll assume that $e_C$ is the capacitor voltage at $t$. $E$ is the power-supply voltage (12V), $e$ equals 2.718, $t$ equals 12.5 ms, $C$ equals 22 μF, and $R$ equals 68K. Now we take the equation:

$$e_C = E(1 - e^{-t/(CR)})$$

and substitute values:

$$= 12(1 - 2.718^{-12.5\text{ms}/(22\text{F}68\text{K})})$$

$$= 12(0.0084)$$

$$= 100\text{ mV}$$

The speaker protector circuit will disconnect the amplifier from the speaker after a 2-second interval using the values shown for $R_8$ and $C_1$. That amount of time will protect the speaker under most circumstances. Charging time for $C_1$ to reach 9 volts can be calculated by rearranging that equation and assuming that $e$ equals 2.718. $In$ is the natural log (the inverse of $e^x$). $E$ is the power-supply voltage (12V), $e_C$ is the capacitor voltage (9V), $t$ is the time for $C$ to charge to 9V, $C$ equals 22 μF, and $R$ equals 68K.

The rearranged equation is:

$$t = CR\ln\left(E/E - e^{-t/(CR)}\right)$$

now we substitute values:

$$t = (22\text{ F}(68\text{K}))(\ln(12/(12 - 9)))$$

$$= 1.49(1.39)$$

$$= 2.0\text{ seconds}$$

To change the time delay for the speaker protector circuit to disconnect the speaker from a DC voltage use the equation $R_8 = t/1.39C$ to recalculate the value of $R_8$.

**Construction**

Construction of the protector...
FIG. 5—PARTS-PLACEMENT DIAGRAM for the protector circuit. The 5-amp relay will mount right on the board, while the 15-amp relay must be mounted on the edge of the board using double-sided tape.

FIG. 6—PARTS-PLACEMENT DIAGRAM for the power-supply board.

circuit depends on the intended use. Once you have a clear idea of the application, then you can customize the circuit to meet your needs. To use the circuit to protect car-stereo speakers, replace R4 and R5 with 3-volt Zener diodes. That will ensure that the window-comparator reference voltages, with respect to analog ground, will be independent of the DC supply voltage. For power levels below 100 watts, you can use the 5-amp relay shown in the parts list; above 100 watts, you must use a 15-amp relay.

The parts-placement diagram for the protector circuit is shown...
in Fig. 5. The PC board is configured for on-board mounting of the 5-amp relay that the author used.

A compatible relay with a different pinout can be used. However, it may have to be mounted on the edge of the board using double-sided tape; it will then have to be hardwired to the board. The parts-placement diagram for the power-supply board is shown in Fig. 6.

After mounting all components, solder leads of adequate length to the board, and use different colors for the speaker and power ground leads to avoid connecting them together. Next, connect the power leads between boards, and connect an AC line cord to the power supply. The author’s completed unit, containing a protector circuit for both the left and right channels and one power supply, is shown in Fig. 7.

The completed boards can be mounted in a case like the one pictured in Fig. 7. Otherwise you can use whatever case you like. When drilling holes in plastic cases, start with a small drill bit and work your way up to the final size. Otherwise you may find yourself with a handful of plastic fragments.

As a final word, the circuit is designed to protect speakers from excessive DC levels caused by amplifier failure. However, it will not protect a speaker that’s rated at power levels much less than the driving amplifier can supply—only your own common sense in keeping the volume down will protect your speakers in a situation like that.

FIG. 7—HERE’S THE AUTHOR’S PROTOTYPE. It contains a protector circuit for both the left and right channels and one power supply. The entire unit is only about 4 inches wide by 6 inches long.

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If you've been looking for a way to generate high voltage, you've undoubtedly run across the voltage doubler. Voltage doubling using diode-capacitor combinations is a common practice. However, whole banks of doublers, called cascades, can also be used for producing extremely high DC voltages from moderate to high AC voltages. Such high DC voltages may be needed for TV sets, lasers, air purifiers, industrial smoke-stack dust removers, negative-ion generators, and, of course, for experimenting, on which we'll concentrate here.

**Half-wave doubler**

Figure 1 shows a half-wave voltage doubler; we'll assume that 

\[ C1 \text{ and } C2 \text{ are initially discharged.} \]

During the first half-cycle shown in 1, the upper terminal is positive and the bottom negative, so D1 conducts and C1 charges to about 170 volts peak. Diode D2 can't conduct, since it's back-biased, so C2 discharges through \( R_L \). In the second half-cycle (b), the analysis is similar, except that D2 conducts and C2 charges.

The circuit is really a transformerless voltage amplifier. While T1 can provide isolation, as well as increase the AC voltage initially going into the doubler, the amplification due to the doubling action would occur without it. When the polarity reverses, both the input voltage and the charge across C1 are in series like two batteries, producing about 340 volts peak. One problem, though, is that a half-wave doubler can't be used with a load that draws much current.

**Full-wave doubler**

Let's see how a full-wave voltage doubler is related to and built from both positive and negative half-wave rectifiers. Figure 2-a shows a half-wave rectifier with a positive output. Fig. 2-b shows the same version with a negative output, and Fig. 2-c shows the two combined into a full-wave voltage rectifier.

The full-wave voltage doubler shown in Fig. 3 has been redrawn for greater clarity; it has better regulation than a half-wave version, and is easier to filter. The circuit produces nearly double the peak AC voltage of 170 volts, or about 340 volts peak across \( R_L \). For the first half-cycle (a), D2 is cut off and D1 conducts, so that \( V_{CL} \) equals approximately 170 volts DC. On the next half-cycle (b), the positive voltage is replaced by a negative voltage, so D2 conducts and D1 is cut off. \( V_2 \) goes across C1 and C2 in series, effectively creating a doubled level of about 340 volts DC.

Unlike the half-wave voltage doubler, the full-wave version has two capacitors across \( R_L \) rather than one. Whereas C1 shown in Fig. 1 is cut off and unsupplied for half of every cycle, C1 and C2 in Fig. 3 are supplied on alternate half cycles. When the capacitor corresponding to the diode that's cut off discharges, it can only do so through the capacitor being supplied, slightly decreasing both its current and the maximum voltage it reaches.

**Measuring high-voltage DC**

Voltage measurements will be possible only to about the second or third stage of a cascaded voltage doubler with most voltmeters. Beyond that, you'll need to use either a high-voltage DC meter or an external voltage divider for use with a standard high-impedance voltmeter (10 megohms or more).

A good voltage divider that can be used for the purpose of high-voltage measurements is the RCA SK3868/DIV-1, a high-voltage DC divider; it's used in TVs to reduce the final anode voltage going to the CRT to the level required for the focus voltage. It consists of resistors R1 (200 megohms) and R2 (40 megohms) in series, as shown in Fig. 4. There are three leads, one for the free ends of each resistor, and the other at their juncture. If you put both a 10-megohm meter (shown as \( Z_M \) in Fig. 4) and a 2.7-megohm resistor (R3) in parallel with the 40-megohm resistor (R2), you can achieve almost exactly 100:1 range multiplication, for a full-scale deflection of 20 kilovolts DC.

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FIG. 1—HALF-WAVE VOLTAGE DOUBLER. During the first half-cycle (a), D1 conducts, D2 cuts off, C1 charges to 170 volts peak, and C2 discharges through R_L. For the second half-cycle (b), the input polarity is reversed, and both the input and C1 are in series, producing 340 volts peak. Now D1 cuts off while D2 conducts, and the current divides between C2 and R_L; the cycle then repeats.

FIG. 2—TWO HALF-WAVE RECTIFIERS, one with a positive output (a) and one negative (b), combine to make a full-wave voltage doubler (c).

Cascaded voltage doublers

Figures 5–8 show four additional voltage doublers. The one shown in Fig. 5 is the most straightforward. If you build it, use 1N4007 diodes with peak inverse voltage (PIV) ratings of 1 kilovolt for D1–D6, and 0.068–0.1 µF capacitors with working voltages of 400 volts DC. Figure 5 is electrically identical to the one in Fig. 6, so keep that in mind if you should come across either format. Figure 7 shows an extended version that's better stabilized for moderate-current applications; it's called either a Cockcroft-Walton or Greinacher cascaded voltage doubler.

You can use a sewing needle as an emitter for the doubler shown in Fig. 8 to generate "corona wind." That will sound like a hissing noise. (We'll show you how to demonstrate the "wind" later on.) The circuit delivers 3.75 kilovolts DC when powered from 120 volts AC, or 7.5 kilovolts DC when powered from 240 volts AC.

The output of a cascaded voltage doubler should be terminated with at least 200 megohms, and only then be allowed to extend beyond a protective plastic case, for safety. Voltages as high as 5 megavolts DC have been generated using...
cascaded voltage doublers, especially when operating in a pressurized atmosphere. The biggest advantage to using voltage doublers is that they use inexpensive low-voltage parts. Otherwise, if all the parts had to be of the high-voltage variety, you would have to use expensive and rather large capacitors like the one shown in Fig. 9.

If you have problems with the circuit in Fig. 8 (or any other high-voltage circuit), you must discharge every capacitor (we'll tell you how in a minute) before you check for malfunctions. When examining the circuit for problems, closely check the solder connections, and then the diode directions and continuity. The 1N4007's should have a resistance of 1.1K when forward-biased and be open when reverse-biased, while the capacitors should all have infinite resistance.

To properly discharge capacitors, build a discharging wand like the one shown in Fig. 10. Use a 2-foot wooden (or plastic) dowel, and connect a stiff wire tip (piano wire works well) to a cold water pipe as earth ground with a good electrical connection. Discharge all capacitors twice, since they generally either hold charge, or tend to recharge from other capacitors. Don’t use an AC line ground or chassis ground instead of an earth grounded water pipe, or you may blow a fuse or damage parts.

