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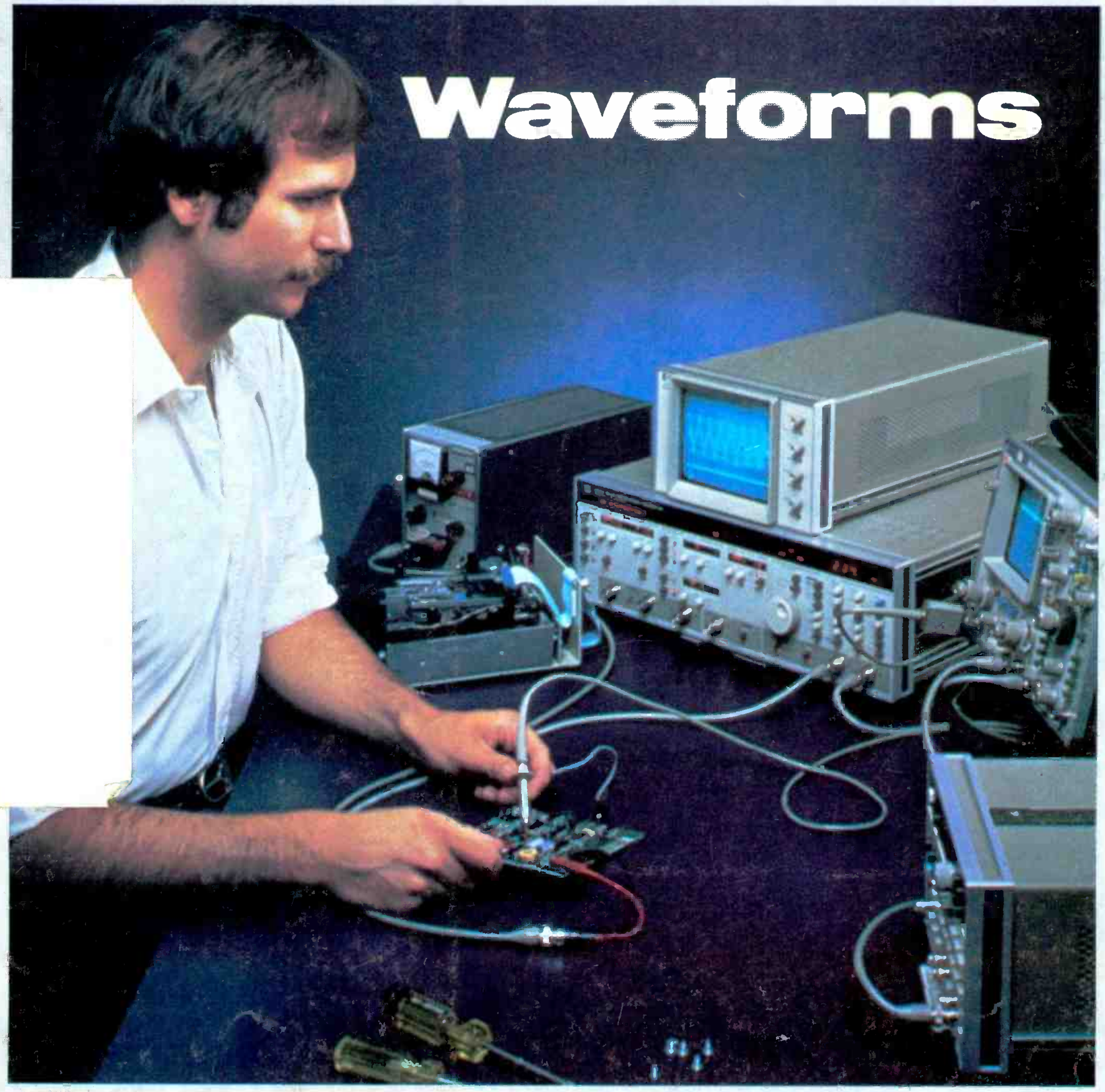

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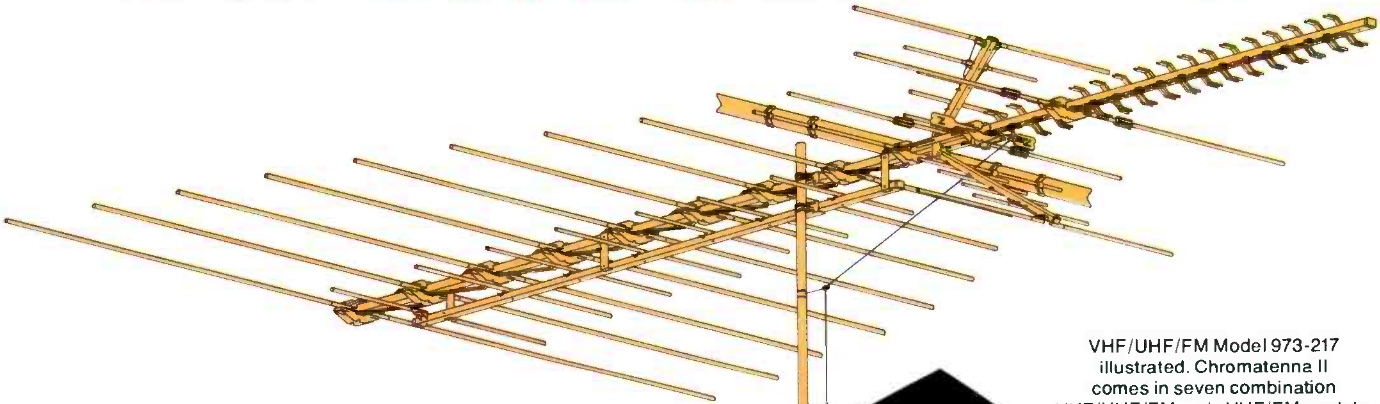

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ELECTRONIC

Servicing & Technology

May 1984

Volume 4, No. 5

Looking at a waveform is like looking at the EKG or EEG of an electronic device: It will tell you a lot about the circuit's health, but you have to know how to interpret the information. See "Waveforms" on page 50. *(Photo courtesy of Hewlett-Packard)*

6 **Test your electronic knowledge**
By Sam Wilson, CET
This month's questions are similar to those that are most often answered incorrectly on the associate-level CET test.

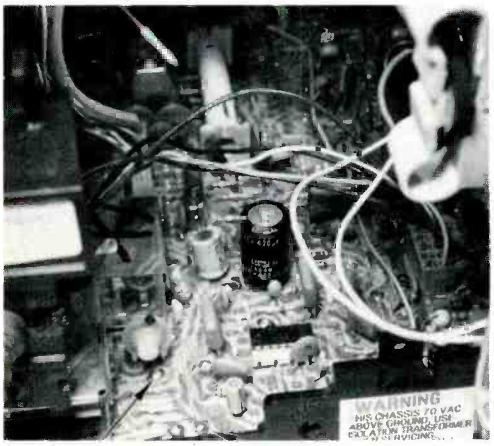
10 **Inside a microcomputer, Part 2**
By Bernard Daien
This article discusses how information is entered and how the MPU interfaces with various input/output devices.

20 **Tips for servicing GE's AB/AC chassis**
By Homer L. Davidson
These service hints and repair symptoms may help you to repair the small GE TV chassis.

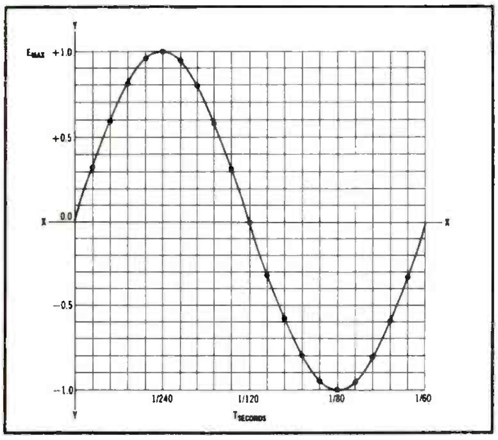
28 **Build this simple DMM temperature probe**
By Michael A. Covington
With just a few basic materials, you can make this temperature probe for your digital multimeter.

40 **Know your oscilloscope**
By Robert G. Middleton
This discussion of oscilloscope basics, CRTs, input impedance and sensitivity may help you use your oscilloscope more effectively.

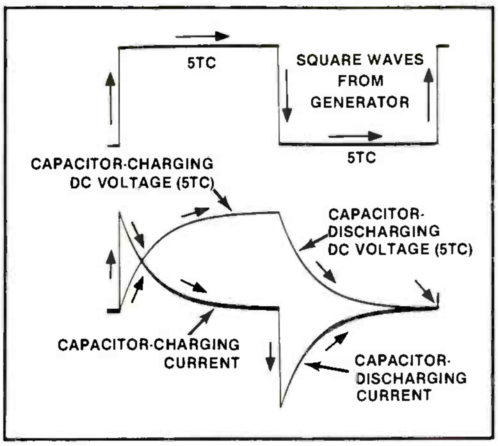
50 **Interpreting waveforms, Part 2**
By Carl Babcoke, CET
A solid understanding of how waveforms are affected by various circuit components can be valuable in troubleshooting electronic equipment.