Figure 11 shows a switch for high-voltage DC that you can use with any of the cascaded voltage-doublers shown here; standard switches may present a shock hazard. Also, use an electromagnetic interference (EMI) line filter like the one seen at left in the photo to keep high-voltage DC out of house wiring, and to prevent shock from static charge. The EMI filter is from Corcom Corp. (1600 Winchester Road, Sewing Needle as emitter)

FIG. 7—THE COCKCROFT-WALTON, or Greinacher cascaded voltage doubler, has improved performance for moderate-current applications.

FIG. 8—THIS 25-STAGE VOLTAGE DOUBLER will generate “corona wind.” It delivers 3.75 kilovolts DC when powered from 120 volts AC, or 7.5 kilovolts DC when powered from 240 volts AC.

FIG. 9—HIGH-VOLTAGE CAPACITORS. A 0.25 µF, 7.5-kilovolt capacitor is on the left; a 100 pF, 15-kilovolt capacitor is in the middle; and 0.0005 µF, 5-kilovolt capacitor is on the right.

FIG. 10—A HIGH-VOLTAGE GROUNDING wand is used to discharge capacitors. A 2-foot wooden dowel is attached to a stiff wire tip. The metal tip must be connected to an earth ground, such as a cold-water pipe.

FIG. 11—HOME MADE SWITCH for high-voltage DC. The line filter at left is a safety measure to keep high-voltage DC out of the house wiring.

FIG. 12—A TYPICAL CASCADED voltage doubler. Note the wide spacings between the diodes, the long connecting wires, and the smooth solder joints.

FIG. 13—THIS IS THE DOUBLER from Figure 12, after being sealed in candle wax. For better protection, you can immerse it in pure paraffin oil.
FIG. 14—CORONA WIND DEMONSTRATION. The flame will deflect toward the ground plate. Note the black ground wire attached near the screw threads.

When you build a cascaded voltage doubler, you can encase the circuit in pure paraffin oil or candle wax to reduce the chances of getting shocked. It will also minimize corona loss, so the high-voltage DC arrives where it's needed. Figures 12 and 13 show a typical ladder-type voltage doubler before and after being sealed in wax.

**Experiments**

There are many experiments that can produce observable effects due to the high-voltage DC produced by voltage doublers.

- With a high-voltage emitter pointed at a ground plate (used to attract ions), with a burning candle placed in between them (see Fig. 14), you'll see the candle flame deflect toward the metal plate.
- You can make a rotor for an ion motor, using a light pivot made from a rivet with thin, stiff wire (like piano wire) attached, as shown in Fig. 15. The rotor must be balanced on top of the sewing-needle emitter (much as in a compass) used for the doubler shown in Fig. 8. (We ran a similar construction project in *Radio-Electronics*, February, 1991.) When powered up, the rotor will spin and a hissing sound will be heard. Both ends of the wire are bent at opposite right angles, so the emitted electrons propel the wire in a circle. You should sharpen both ends of the rotor wire to provide a sharp surface good for corona generation and electron emission. The sharpened ends will have a small radius of curvature (a tight curve or bend), giving rise to a highly distorted electric field at its surface. The high electric field is what tends to ionize air molecules in the vicinity.

- Another experiment you could try involves holding a fluorescent tube near the emitter. The tube will glow, but be careful not to touch the terminals on the ends, or you'll get a shock.
- Lines of force of an electrostatic field can be demonstrated by placing the electrodes (the high-voltage DC output and ground) in a tray covered with castor oil containing some farina. The farina will produce the pattern of the electric field lines: similar to iron filings shaken lightly on a piece of paper in the presence of a bar magnet.
- If you place two round door knobs on insulated stands made from plastic cups filled with candle wax, and then charge them, then a plastic ball suspended from a string will be drawn to and touch the positive electrode, and fall back to center when the spheres are discharged (see Fig. 16-a). A plastic ball coated with conductive lacquer swings toward the positive electrode like a pendulum: when the ball and doorknob touch, the ball becomes positively charged, so they repel one another. It then swings toward the negative side, absorbs electrons, becomes negatively charged, and is repelled back to the positive. The process repeats indefinitely as long as the high-voltage DC is present, and it will continue to operate for some time after it's shut off. The charge exchange is slow, and there'll be arcing at the positive electrode.
- A grounded metal ball alternates between both electrodes, like the conducting plastic ball. However, the arcs are smaller due to its greater weight, and should be observed at both ends, but more on the positive side.
- A light cotton ball should be drawn to the positive electrode and hang there by itself, as shown in Fig. 16-b. It's then repelled 0.5-inch toward the negative electrode, and the process should repeat indefinitely.

FIG. 15—THIS ION-MOTOR ROTOR, when placed on top of the sewing-needle emitter, will spin in a circle.

FIG. 16—TWO CHARGED DOOR KNOBS cause a suspended, lacquer-coated plastic ball to behave like a pendulum (a). A light cotton ball will bounce back and forth without being suspended on a string (b).
SOME OF OUR READERS MAY NOT BE AWARE that 1991 marks the 100th anniversary of the third edition of James Clerk Maxwell's *A Treatise on Electricity and Magnetism*, the ultimate reference on electromagnetic theory. What better way to recognize the impact that Maxwell had on the study of electromagnetics than to present the first of a series of articles in Radio-Electronics on the subject? In this edition, we will take a physical, intuitive look at the basics of electromagnetism, how they relate to some common electronic components, and how to interpret some of the complex mathematical symbolism. Only a familiarity with vector algebra is needed.

Maxwell's equations were first formulated in 1873. In his first publication, a mathematical foundation for relating electric and magnetic effects were given. In the Preface to the 1891 edition, J.J. Thomson noted that most of his students had difficulty with some aspects of electromagnetic theory. One hundred years later, not much has changed in that regard. One reason is that electromagnetic theory requires knowledge of some involved mathematics such as vector and tensor calculus and integral-differential equations.

Maxwell's idea that a changing electric field gives rise to an associated magnetic field developed from an intuitive sense for the natural order in the world. By presenting physical concepts in such an "intuitive" way, the reader will find it easier to understand Maxwell's equations, and his mathematical approach. Let's begin by examining the concept of an electric field.

**The electric field**

A scaler can be thought of as a quantity that can be completely characterized by its magnitude. Some examples of scaler quantities are mass, time, and volume. A scaler field is simply an extension of the scaler concept. It is a function of position that is specified by its magnitude at all points in a region of space. Land elevation is a two-dimensional scaler field because at each point of latitude and longitude there is an associated height above sea level. Air temperature is an example of a three-dimensional scaler field. With the appropriate instrument one could measure the height, or temperature, at each point. A scaler quantity is symbolized by a letter, such as h, for height.

A vector is a quantity that is characterized by its magnitude and direction. Some examples of vectors are velocity, acceleration, and force. A vector field is a function of position that is specified by its magnitude and direction at all points in a region of space. An example of a vector field is air velocity, where at each point in space, the magnitude and direction of air flow can be measured with the proper instrument. Vectors are often symbolized by letters with arrows above them, however, we will use boldface letters to indicate vectors.

When using vector notation, **A** is a vector with a specific magnitude and direction, and -**A** is a vector of the same magnitude but pointing in the opposite direction. Vectors are illustrated graphically by arrows, which have a direction and a corresponding length, which is proportional to the magnitude.

The field concept allows us to associate something that happens at one point with what hap-
produces a force $F_c$ directed opposite to $r_2$. The total force on $+q$ is the vector sum $F_c$.

A negative charge placed at a point in empty space, nothing appears to happen. But if another charge, $q$, is placed at another point, as shown in Fig. 1-b, the force vector of each would all add vectorially to give the total force

$$F_c = \sum_{k=1}^{n} \left[ k \frac{q_k q}{r_k^2} \right] r_k$$

where $r_k$ represents a vector of magnitude 1 (a unit vector which defines the direction) directed from $q_k$ to $q$. $r_k$ is the separation distance in meters. The constant of proportionality, $k$, is a number that is chosen to make the units work out. Coulomb's constant, $k$, has the value in a vacuum of

$$k = 9.0 \times 10^9 \text{ N m}^2/\text{C}^2$$

The value of $k$ in air is slightly greater. Using the mks system, the constant $k$ can also be written as

$$k = 1/(4\pi\varepsilon_0) \text{ N m}^2/\text{C}^2$$

which will give familiar units such as volts, ohms, and amperes. $\varepsilon_0$ is the permittivity of free space, and is equal to

$$\varepsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$$

The Coulomb force, $F_c$, on a charge, $q$, will have a magnitude proportional to the product of the charges, and inversely proportional to the square of the separation distance. That force will also be directed away from $q_1$. If one of the charges is negative, then the direction will be opposite. That force tends to provide an acceleration, $a$, to $q$ in the same direction. There is, of course, an equal and opposite force on $q_1$, and Coulomb's law for that is written by simply redefining $r$.

If there is a number, $n$, of point charges instead of just $q_1$ present, as shown in Fig. 1-b, the force vector of each would all add vectorially to give the total force

$$F_c = \sum_{k=1}^{n} \left[ k \frac{q_k q}{r_k^2} \right] r_k$$

The fact that the vector forces add in this manner is called linear superposition.

If a charge $q$ is spread out over a region of space instead of being located at one point, we consider the charge by dividing it up into an infinite number of infinitesimal charges, $dq$, and sum the contributions from each. The force that is exerted on a charge $q_0$ at another point is given by the calculus notation

$$F_c = \int k \frac{q dq}{r^2}$$

where the integration symbol $\int$ can be "read" as the sum of an infinite number of infinitesimal contributions.

The electric field $E$

Coulomb's law defines the force only at one point where $q$ is located. It does not define a field in the sense used here, but it provides a starting point to develop the idea of an electric field. Suppose we make $q$ a very small positive charge and use it as an instrument to explore all points other than where $q_1$ is located. Since $q$ experiences a force $F_c$ at every point it is placed, we get the impression that the condition of space is affected by the presence of $q_1$. We can amend the statement that "if $q_1$ were alone in space, nothing appears to happen" to "if $q_1$ were alone in space, then space has the propensity to exert a force on another charge, if it is present, according to Coulomb's law." Since that inclination appears to apply to space, independent of any $q$, we divide $q$ out of Coulomb's law to obtain a definition of the electric field (also called electric field intensity)

$$E = \frac{F_c}{q} = k \frac{q_1}{r_1^2}$$

which can be thought of as a measure of the propensity. $r_1$ is a unit vector pointing from $q_1$ to whatever point in space is being considered and $r_1$ is the distance. That assigns an $E$ vector to every point in space (except at $q_1$ where $r_1 = 0$).

In the case of a number of point charges, $n$, the $E$ field is obtained by linear superposition

$$E = k \sum_{k=1}^{n} \frac{1}{r_k^2}$$

For a spread out charge distribution, summing by integration gives

$$E = k \int \frac{1}{r^2} \ dq$$

Figure 2 illustrates the $E$ fields for a number of charge configurations. The Coulomb force on any charge $q$ at a point is just $F_c = qE$ where $E$ is evaluated at that point.

A small charge $q$ is used to explore the field so that it has a minimal effect upon the object it is measuring. Suppose we let $q$ ap-
FIG. 2—THE E FIELD IS A RESULT OF the forces between static electric charges. Field vectors are shown in a cross section of a 3-dimensional space for a static positive-point charge (a) and for a static negative-point charge (b). In (c) and (d) the E fields for two static charges are shown; the vectors are located at their tail points.

proach 0. In reality, we can't vary the charge continuously since charge appears to come in multiples of e, but we can idealize the process. The force felt by that charge will decrease as the charge decreases, but the ratio of the change in force to the change in charge will reach some limiting value. That relationship is written in the calculus notation

\[ E = \lim_{\Delta q \to 0} \frac{\Delta F}{\Delta q} = \frac{dF}{dq} \]

Very small positive point charges (so small that their E fields can be neglected) can be thought of as ideal devices to explore the E field.

Field characteristics

A scaler field, as shown in Fig. 3, can be characterized by the fact that a scaler value can change by a certain amount in a particular direction. In any real field, the values differ little from one point to neighboring points. The gradient of a scaler field is a mathematical operation. It gives a vector that points in the direction for which the value undergoes the largest change, and whose magnitude is that rate of change. The gradient of the scaler field \( h \) is symbolized by \( \nabla h \). If \( \nabla h \) equals zero, then the neighboring points must all equal \( h \)

values. If \( \nabla h \) is non-zero at a point, then the neighboring points at right angles to \( \nabla h \) have the same value \( h \).

For example, imagine standing at a point on a hillside with the height, \( h \), at every point known. \( \nabla h \) would point in the direction of maximum increase in \( h \), and the maximum decrease would be in the opposite direction, \(-\nabla h\). If you walked at right angles to \( \nabla h \) at each point, you would walk along a level or equi-height line. If \( \nabla h \) equals zero, you would be at a flat spot. \( \nabla h \) is a vector field since it gives a vector for each point.

Vector fields can be characterized by the fact that they give the impression of flow, as shown in Fig. 4-a–e. In general, near any point the apparent flow diverges away from (or toward) the point, rotates or curls around a point, or is a combination of both. If the field describes a material, such as air velocity, then there is an actual flow of material.

To measure the apparent flow, or spreading out of the E field from a point, imagine an arbitrary closed surface, called a

FIG. 3—THE GRADIENT OF A SCALER FIELD is a vector field. The scaler value is the same along each dashed line called an equi-line. Each of the vectors have a magnitude proportional to the greatest rate of change in scalar value per unit distance, and point in the direction of the greatest change. The vectors are perpendicular to the equi-line at their respective points.

FIG. 4—VECTOR FIELDS GIVE the impression of flow that diverges from, or curls around, an arbitrary point \( p \). Both the divergence and curl of the field are zero in (a). There is zero divergence and non-zero curl in (b); the curl is a vector out of the page at the point. In (c), the direction is reversed, and the vector points into the page. In (d) there is zero divergence but non-zero curl since there are non-symmetrical contributions around the closed line. Both the divergence and curl are non-zero in (e); these fields could not be static E fields.
Gaussian surface enclosing a charge \( q \), as in Fig. 5-a. Divide the surface into an infinite number of infinitesimal surface areas \( ds \). Area is a vector because it has a magnitude and also a direction, or orientation in space which is taken as normal (perpendicular) to the surface, and pointing outward away from the enclosed volume. Each infinitesimal area is essentially a small plane with an \( E \) vector through it. Because the surface is arbitrary, each \( ds \) and its \( E \) vector does not have to be parallel. In other words, \( E \) may not be normal to the plane.

To find the apparent outflow, we need to consider only the component of \( E \) normal to the plane: the rest is just flowing over the surface. The scaler, or dot product, \( E \cdot ds \), does that by giving the product of the magnitude of \( E \) parallel with \( ds \) times the magnitude of \( ds \). That is the same as the product of the magnitude of the effective area (the projected area with \( ds \) parallel to \( E \)) times the magnitude of \( E \). The apparent flow is electric flux. Summing the contributions from each \( ds \) over the entire surface gives the total flux

\[
\psi = \int E \cdot ds \quad \text{(N/C m²)}
\]

\( \psi \) is proportional to the charge \( q \) within the volume since \( E \) is proportional to \( q \). Because \( E \) obeys the \( 1/r^2 \) law, and the effective area obeys the \( r^2 \) law, \( \psi \) is independent of the surface. If a number of point charges were contained inside the volume, \( \psi \) would be proportional to the total charge because the total \( E \) field is the linear superposition of their \( E \) fields. The proportionality constant is \( 1/\varepsilon_0 \), therefore

\[
\psi = q/\varepsilon_0
\]

Charges outside the volume would not contribute to the \( E \) field. The reason for that is if some \( E \) came in through some \( ds \)'s, it would go out through some other \( ds \)'s in just the right amounts to cancel out because of the \( 1/r^2 \) and \( r^2 \) dependence. Graphically, lines having the direction of \( E \) at each point, and with their closeness proportional to \( \psi \) are sometimes used to depict the \( E \) field. That's a convenient approach, but it must be remembered that the \( E \) field is actually a vector at each point in space.

If the Gaussian surface shrinks down to a point, then all the \( ds \)'s would shrink to zero and so would flux \( \psi \). The ratio of the change in flux to the change in volume as the surface shrinks reaches a limiting value. That limiting value is called the divergence, and is symbolized by

\[
\nabla \cdot E = \frac{\partial E}{\partial volume} = \rho
\]

That must be proportional to the charge per unit volume

\[
\frac{\partial q}{\partial volume} = \rho
\]

which is called charge density within the surface. Therefore

\[
\nabla \cdot E = \rho/\varepsilon_0 \quad \text{(N/C m)}
\]

Since \( \varepsilon_0 \) is a constant and is independent of the volume, the above equation could be written as

\[
\nabla \cdot E = \rho/\varepsilon_0
\]

A number of \( E \) field instruments (small +q's) scattered around a region, would diverge away from a positive charge (a positive divergence) or converge upon a negative charge (a negative divergence). A field with zero divergence cannot start or end at the point.

The apparent rotation of the \( E \) field around a point can be measured by imagining an arbitrary closed curve, called an amperean loop, of length 1, encircling a charge \( q \) as in Fig. 5-b. Divide the loop into an infinite number of infinitesimally small lengths, \( dl \). The direction of \( dl \) is taken as counter-clock wise. A loop is used because the \( dl \)'s define general directions around \( q \), whereas for a surface, the \( ds \)'s define general directions away from \( q \). Each \( dl \) is so small that it is essentially a straight line segment with an \( E \) vector through it. The apparent rotation at each \( dl \) is the magnitude of the component of \( E \), parallel to \( dl \) times the magnitude of \( dl \). We must again use the dot product \( E \cdot dl \) to allow for the fact that \( E \) may not be parallel to \( dl \). That gives the magnitude of the \( E \) component parallel to \( dl \) times the magnitude of \( dl \).

Imagine moving around the loop, summing up \( E \cdot dl \) to obtain the total apparent rotation, or electric circulation. Since \( E \) points radially along \( r \), the only place \( E \cdot dl \) is non-zero is where \( dl \) has a component parallel to \( r \). But the entire loop is closed, so for any amount it moves out radially, it must at some place move that same amount inward. The field is symmetrical, therefore whenever \( E \cdot dl \) is positive along some \( dl \)'s, it is negative by the same amount along other \( dl \)'s, with a net result of zero. In calculus notation

\[
\int E \cdot dl = 0
\]

The circle on the integration symbol reminds us that the loop is closed. Again, by linear superposition, that is true for any static charge configuration.

If the amperean loop shrinks down to a point, all the \( dl \)'s would shrink to zero, and so would \( \int E \cdot dl \) (even if it weren't already zero). But the ratio of the change in \( \int E \cdot dl \) to the change in the enclosed area as the loop shrinks reaches a limiting value. That limiting value is called the curl, and is symbolized by

\[
\nabla \times E = \frac{\partial (E \cdot dl)}{\partial area}
\]

The curl is a vector, since area is a vector. It's direction is taken as continued on page 79.
let us start off with a few updates to the infrared people detectors we looked into a column or two ago. It seems Amperex/Phillips decided to jump ship and abandon their line of IR detectors. Their great ap notes seem to have been discontinued. Several remaining pyroelectric detector chip samples are supposed to still be available through their sales support line (401-762-3800).