Page 20



Page 40



Page 50

Departments

4 Editorial
8 News
37 Photofact
38 Troubleshooting Tips
58 Books
60 Readers' Exchange
61 Products

Next month...

Servicing the Intellivision video game. This how-to article tells you what can go wrong with the Intellivision video game and how to fix it. It also serves as an introduction to microcomputer servicing.

Editorial

Diagnosing a sick circuit

When you go to see the doctor for a checkup, or for a diagnosis if you're not feeling well, the first thing they do to you is put you on a scale to check your weight, slip a thermometer under your tongue to record your temperature, count your pulse and slap a cuff on your arm to see what your blood pressure is up to. Before the doctor even sees you he has the results of four tests. He'll probably probe and poke, and if he doesn't like what he sees he may order some more tests: an electrocardiogram perhaps, maybe a blood analysis. The results of all these laboratory tests, properly interpreted, can help the physician determine if something's wrong, if so what, and what corrective action is necessary.

When you bring your car into the garage for any kind of major service work, the mechanic will probably hook up the engine analyzer for a check of all the electrical functions. Next would probably come cylinder pressure readings, intake manifold vacuum, and maybe even such things as a cooling system pressure check, belt tension and possibly a host of other tests and readings.

No matter what the equipment, the human body, your car or a piece of electronic equipment, the only way to determine if it's operating properly, and if it's not to determine corrective measures, is to apply the appropriate test equipment in the required manner and properly interpret the results of those tests.

Test equipment has become more sophisticated. For medical diagnosis, for example, today's arsenal of test equipment includes X-ray, CAT scan equipment and thermography and ultrasound, to name just a few.

In electronics, new and more sophisticated test equipment is constantly being developed. Oscilloscopes are offered with broader bandwidths and greater ease of use. Logic testers and analyzers check out digital circuitry. Hand-held DMMs come with measurement capability that was previously only available in benchtop models. The capabilities of modern electronic test instruments have kept pace with the increasing sophistication of electronics products and provide adequate information for diagnosis and repair.

One thing that hasn't changed, though, is the need for proper interpretation of the data derived from test instruments. Without that, the instrument is nearly useless. The article "Know Your Oscilloscope" in this issue gives a broad brush picture of the internal workings of that venerable instrument. That, along with another article in this issue, "Waveforms – Part II" should enhance a readers' application and interpretation of oscilloscopes.

If that's not enough to solve your diagnostic problems, we tell you in "Build this DMM temperature probe" how to construct a thermometer to take your circuit's temperature.

Nils Conrad Persson

ELECTRONIC Servicing & Technology

Editorial, advertising and circulation correspondence should be addressed to: P.O. Box 12901, Overland Park, KS 66212-9981 (a suburb of Kansas City, MO); (913) 888-4664.

ELECTRONIC SERVICING & TECHNOLOGY (USPS 462-050) (with which is combined Electronic Technician/Dealer) is published monthly by Intertec Publishing Corp., 9221 Quivira Road, P.O. Box 12901, Overland Park, KS 66212-9981. Second Class Postage paid at Shawnee Mission, KS 66201. **Send Form 3579 to P.O. Box 12952, Overland Park, KS 66212-9981.**

ELECTRONIC SERVICING & TECHNOLOGY is the "how-to" magazine of electronics. It is edited for electronic professionals and enthusiasts who are interested in buying, building, installing and repairing home-entertainment electronic equipment (audio, video, microcomputers, electronic games, etc.).

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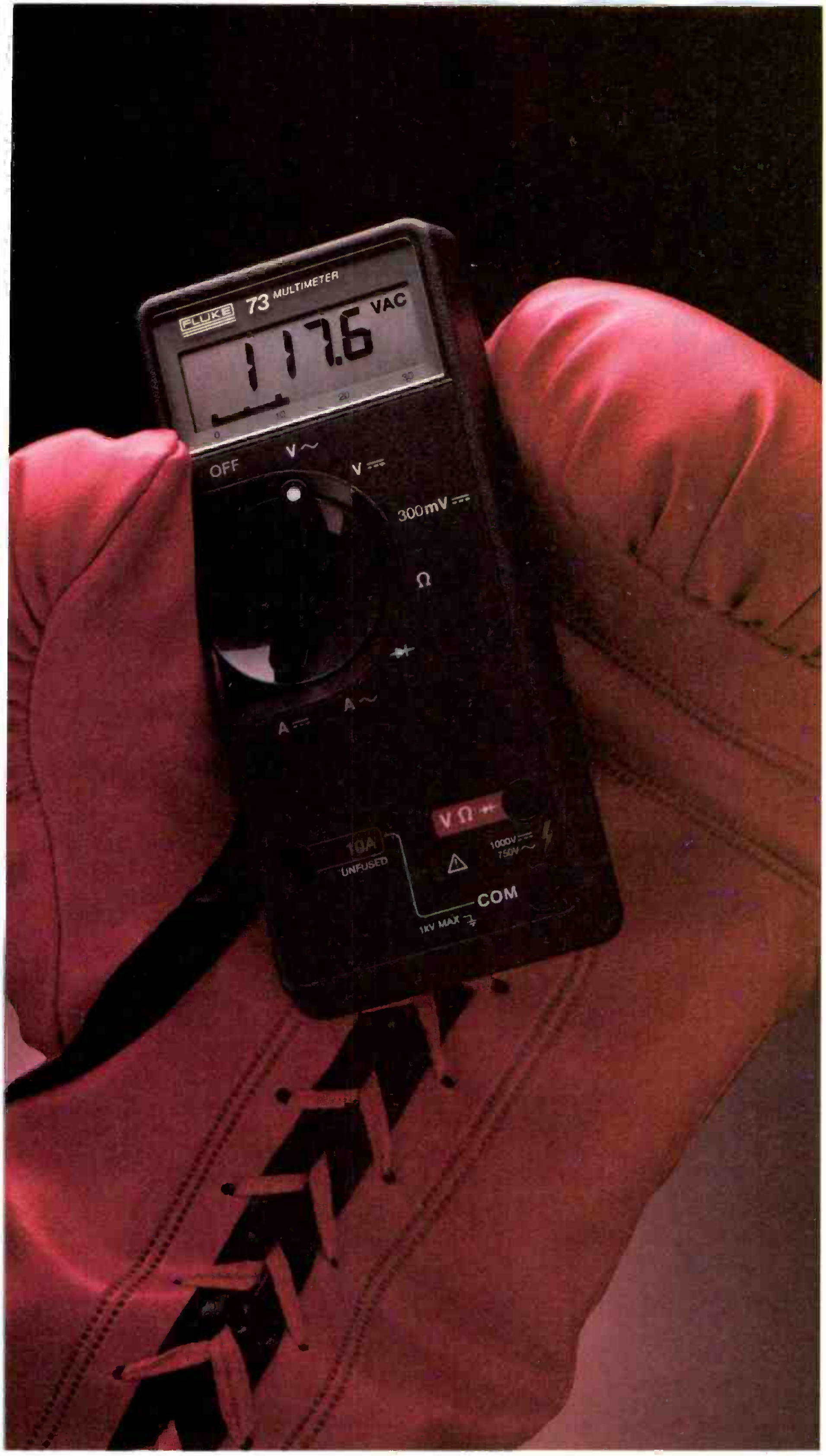

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Test your electronic knowledge

By Sam Wilson

Here are some examples of questions often missed on the associate-level CET test. You will not get these same questions, but the subject matter is the same. (Answers on page 59.)

1. A technician is troubleshooting the L-F stage in a receiver, and has reason to suspect that the second L-F amplifier (Q406 of Figure 1) is defective. He connects a probe from base to collector in order to bypass the signal around the amplifier. Which of the following statements is correct?
   A. The receiver should work for local stations with strong signals.
   B. Now he *knows* Q406 is defective. He just destroyed it.
   C. Resistor R will be destroyed by this test.

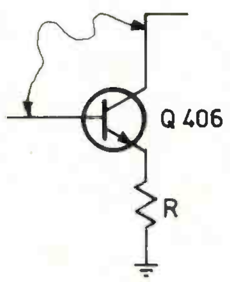

Figure 1

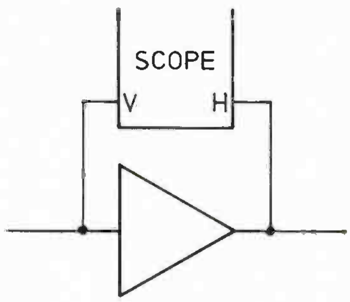

Figure 2A

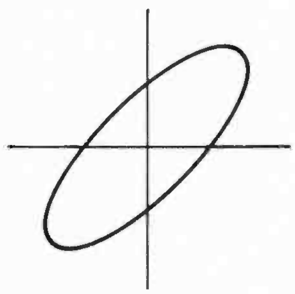

Figure 2B

2. The amplifier in Figure 2A is being tested for distortion at 2.5kHz. The pattern is displayed in Figure 2B. The indication is
   A. Normal
   B. Noise
   C. Clipping, or amplitude distortion
   D. Phase-shift distortion
   E. None of the above.