On the other hand, people detectors have suddenly become a low-cost commodity. So much so that it is now usually cheaper to buy retail and modify, rather than building your own motion sensor up from scratch. Especially when you factor in the critical Fresnel lens design. One cause for the sudden price drop is a new California law which mandates these on nearly every light switch in new office building construction.

Herbach and Rademan offers a great ready-to-install infrared people detector as #TM90SE1491 for $12.50. And the Heathkit folks have several new occupancy and intrusion detector variations in their free home-security electronics catalog. Or, you might also want to check your local price club or warehouse builder’s supply outlet.

A reminder that we have a great help line available for tech questions, off-the-wall networking, and useful consultant referrals. All per the box below. And please remember that we are using California time during the summer. Those 4:30 AM calls tend to get just a tad old. And please, please carefully read the entire column, especially the Names and Numbers sidebar.

Oh yeah—please note the French mathematician’s name is “Fre’-nell,” not “fresh-nell.” And, of course, the correct pronunciations found on our ongoing voice helpline are “hee-lah” and “ten-ah-hah.”

Our biggie for this month involves telephone caller identification chips and standards. But, first, let’s find out how you go about...

Getting telephone information
Contrary to popular belief, it's real easy to get full technical details on nearly everything that involves the telephone company. All you have to do is ask them.

There is a great publication known as the Bell System Technical Journal that has been around for over 60 years now. Included are full details on just about everything involving telephone hardware and software. Check almost any large technical library for your access. There’s also the Bell System Record, but it focuses more on nontechnical policy issues.

For ongoing telephone standards and tutorial information, start out with the no-charge Bellcore 1991 Catalog of Technical Information. Then order the individual papers you want. These do tend to be a tad on the pricey side, with $20 to $90 being typical. VISA orders are accepted with one-week delivery. Sorry, but I don’t know of any library that has a full set of these to loan out. Please let me know if you find a lower-cost access source. The library obviously screams to be made available on CD ROM.

Caller number delivery
Most of your telephone operating companies are now in the midst of upgrading to a totally digital system that includes a number of new CLASS services. By far the most popular new service is known as Caller Number Delivery, which can show you who is calling you before you pick up your telephone handset.

Caller number delivery does appear rather controversial. But, for most people most of the time, knowing who is calling you is infinitely more important than protecting people’s “rights” to make undetected obscene phone calls. Very sadly, at least one state (Pennsylvania) has stupidly banned this wonderful new service. In other areas, the caller is given the option of blocking their caller ID, for those one-in-a-thousand calls when your anonymity might legitimately be desired. Maybe for a drug overdose hotline. Blocking can get done by entering a three-digit code before you make your call.

So what is caller ID, and how does it work?

Figure 1 shows you some of the more interesting Bellcore documents that involve caller ID. But the key horse’s-mouth paper you’ll need is Technical Reference TR-TSY 00030 and titles SPCS Customer Premises Equipment Data Interface. The cost is $25 via VISA.

Figure 2 shows you the exact placement of the tone codes. Caller number delivery is normally provided as a code burst between the first and second full rings while your phone is still on its hook. Enough delay is provided to allow for the short half-second breaks sometimes involved in selective ringing.

After your first full ring gets detected, a data path is established. A data path is simply any method of receiving some modem tones. The ID tones are then routed to suitable circuitry to recognize the data burst and strip out the needed information. The format and codes are related to the digital codes used in pagers.

The tones sent out are plain old serial binary modem tones at 1200 baud. A digital logic one (or a mark) is defined as one cycle of a 1200-Hz sine wave. A digital logic zero (or a

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(602) 428-4073
space) is defined as nearly two cycles of a 2200-Hz sine wave. Each eight-bit character is preceded by a space start bit and a mark stop bit.

The transmitted signal level is –13.5 dBm. While the code transmission is asynchronous, phase coherence is preserved throughout the entire caller ID message. No more than 20 marks are permitted between characters.

Figure 3 shows you the data format. It might appear fairly complicated at first, but making sure the number is valid is quite important. Almost certainly, you will elect to use a computer, or at the very least, some simple microcontroller in your caller-ID display circuitry.

The first thing sent is called the channel seizure signal. That consists of 30 bytes of a Hex $55$ code. After decoding, another way to look at this “hey wake up!” signal is one quarter second of a 600-Hz square wave.

After the channel seizure signal, a carrier signal is sent. It’s used to condition your receiver for valid data. The carrier consists of at least 150 milliseconds worth of marks. After the decoding, you have a one-sixth second

- The DATA WORDS are the actual ASCII characters for the actual caller ID digits in ASCII character form, least significant digit first. Each digit byte is preceded by a zero “space” start bit and followed by at least one “mark” stop bit.
- The MESSAGE LENGTH WORD is the number of characters being provided as the calling number.
- The MESSAGE TYPE WORD is a Hex $04$ when providing for the identification of a calling number.
- The CARRIER SIGNAL consists of a solid string of logical ones following your quarter-second burst square wave at 600 Hz.

Your caller-ID receiver circuitry is supposed to use this “wake up call” and string of marks to prepare itself for valid data reception. After setup, the first valid data byte is called a message type word. If that burst is for the caller number delivery, your message type word will be a hex $04$. Other codes could get used for other purposes. For instance, a hex $0A$ means “message waiting” for pager applications.

The next byte is called the message length word that tells you how many digits are to be provided in the caller ID numbers that are to follow. The message length does not include itself or the checksum in its count.

The actual ASCII characters for the caller phone number follow, starting
error detection, you run your own 8-bit sum of all the data words provided. To provide an error detection, your message format to you. Some nasty complications can arise if you have multiple data messages or several CLASS services active, such as call waiting. See the Bellcore info for further details.

There are a number of caller ID devices commercially available, with pricing in the $60 to $500 range. Typical are the Allied incoming call identifier, the BellSouth calling line identifier, the Cidco Slimline series, and the TC-1021, TC-1080, and the TC-1082. One discount source of all these is VSI Telecommunications.

Do note that your caller number delivery service must be provided to you before you can use any of these devices. If the code is not being sent, there is no way you can receive it. There might be certain state laws prohibiting their use as well. That, of course, can be cured by staking your state representative to the nearest ant hill. Finally, anything you connect to the telephone line has to be FCC Type 68 approved. Meeting the rules for type approval is fairly reasonable and simple. But the approval process itself is a bear.

We do have several experimental caller ID projects in the works here at Radio-Electronics, along with some simulator and test software. But there are ongoing problems with service availability, with meeting FCC part 68 specs, and in keeping the price low enough. Probably some absolute minimum general purpose caller-ID interface kit that demands use of a personal computer programmed in machine language to develop your own circuits makes the most sense at this time. Let us know what you want to see here.

A caller-ID chip

As Fig. 4 shows us, there are usually four stages to the caller ID receiver. The first stage is called an FCC Part 68 Interface. That is needed to safely and legally connect to your phone system. Full details on Type-68 interface secrets appear in the Hardware Hacker II reprints.

The second stage is the analog front end. The analog front end provides filtering and amplification, and converts all of your tones into actual TTL ones and zeros.

Figure 5 shows you an analog front end circuit that uses the brand new Sierra Semiconductor SC11211N caller-ID chip. You input the low-level telephone tones and get out a serial data stream ready for computer or microcontroller interpretation. Inside the chip is a fancy filter, an energy detector, a tone demodulator, and a clock. An ordinary TV color crystal
There’s also a fancier SC11210 chip fabricated in a smaller package that deletes the internal crystal oscillator, the level setting, and all of the energy-detection features. Sierra also has ap notes on suitable FCC part-68 interfaces.

While these chips are low in cost and work rather well, note that they are only analog front ends. “All” they do is reliably accept low-level tones from the part 68 interface and then convert them into a string of digital ones and zeros.

The third ID stage is the number extractor. The number extractor takes the serial data stream, makes sure it’s valid, and then extracts and formats the calling number. The number might also be displayed. The number extractor almost has to be a computer or microcontroller, since it probably would be unbearably complicated and expensive otherwise.

The final and optional stage is any “gee whiz” stuff. Things like looking up the actual name of the caller. Or pulling their sales or service records. Or keeping a full record of the last hundred calls. Or interacting with a humongous CD-ROM data base. Once again, be sure to let us know what you want to see in the way of further caller-ID projects.

Carbon is one of the more interesting chemical elements. It forms the basis of all life as we know it. And, because of some energy and bonding restrictions, carbon quite possibly will also turn out to be the basis of all life as we don’t know it. Carbon is also the key to most fuels, plastics, and foods. It bonds readily with many other elements, creating by far the richest assortment of useful chemical compounds.

Until recently, there were only two known forms for any pure carbon molecules. These were the supersoft graphite and superhard diamond. But several chemists (Kroto, et al. Nature v318 p162, 1985) have discovered a uniquely bizarre third form of carbon molecule. By taking 20 hexagonal groupings of six carbon atoms and then fusing them properly with 12 pentagonal groupings of five carbon atoms, a hollow geodetic pure-carbon molecule consisting of 60 atoms gets created.

Since this hollow all-carbon C-60 molecule looks like a geodetic dome or a soccer ball, they were promptly given the name of Buckyballs. Named after the late Buckminster Fuller, a leading early proponent of geodetic dome structures.

Initially a few C-60 molecules were painfully hand-collected, measured, and tested. And, sure enough, C-60 is for real. An experimental proof of the Buckyball shape has just recently appeared (Hawkins, et al., Science, v252, p312), along with a very fine bibliography.

After the discovery, several other chemists (Kratschmer, et al. Nature v347 on p354, 1990) were playing around with carbon rods in a plain old arc welder and figured out how to make lots of Buckyballs in a process almost as complicated as smoking a piece of glass with a candle.

As a result, the price of Buckyballs has plummeted to an astonishingly low $1200 per gram. Quantity pricing is even less, and 100 milligrams of Buckyballs are available for $250 if you are on a limited budget. You can get all the Buckyballs you want off the shelf from Materials and Electrochemical Research.

The latest games include putting Osmium “handles” on a Buckyball to make them easier to align, and adding precise doping impurities to create several new families of “Dopeyballs.”

While nobody has yet come up with a proven commercial use for Buckyballs, they are now by far the hottest topic in physical chemistry. Buckyballs will even superconduct, although only at rather low temperatures so far. The hollow molecule suggests all sorts of stunning new possibilities which include super lubricants, new batteries, ultra-strong fibers, improved semiconductors, and entire new classes of materials and compounds.

Needless to say, Buckyballs are a sure-fire winner for a Science Fair topic or school research paper. And we here at Radio-Electronics would certainly be most interested in any Buckyball project that’s even remotely related to electronics. Let us know what you can do here.

Ongoing info on Buckyballs will appear in those Science and Nature
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magazines, and, of course, through the Dialog Information System.

**EPRI**

The Electric Power Research Institute is a rather low-key research consortium. You have to be a power company to join them. Even then, their annual membership fees are astronomical. But, with their $400 million annual budget they now do all sorts of top-quality energy research, including thorough coverage of such subjects as solar power, efficient lighting, cogeneration, conservation, environmental quality, cold fusion, and alternate energy sources. Plus, of course, nasty old nuke stuff.

EPRI does have plenty of videos, technical reports, papers and such available. They also have products for licensing. The summary report of most of their recent key papers costs $45. You might like to contact them directly for more info.

**New tech literature**

A new method of focusing X-rays known as a Kumhakov lens is now described on page 208 of Science volume 252. If it proves as good as it looks, this could revolutionize everything from high-density integrated circuits to safer dentistry. The lens consists of scads of glass capillaries, and the X-rays skip along the surfaces at low angles, rather than shooting right on through them.


Satco is a great source for oddball tools and supplies. They usually sell to those school vocational education programs. They do have a great new thousand-page catalog available.

Unusual scientific images of all sorts of geologic, oceanographic and atmospheric stuff is available on a GRIPS-2 CD-ROM from Meridian Data. It is part of a new program to release obscure government research to a wider audience.

Our unusual trade journal of the month is Power Quality, aimed at the higher-end users of uninterruptable power supplies.

Chip capacitors and resistors for surface mounting are now finally becoming widely available in small quantities at sane pricing. While Mouser Electronics is a good source, some ready-to-go $49.95 resistor and capacitor kits are available through Communications Specialists. That's three cents each for the resistors and fourteen for the caps.

Turning to my own products, for the fundamentals of digital integrated circuits, do check out my TTL Cookbook and CMOS Cookbook. Or you can pick up all of those "oldies but goodies" all at once in my Lancaster Classics Library.

I also have a BBS up as GEnie PSRT. Besides all the PostScript and desktop publishing stuff, you'll find all sorts of ongoing Hardware Hacker and Midnight Engineering resources here. You can get your voice connect info by dialing (800) 638-9636.

We also now have the Hardware Hacker III, Ask the Guru III, and the new Midnight Engineering I reprints available, which have the latest and best of all these columns in them. All edited, revised, and indexed.

Finally, I do have a new and free mailer for you that includes dozens of insider hardware hacking secret resources. Write or call for info. Our usual reminder here that most of the items mentioned appear in the Names and Numbers sidebar.

**FCC NO-CODE AMATEUR RADIO LICENSE**

The FCC recently passed Docket 90-55 which for the first time allows a new codeless entry ham radio license of technician grade, Privileges 30 MHz and above — All modes! (See R.E. article in April 1991 issue).

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**CIRCLE 176 ON FREE INFORMATION CARD**
Some things are enjoyable and some things aren’t. This is true in life and it’s just as true in electronics. Going through the whole process of a design—from idea to paper to breadboard—is a great exercise in brain stretching and a chance to let your subconscious do a bit of work. For a lot of people (at least judging by the things I get asked about in the mail), the real hassle starts when they finish all the development work and have to come up with a final version of whatever they have on the bench.

We’ve been spending the last couple of months on the development of handy dandy bench equipment and the logic probe we just finished up is a really neat piece of gear to have around when you’re working on a prototype circuit. Once you put it together, you’ll find that it’s one of those things you’ll always reach for first when you want to do some electronics snooping.

That’s all well and good but, even though one measure of a tool’s worth is how much it can do, another important criterion is how easy it is to use. Companies that make test equipment spend a lot of money designing the “user interface” since they know all too well that no matter how versatile their products are, if they’re not convenient to use as well, people just won’t buy them. The more time you spend in the electronics business, the more you’ll learn that appearance and convenience is just as important as substance and power.

All this is leading up to the fact that the logic probe we designed is going to be useful only if it’s conveniently packaged and securely made. And that means you can’t reasonably expect it to be a permanent member of your toolkit unless you put it on a PC board. This is the part of the design process that most people dread. Laying out a board is one of the most tedious and least enjoyable activities you’ll ever come across in electronics.

Because I’m a nice guy, I’m going to save you a lot of work and give you a foil pattern for the logic probe. I found the circuit so useful that I designed the PC board and don’t have any functional effect on the circuit. Some of the comparators have been swapped and the LED’s are set up differently so it was simpler to bring their leads out to the edge of the board.

When I did the board a few years ago, I kept the board as small as possible so it could be housed in a handheld case. I wound up making my own case for the probe but there are several companies that make suitably sized cases.

There’s nothing critical about the board—none of the traces are very thin and there’s plenty of room on the board to make them all at least a sixteenth of an inch thick. It’s an easy board to etch with even the crudest equipment. The parts-placement diagram is shown in Fig. 1 and the only components I haven’t put on the board are the switches and the speaker. If you can find a small enough speaker, you can leave space for it on the end of the board.

If you trace the circuit as it’s laid out on the board, you’ll see that I made some changes to the original circuit we finished designing last time. The changes were done to make it easier to design the PC board and don’t have any functional effect on the circuit. The parts-placement diagram is shown in Fig. 1 and the only components I haven’t put on the board are the switches and the speaker.
The PC board is the final touch for the probe and, if you plan on using the circuit on the bench, you should give serious thought to making it. Just about the only problems you should have are the common ones that always show up when you’re making a board. These are things like solder blobs, bad joints, and backward components. You should use sockets for the components. You should use sockets for the parts to be inserted or removed. These are things like solder, sockets, etc. about the only problems you should have.

If you don’t want to fool around with switching the components, you can replace the chip with a 556 and use one side of it for the existing 555. You can replace the chip with a 555 and use one side of it for the original probe and the other side for the pulse detector.

If you add that feature to the probe, or if you think of something else that’s particularly slick, let me know about it and I’ll put it in the column. As a matter of fact, we’ll make a contest out of it and the two best modifications to the circuit will win something. I need some time to figure out what that something will be—either the usual magazine subscription or something else—but I’ll let you know what it is.

There isn’t enough room left this month to run through our next topic—a digital oscilloscope—but there is enough room for me to pass along the schematic shown in Fig. 2. It’s a handy circuit that will monitor a power supply and let you know if the output voltage strays more than a half a volt away from five volts (or whatever voltage you set as the trigger).

You’ll notice that the circuit has two very similar sections. The first one, the low-voltage monitor, taps the system voltage through R3 and uses the Zener voltage to keep transistor Q1 turned on. The high-voltage monitor taps the system voltage through R4 and, until the voltage is high enough for the Zener to conduct, it keeps transistor Q2 turned off.

If you use multi-turn potentiometers, you can set the low and high thresholds just about anywhere you want to.
FIG. 2—THIS CIRCUIT WILL MONITOR A POWER SUPPLY and indicate whether the output voltage strays more than a half volt away from whatever voltage you set as the trigger.

THE LOGIC PROBE CAN BE ASSEMBLED on this single-sided board.

The direction of the extended thumb of the right hand with the fingers wrapped in the general direction taken around the loop. In the case of the static field, the curl is zero, therefore \( \nabla \times \mathbf{E} = 0 \).

The curl is a vector measure of the apparent rotation of the field about a point. If a number of field instruments were scattered around a region, the group would not rotate.

The divergence and curl of the types of fields we’re discussing completely characterize the field: \( \mathbf{E} = \) can be found if \( \nabla \cdot \mathbf{E} \) and \( \nabla \times \mathbf{E} \) are known. This is known as Helmholtz’s theorem.

The curl of a vector field is always zero, if, and only if the field is the gradient of some scaler field. Consider our \( \mathbf{h} \) field example. If \( \nabla \times \mathbf{h} \) were non-zero, then in following a closed path from some point and back to the beginning, one encounters different rates of change of height times distance when taking different paths. \( \nabla \times \mathbf{h} \cdot \mathbf{dl} \) would be path dependent. That would amount to leaving from a point at, for instance, 50 meters in elevation and returning only to find the elevation is 300 meters, or 2 meters, depending upon what path was taken!

The divergence of a field is always zero only if the field is the curl of another field. Imagine the fields of Fig. 4 in 3-dimensional space. Curl the right-hand fingers in the direction of the apparent rotation around the point. The extended thumb is the direction of the curl vector at that point. Conversely, consider the vectors shown as curl vectors. Direct the thumb along them and the fingers will curl in the direction of the field vectors. The field vectors seem to cancel, and not spread out. Those fields are the curl of another vector field. Try that with Figs. 2 or 4 and you’ll get conflicting results.

Next time, we’ll develop Ohm’s law and look at the \( \mathbf{E} \) field in materials, which will provide further insight into Maxwell’s equations.
New audio/video formats are a big part of what makes life interesting for an audio journalist. I've witnessed more than a few such introductions in the 30-odd years that I've been in the business. Some "revolutionary" new product designs immediately sank without a trace, others floundered for months or years struggling to keep afloat in the marketplace, and some—such as the LP, the cassette, the VHS VCR, and the CD—went on to make it big.

What makes for new-format success? It's clear that the backing of a "big name" manufacturer is not sufficient. As evidence, I cite the bal-hooed—but very short-lived—RCA, 3M, and Columbia home tape cartridges, the Fidelipac car stereo cartridge, and so forth. I'm sure that other ephemeral audio and video formats come to mind for those readers who made the mistake of investing in them.

The Japanese are certainly not immune to cartridge-marketing mis-calculations. The Elcaset cartridge, introduced in 1976, was backed by Sony, JVC, Technics, Teac, et al., and was intended to supplant both the open-reel and Philips cassette formats. As explained to me at the time by its project engineer, it was meant to appeal to those dedicated tape buffs for whom open reel was too inconvenient and cassettes were too low in fidelity. Although the Elcaset system worked well, its projected audience didn't exist in sufficient numbers to get the product off the ground. Unfortunately, several warehouses worth of Elcaset players were ultimately scrapped.

Obviously, I'm not trying to imply that the tape-cartridge/cassette format, per se, is inherently unsalable. The Compact Cassette—to give it its official Philips designation—got off to a slow start in the mid-sixties but ultimately, as we know, became a huge success both for home recording and in its prerecorded form. My suspicion that the positive response to the cassette format had no necessary relationship to its fidelity—or lack of it—was confirmed in the early 1980's. It was at that point that the annual sales of prerecorded music cassettes outstripped those of the less expensive and better sounding LPs.

If the fidelity of a format is not the key issue for most music buyers, what are consumers looking for? Convenience, durability, and reasonably low cost both for the machine and for blank and prerecorded tapes that feed them all are desirable attributes. And, of course, there has to be a wide range of popular artists available on the format. (The recent rapid replacement of the LP by the CD doesn't contradict my analysis. Sure, the CD sounds better than the LP, but the CD also is far more convenient to play, takes up much less space, and is much more durable. Furthermore, you can buy an excellent CD player at a fraction of the cost of an equivalent sounding, high-quality record player and phono cartridge.)

**DAT disappointment**

When the home digital-audio-tape (DAT) machine was first introduced, my initial reaction was that it was an effective and sophisticated response to an essentially minuscule demand. There's no question that there has never been anything quite as good as DAT for the serious home recordist, for rock bands making live demo tapes, and for nature or sociological recordings. DAT's wide audio bandwidth and excellent noise, distortion, and wow and flutter levels match or exceed those of the finest studio equipment.

But is there a DAT advantage for the non-professional or the average music listener not obsessed by the need to be the first on his block to own a new product? If you were to compare a DAT recording to one made on a quality cassette deck, you would find DAT's real-world sonic advantage to be slight. And for playback in a car system, it would probably be nonexistent. That leaves longer playing time and ease of locating selections as DAT's only consumer advantage. Among DAT's disadvantages are the high cost of both the machine and the blank tapes, and the dearth of prerecorded tapes—possibly because of difficulties achieving high-speed duplication.

The Music Publishers Association (MPA) is still fighting for surcharges

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**THE NEW PHILIPS DIGITAL CASSETTES** will deliver CD-quality sound in a player that is compatible with standard cassettes.
The friendly Amiga.

JEFF HOLTZMAN

War—or at least an intense skirmish—broke out over my response to a letter from an Amiga-phile in the April issue. A reader chided us for not publishing more Amiga-related material; I responded rather harshly. Since then numerous readers took the time to write and try to enlighten me. Several people simply rehashed Amiga technical specs, but others raised some excellent points, especially regarding my admitted preference for IBM and compatible PC's. Ironically enough, in all the hubbub, we've still received no new articles on the Amiga, although a few are in the works.

Before I discuss the reader responses, let me explain why I have the attitude I do. Then when you disagree at least you'll understand where I'm coming from.

How I became a PC-philiac

In the fall of 1979 I bought a computer called the SYM. It had a 6502 CPU and 1K of static RAM, expandable to 4K on-board. The SYM was 99% compatible with a previous 6502-based computer, the KIM, but better in that it had more on-board memory and I/O, better expandability, a faster tape interface, and the ability to display ASCII text on an oscilloscope. (Video terminals were so expensive in those days that people would use any CRT!) The SYM had a machine language monitor, but no assembler or BASIC. The company promised a ROM-based assembler and BASIC "real soon now (RSN)," but suffice it to say that it took a long time to get those items, during which time I learned much about the joys of programming in machine language by hand.

A user's group sprung up; by then I had written a machine-language debugger (which I sold through the user's group), a primitive RS-232 communication program for transferring files with a friend who used a SWTPC 6800), and had "modified" (disassembled and patched) a commercial text editor to work the way I wanted. (At work I used CP/M machines, still too expensive for "personal" use.) I also built my own EPROM burner and continually fiddled with enhancing my software, burning it into 2716's, and installing them on the board.

Eventually I bought a card cage and a memory board, and expanded to the limit of 32K. I almost bought disk drives at several points, but just couldn't justify spending $2000 for a pair of 80K drives (albeit with power supply). I learned a lot from those experiences. I used to know most 6502 op-codes in hexadecimal, and could view an uncommented assembly listing and get a pretty good idea of what was going on. I knew every address used for I/O in the machine. I knew every product on the market, as well as the expected release dates of all of those that were still in the RSN category.

Eventually I got married and went to graduate school; at that point I couldn't afford to maintain the SYM as a full-time avocation. I needed something that worked, that I could count on, and that was supported in such a way that I knew I would be able to get the tools I needed. If you wanted to pin down a precise moment when I adopted my current attitude, that was it.

I looked long and hard at Apple II's and Commodore PET's, for which lots of interesting software was available, but found that their video displays were poor, and expansion prices too high.

Then Morrow Designs introduced a cheap (under $2000) 4-MHz Z80 system that included two 160K floppy drives, 64K of RAM, a 19,200 baud video terminal, and came bundled with some basic software, including WordStar and MBASIC. Of course, CP/M had its own assembler and debugger. The Morrow system got me through graduate school, and also helped me launch my career as a writer and journalist.

I was working for a company in lower Manhattan that suddenly moved out to the middle of Long Island. Rather than change jobs, I bought a Radio Shack Model 100, and tapped out numerous stories while commuting on the Long Island

FIG. 1—MICROSOFT'S UPCOMING OS/2 3.0 provides an operating system kernel that can run Windows, OS/2, and POSIX applications in their native modes on Intel and MIPS processors.
Railroad. In fact, one of the first stories I ever sold (to the now-defunct 80 Micro) was a hardware/software interface to allow the M100 to be used as a modem for a desktop machine—the Morrow.

I used the Morrow until early 1986, when I decided that I just couldn’t afford to let the PC world go by any longer. So I bought an XT, some IBM Technical Reference Manuals, and started learning everything I could about the machine. It was all downhill from there.

I have no religious attachment to the IBM/compatible world. However, I do have a substantial investment in time and brain cells in it. I try to keep an eye on other markets, but it’s impossible even to keep up with all facets of the PC market.

Perhaps that type of personal history has no place in a column like this. But I felt it important to show that I didn’t just jump on the PC bandwagon arbitrarily. I’ve paid some dues, and I’ve always made my technology decisions with care.

On the other hand, as several readers pointed out, I as an editor of Radio-Electronics have a responsibility to my readers. And I take that responsibility seriously. Over the years we’ve published stories on virtually all major personal computers, including Amiga’s, Atari’s, Macintoshes, Apple II’s, etc. And don’t forget the 13-part series on the PT-68K we ran in 1986-87.

Nonetheless, surveys repeatedly confirm that 80% or more of our readers own and use PC compatibles. And I suspect that 80% or more of our authors do as well. Unlike most other magazines, Radio-Electronics relies heavily on its readership for editorial input. The lack of Amiga stories is traceable to that fact.

Reader replies

Anyway, here’s what some readers had to say about the April column.

Jim Belcher of Greenville, TX brought up an extremely important point: Standardization can stifle innovation. I agree—but there must be a balance, and it must be a dynamic, ever-shifting balance. Too much standardization leads to innovation, which in turn leads to efforts at standardization, and so on. My interest in standardization relates to interoperability, data exchange, and volume production. I’d like to be able to transparently connect numerous heterogeneous computer systems to a network, and to share data among them. I’d like to be able to trade floppy disks with Mac and Amiga users. I’d like to be able to plug-n-play SCSI devices among them as well. I’d like video standards that would allow volume manufacturing techniques to produce high-resolution video displays as cheaply as TV sets. And so on. Innovation is absolutely necessary—but it must be carried out within the context of solving real problems.

Paul Schick of Madison, WI wrote a really thoughtful letter touching on standards and standardization, and points out that the issue is not "doomed PC’s versus doomed Macs versus doomed Amigas. The issue is our own data, which we must somehow get out of that DOS window and onto that machine of the future, to say nothing of moving it from one application to another." Mr. Schick then goes on to lament how we have allowed manufacturers to bamboozle us into accepting proprietary data formats as a method of market control. Hear, hear!

Tom Hutchison of Pilot Rock, OR suspects that the whole thing was an April Fools joke. Sorry.

Neil Gjere of St. Paul, MN suggested that we do a price/performance comparison of various architectures (Mac, Amiga, PC). When Apple first introduced the Mac II line, we approached the company for a review machine to do just that. The company unceremoniously declined. Attempts around the same time to contact Commodore went totally unanswered. IBM on the other hand has always been extremely cooperative, as have hundreds of other PC hardware and software vendors. We don’t have the resources of Byte, PC Magazine, or Amiga World. But we don’t try to compete with those magazines either.

Patrick Greene wrote from Fort Ord, CA and objected to my statement that Windows has done more to promote graphical environments than all the Amigas and Macs put together, and goes on to point out how the Amiga provides a better multi-tasking operating system. I did not say that Windows is better, but that it has been more successful in marketing the GUI. It wasn’t long ago when the vast majority of PC users considered mice wimpy. The cultural shift brought on by the acceptance of Windows is amazing.

Brian Redman of Richmond, BC (Canada) states that the success of the PC was due to two things, “its birth under the IBM logo, and the company’s now recanted policy of open architecture.” Good points. But then he goes on to say that , “The fact that IBM and Apple are just now waking up to the usefulness of multi-tasking, multimedia, etc., is a testament to the vision of the original Amiga development team, Xerox Star notwithstanding.” Now there’s an original way of distorting history. Multi-tasking predates both Commodore and the Xerox effort in the mainframe operating systems that were being used in the 60’s.

Frank Podroskey, Jr. of Monongahela, PA berates my snobbish attitude toward Amigas, saying that it “is what most Amiga owners resent more than anything else from owners of other machines.” To that I plead guilty, and promise to try to be more open-minded.

Your turn

So what are we going to do, readers? I say we because admittedly I can’t do it all myself. You want more Amiga coverage? OK. Do it. The ball’s in your court. It’s time to stop saying “somebody oughta do something” and start doing it. Don’t rewrite the technical specs, but do something creative—that’s what all that multi-tasking and multi-media are about. Then tell us. We’ll get the word out. Regarding news coverage, we’ll try to keep a closer eye on the Amiga market. But if you see something you think should be publicized, let us know about it. Give us a company name, product/technology description, and a phone number. We’ll take it from there.

News bits

486SX Released. Intel finally unveiled the 486SX, a 20-MHz coprocessor-less 486. Adding a coprocessor involves adding a new IC, which in effect is a full 486 that completely takes over for the 486SX. That’s required because the CPU and the FPU must reside in the same package, else propagation delays negate any performance advantage. However, together the two cost...
about 30% more than a real 486. Initial benchmarks indicate that the 20-MHz 486SX runs roughly equivalent to AMD's 40-MHz 386. IBM, Acer, ALR, AST, Everex, and others immediately announced systems based on the 486SX, some priced well under $3000. IBM also showed a prototype 50-MHz 486 system, but there is no word from Intel on when production quantities will be available. One report mentioned a 486 that runs internally at 50 MHz but has a 25-MHz bus interface: the chip could be a drop-in replacement requiring no system redesign or FCC certification. Clearly, with competition heating up in the 386 market, Intel is trying to establish a range of 486's at popular price points. Meanwhile AMD has announced a 25-MHz 386SX but we don't know how much it will cost.

**Notebook Nirvana.** HP and Lotus introduced a 10-oz hand-held 512K 8088-based PC compatible with 1-2-3 version 2.2 and several small application programs built in. It's amazing how much they packed in, but the display is only 40 characters by 16 lines, and the keys are too close together for touch typing. Fujitsu has released (in Japan only) a two-pound notebook that is an inch thick, has a full keyboard, runs for 8 hours on two AA batteries, and has no rotating parts (i.e., disk drives). It's based on Intel's 386SL and uses IC cards for volatile and non-volatile storage. And Kyocera has released (also in Japan only) a pen-input DOS-based system built into a thin binder. The inside cover contains a 240 x 340 pixel screen used for both input and output. A separate tablet clips into the binder, communicates with the screen via inductance, and provides some sort of keyboard. There's talk of marketing the device in Europe, and possibly also here in the U.S., although no firm date has yet been determined.

IBM and Microsoft continue to diverge on Windows and OS/2. IBM has teamed up with Micrografx, a premier developer of Windows-based drawing tools, device drivers, and Windows-to-OS/2 porting technology, to co-develop a 32-bit graphics engine to replace the current 16-bit engine for the OS/2 Presentation Manager. There's also talk that, like Windows, OS/2 2.0 will include a suite of basic desktop applications. In addition, IBM has shown OS/2 2.0 running DOS and Windows apps simultaneously and faster than in their native modes.

On the Windows front, Microsoft talks more and more about OS/2 version 3.0, AKA "New Technology," a portable version that will have the ability to run Windows, OS/2, and POSIX applications simultaneously over the same operating system kernel.

Microsoft is still struggling with TrueType, its PostScript killer, and in the meantime, Adobe's ATM is getting lots of good exposure. In addition, Adobe is about to introduce an enhanced version of its font technology that will allow a continuous range of letter weights from very light to very bold. The FTC is investigating charges that Microsoft hasn't been on the up and up regarding separating its systems and application divisions. Look for the company to split by year end.

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**AUDIO UPDATE**

**continued from page 80**

on blank DAT tapes to compensate them for the assumed losses resulting from unauthorized dubbing of their copyrighted material. Their argument is that since DAT copies of CD recordings are virtually perfect, consumers will be encouraged to engage in orgies of unauthorized dubbing. The fact that you can already make a virtually perfect copy of a CD with any high-quality cassette deck seems to have escaped the MPA's attention. And the additional fact that all DAT decks come with circuits that prevent multiple copies of the same CD seems to have deterred the litigating music merchants hardly at all in their pursuit of enhanced royalties.

In my May 1988 column, I predicted that the DAT format—for all the reasons discussed above—wouldn't make it as a mass-market product. (I was probably the only U.S. audio writer who wasn't all moist- and starry-eyed about DAT's prospects during those early days.) The present word in the hi-fi industry is that DAT sales are poor and that as a consumer product it is dead or dying. Any childish pleasure that I may derive from "I told you so's" is offset by consideration of the enormous amounts of time, effort, and cash invested in developing the DAT technology. I hope it won't be a total waste, and that there will be some worthwhile spin-offs in the future.

**DCC?**

Are you waiting with bated breath for my pronouncements on the Digital Compact Cassette? Or have you even heard of it? Philips promises that by mid-1992, new format machines will be available that will play both standard cassettes and similar size digital cassettes employing a new "precision adaptive sub-band encoding," data-compression system. PASC encoding, perhaps needless to say, is incompatible with any current coding system.

Philips promises that the DCC tapes will sound as good as CD's and will have the advantage (over conventional cassettes) of CD-type program selection. Projected playing time is 90 minutes, but that will probably be extended. Tandy has already demonstrated prototypes, and there's a rumor that the giant Matsushita Corporation (Panasonic, Technics, JVC) is ready to commit to the format. Price of the machine is projected at between $500 and $600—about the same price as a high-quality cassette deck.

Will DCC be a hit or a miss? Short of unlikely fidelity problems in the PASC encoding, and endless litigation by the music merchants, I don't see how the format can fail commercially. It incorporates the known and well-accepted virtues of conventional cassettes and promises CD-level performance and convenience for its digital cassettes. There are design errors waiting to be made in the new machines—such as providing less than state-of-the-art performance from the conventional part of the machine—but if these are avoided, then DCC will be the wave of the future. I'm sure that Sony will go down fighting for DAT—as they did for Beta—but I'm afraid it's a lost cause. As I've said before in this column: In a year or two, we'll know if I'm right about the future.
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Perfectly Tuned for

Test/Measurement and Prototype Equipment

51-Piece Electronic Tool Kit

Tools Included in Kit:
- 1" measuring tape
- 5.25" needle nose pliers
- Electric tape
- Utility components box
- 6 piece precision screwdriver set
- 6" long tweezers
- 8 piece hex key wrench set
- 7" brush and scraper
- Digital Multimeter
- Brush
- 7" line point probe
- Round needle file
- 10 piece screwdriver set: 6 Slotted & 4 Phillips
- 7" slotted probe
- Flat needle file
- 4.5" diagonal cutting pliers

Jameco Logic Pulser

- Compatible with TTL, DTL, HTL, HNL, MOS and CMOS ICs.
- 5.5V Soldering stand
- 5mA  Audible current
- input impedance
- 0.1V, MOS and CMOS ICs.

Jameco Logic Probe

- Max Frequency 80MHz
- Minimum detectable pulse: 10mV + 120kHz input impedance
- 4.5" diagonal cutting pliers
- Manual ranging w/ overload protection

Metex Digital Multimeters

General Specs:
- Handheld
- high accuracy
- AC/DC voltage, AC/DC current, resistance, diodes, continuity, transistor HFE
- Manual ranging w/ overload protection

A.R.T. EPROM Programmer

- Programs all current EPROMs in the 2716 to 27512 range plus the X8234 EEPROM
- RS232 port
- Software included

UVP EPROM Eraser

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

EPROMs - for your programming needs

<table>
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Handheld Multimeter

- 3.5 digit LCD with automatic polarity indication
- 500V AC/DC voltage measurement up to 500V
- AC/DC current measurement up to 200mA
- Resistance measurement up to 20MΩ
- Continuity checker with audible tone
- Diode and logic test
- Manual ranging and data hold functions
- All range protection and function indication

PB503

- Two debounced push-button switches
- Two SPDT slide switches, all leads available and uncommitted
- A total of 2520 uncommitted tie-points
- Potentiometers: one 1KΩ and one 10KΩ
- Includes power supply, instrumentation and breadboarding

PB503

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Jameco 16MHz 80386SX Desktop Computer Kit

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  - 101-key enhanced keyboard
  - Multi I/O Card
  - Toshiba 1.44MB, 3.5" DSHD floppy disk drive
  - Baby sized desktop case
  - 200 Watt power supply
  - DB1030 5.0 by Digital Research and AMI diagnostic software

Integrated Circuits

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Miscellaneous Components

- Supports VGA, EGA, CGA, Hercules or Compaq with 256KB Video RAM upgradeable to 512KB (eight 41464-100) - Capable of 640 x 480 with 256 colors, 800 x 600 with 16 colors.

Integrated Circuits

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- Quality prototype and test equipment
- Computer kits and accessories

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CATS C-GM - $1.25 each + 10 for $10.00

TOUCH DIMMER

The "brain" part of the "U.T.E." touch dimmer which is connected to any lamp, will turn it on and off and change the brightness level when any metal part is touched. We don't have the wire and diodes that originally connected this to the lamp, but we can provide a simple hook-up diagram and instruction sheet. The solid-state circuitry is contained in a thermoplastic box 1" x 3 11/32" x 0.835".

CATS DMR-1 - $3.50 each

INFRARED SECURITY LIGHT (A-IS)

Electrico # SL-101 - Experiment with infrared sensors with these outdoor security lights. Contain lots of interesting components, and IR detector, photodetector, relay, transformer, IC's, voltage regulator, capacitors, trimpots and other goodies. Refer to the distributor for variety of reasons, we've found that most of them work to some extent. We don't want to test them and would prefer to sell them "as-is" at a greatly reduced price. Mounts to any standard electrical junction box or as an add-on to any security system. Movement up to 65 feet and turns on lights. Sensor can be adjusted for sensitivity and duration of lighting. The position of the sockets, and the infrared sensor can be easily adjusted. Will handle two 150 watt PAR 38 lamps. Suitable for wet locations. 

Bubs not included CATS L-101 - $1.50 each

CATS OSR-4 2 for $1.00

Rectangular package with postage for a catalog.

Switches

Dip P.C. Pushbutton
ITT Schadow Digitast Series ELC 94 S.P.D.T. momentary pushbutton. Mounts in 14 pin DIP configuration. Designed for low current switching applications. Grey keycap is 0.68" x 0.67".

CATS PB-28 - $1.00 each + 10 for $9.00 + 50 for $55.00

Pushbutton Switch
SMK Manufacturing 0.47" square black pushbutton. SPST normally open. 4 p.c. pins for mounting. Ideal for low current switching applications.

CATS PB-29 - 5 for $1.00 + 10 for $15.00

Rotary BCD Switch
EECO #231-02G
BCD 10 position rotary switch. DIP configuration fits in standard L.C. locoted. High angle style Screwdriver actuation. 0.42" c.t.a.

CATS RDP-P - $1.75 each + 10 for $16.00 + 100 for $145.00

Miniature Toggles
Rated: 3 amps @ 120 Vac

S.P.D.T. (ON-ON) solder lug 10 for $12.50 + 100 for $110.00

S.P.D.T. (ON-ON) solder lug 10 for $1.25 + 100 for $11.00

D.P.D.T. (ON-ON) solder lug 10 for $1.00 + 100 for $10.00

D.P.D.T. (ON-ON) P.C. mount 10 for $2.00 + 100 for $17.00

Telephone Keypad

12 button telephone keypad. Ivory finish. 2.83" x 2.2" x 0.58" thick. Matrix wired. Ideal for telephone or security keypad.

CATS KPT-1 - $1.00 each + 10 for $9.00

Op-amp Sensor

TRW Op Amp # OP8447-2 An active op-amp sensor in a
Rectangular package with 28" color coded leads. CATS OSA-2 - $1.00 each

Photosensitive Capsules

Rubicon CE
210 Mild 330 Volt photoflash capsule 70" dia.

CATS CD-7 - $1.00 each + 10 for $9.00

1.1" x 1.1" high. These are like new for 150. All have been prepped with 14" black and red wire leads soldered to the terminals.

CATS PRC-219 - $1.25 each + 10 for $11.00 + 100 for $100.00

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6 Volt 1 Amp/ Hour
Japan Storage Battery Co.

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6 Volt Air rechargeable sealed lead- acid

CATS GC-61 - $4.75 each + 10 for $42.50

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Dual 1K audio
3 1/2" long, 2 1/2" slide

CATS ASP-1K - Reduced to 50c each + 100 for $4.00

I.E.C. Power Cord

Red CATS CAB-1
Green CATS CAB-2
Yellow CATS CAB-3

10 for $2.00 + 100 for $17.00

Flash Assembly

New compact flash assembly from a U.S. manufacturer of camcorders. Operates on 9 Vdc and measures 2.12" x 1.14". Ideal for use as a strobe, warning light or attention getter. Includes hook-up diagram. CATS FSAH-I - $3.75 each + 10 for $35.00 + 100 for $225.00

Flasher Kit

DIP 12 Volt, 6 pin connector. Black and red leads terminated. These are new.

CATS FL-101 - $4.50 each + 10 for $40.00

1.2 volts 1200 mAh

CATS ASK-1 - $4.25 each + 10 for $37.50

100 for $100.00

L.E.D. and Flasher Kit

Two L.E.D.'s flash in unison when a 9 volt battery is attached. This kit includes a prebuilt circuit, the parts and instructions to make a simple flasher circuit. A quick and easy project for anyone with basic soldering skills.

CATS LBDK - $1.75 per kit

Chaser Kit

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.

CATS AEC - $6.50 each

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CATS SMKIT - $18.00 each

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  - with 0.15,90 and 100% markers
- **Acceleration potential:**
  - Approximately 2KV
- **Z-axis input:**
  - Sensitivity: At least 5 V/div
  - Polarity: Positive-going input decreases intensity
- **Usable frequency range:**
  - DC to 2MHz
- **Maximum input voltage:**
  - 30V (DC+AC peak)
- **Input impedance:** 47KΩ (typ)

- **Vertical Deflection System**
  - Sensitivity and accuracy
    - 5mV/div to 5V/div ± 15% calibrated steps
    - 1mV/div to 1V/div ± 15% (when using x5 magnifier)
  - UCali microswitch automatic gain control between steps
  - at least 1:2.5 with uncalibrated
- **Bandwidth**
  - DC to 20MHz (-3dB)
  - When using x5 magnifier: DC to 7MHz (-3dB)
  - Rise time
    - Approximately 17.5ns
- **Input coupling**
  - AC, GND, DC
- **Input impedance**
  - 1MΩ approximately 30:1:1F
- **Display mode**
  - CH1, CH2, ALI, CHOP, ADD
- **Polarity inverter**
  - CH2 only
- **Dynamic range**
  - 8 divisions or more
- **X-Y Operation**
  - CH1: X-axis
  - CH2: Y-axis

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Fax 1-818-986-2009

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**BEST SENSITIVITY**
**BEST RANGE**
**HOLD SWITCH**

The Original Handi-Counter™
Imitated but Never Duplicated

OPTOELECTRONICS brings you the latest in a long line of quality LED Handi-Counters™ - The New 2300. The 2300 has inherited the outstanding features of the 1200H, 1300H, 2400H & 1300HA.

No other counter can match this family history. Additional new features include:

- **Dual MMIC Amplifiers** for maximum possible sensitivity. (<1mv 150MHz <5mv 850MHz <25mv 2GHz.)
- **Continuous Range.** No cumbersome range switch.
- **Hi-Tech Painted Finish.** More rugged than anodized cases
- **600 mA Hr. Batteries.** Not the cheapest but the best!
- **Display Saving Power Switch.** Avoids Premature LED Burn out. (Leading cause of counter failure.)
- **17 years of quality and dependability to back our products.**

### Model 2300 Specifications

<table>
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<tr>
<th>Model</th>
<th>Function</th>
<th>Range</th>
<th>Display</th>
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<th>Price</th>
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<td>2300</td>
<td>LCD w/Function Annunciators</td>
<td>10 Digit</td>
<td>16 Segment Adjustable Bargraph</td>
<td>$579</td>
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Sensitivity: <1 to <10mV typical. Time Base: ± 1 ppm. ± 3 ppm add $100. LCD Models: NiCads & AC chargers/adaptors included except for 2300. For 2300, NiCad installed, $20 & AC charger/adapter, $9. Carry case and a full line of probes and antennas are available. One year parts & labor warranty on all products.

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Isolate These And Other Major Components In All TVs And VCRs—Guaranteed Or Your Money Back!

Plus, Cut Your Video Troubleshooting Time By 54%* With The Patented VA62A Universal Video Analyzer!

Identify tuner problems with the only integrated all-channel, VHF, UHF, and cable RF generator. Standard TV, standard cable (2-99), and exclusive programmable cable channels eliminate the question "Is it the TV or is it the cable?"

Pinpoint IF troubles with modulated troubleshooting signals and exclusive programmable IF generator. How do you presently identify if the suspected defect is in the AGC, IF/Detector IC, or caused by the tuner? Wouldn't you like to know exactly where the defect is before you order the part or pull the tuner. With the VA62A you will!

Exclusive video patterns completely performance test TVs, VCRs, and monitors — without removing the cover. Is there a picture, is it locked in, is the bandwidth correct, is the brightness and contrast correct, and is the color tint and saturation correct? You'll know in less than 60 seconds using the VA62A's exclusive video patterns.

Find defective stages, without disconnecting parts, with exclusive phase-locked drive signals. "Swamp out" the suspect signal and replace it with a known-good signal. You'll isolate the problem to a bad stage in minutes, guaranteed.

Test yokes and flybacks with the patented "Ringer". Most shops are forced to substitute yokes and flybacks instead of analyzing circuits. The VA62A's patented "Ringer" and exclusive flyback drive tests allow you to completely analyze all yokes, flybacks, and IHVTs before you order a new one.

Measure signal levels with a fully autoranged PPV and DCV digital meter. The VA62A's built-in meter shows when you are driving into a shorted circuit and prevents you from overdriving critical stages. Plus, measure bias voltages and signal levels throughout the entire TV and VCR.

It's obsolete proof: update for new technology with exclusive phase-locked accessories. We'll provide new companion units as the manufacturers announce new formats, test patterns, etc. This makes your VA62A a protected investment.

* Based on a nationwide survey of users who reported an average time savings of 54% compared to their previous test equipment.

For More Details Call 1-800-SENCORE ext. 612

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