3. The trimmer of Figure 3 is adjusted by a screw that moves the plates closer or farther apart. It is in parallel with a tuning capacitor for a radio. When the dial of the radio points to 1000kHz, the tuned circuit is actually resonant to 998kHz. To make the dial reading accurate,
   A. Move the plates of the trimmer closer together.
   B. Move the plates of the trimmer farther apart.

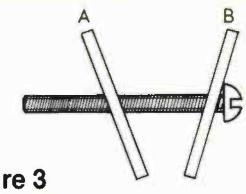

Figure 3

4. Inductive reactance is measured in
   A. Farads
   B. Drafts
   C. Henries
   D. Ohms
   E. Degrees.

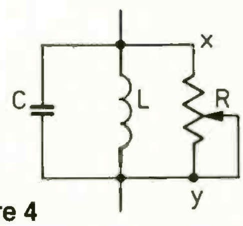

Figure 4

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5. To make the circuit in Figure 4 tune more broadly, adjust the variable resistor by moving the arm toward
   A. point x
   B. point y.

6. Which of the following gives the relationship between bandwidth and the output rise time of a step function that is delivered to the amplifier input?
   A. A longer rise time is an indication of a narrower bandwidth.
   B. A shorter rise time is an indication of a wider bandwidth.

7. The maximum amount of power that can be delivered to a component that is connected between *x* and *y* in Figure 5 is
   A. 6W
   B. 9W
   C. 18W
   D. 36W
   E. The answer cannot be determined from the information given.

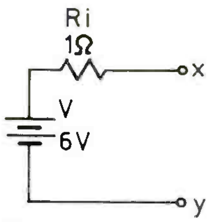

Figure 5

8. When you add 1001_2 to 110_2 you get
   A. 11_8
   B. 10000_2
   C. 10_8
   D. 15_{10}
   E. None of the above.

9. Which of the following operates as an analog memory?
   A. Sample and hold
   B. Integrator
   C. Differential amplifier
   D. Programmable counter
   E. Slope detector.

10. Which of the following normally is not associated with operational amplifiers?
   A. Virtual ground
   B. Common mode rejection
   C. Exponential rolloff
   D. High over-loop gain
   E. Slewing rate (or, slew rate).

News

Legislation affirms legality of satellite TV

Legislation has been introduced in the Senate and House of Representatives that affirms that it is legal for private individuals to receive TV programming from orbiting satellites.

The bill would amend the Communications Act of 1934, Section 605, which provides for the prosecution of anyone intercepting and divulging certain types of wire communications. Opponents of the satellite TV industry—including certain pay TV services and cable companies—have sought to have this section applied to the reception and viewing of satellite TV programming, and to have the manufacture, sale and use of equipment for this purpose banned.

"Our opponents have sought to advise the lawmakers of 1934 with space-age foresight," said Peter Dalton, president of the Society for Private and Commercial Earth Stations. SPACE has fought against the sweeping interpretation of the 1934 law because the technology for satellite TV reception did not exist at that time and was not even contemplated. "Unfortunately, no such crystal ball existed 50 years ago and there is no rational basis for applying this old law to the modern-day miracle of satellite receiving technology."

Dalton declared the introduction of the bill a victory for the American consumer. Approximately 600,000 installations of satellite receiving systems are expected to be made in 1984, with a retail value of $1.4 billion.

Troubleshooting seminar offered

Understanding and Troubleshooting Microprocessors is the title of a four-day seminar designed for individuals responsible for troubleshooting microprocessor-based products. Those attending the seminar will learn alternative methods for troubleshooting microprocessors, and will analyze the cost and benefits of each so they are able to make better decisions concerning the best solutions. The business aspects and the technical aspects of troubleshooting are examined.

The seminar offers hands-on experience with selected examples of solutions to the troubleshooting problem. These include some actual failures in addition to a wide range of other experiments. The instructor for the seminar is Dick Gasperini, author of two books on troubleshooting digital products.

The seminar will be held May 15-18 in Boston, June 4-7 in San Diego, June 25-28 in Chicago, July 10-13 in Minneapolis, and Sept. 17-20 in Dallas. For other dates and locations or other additional information, contact Movonics Company, Box 1223, 4966 El Camino Real, Los Altos, CA 94022; 415-960-1250.

Telecommunications servicing added to NPEC agenda

A session on servicing telephones and telecommunications equipment has been set for the afternoon of Wednesday, Aug. 8, at the National Professional Electronics Convention in St. Louis. Gus Rose, director of engineering at B&K Precision/Dynascan, will conduct the session on the servicing of electronic phones, cordless phones and answering machines. Problems with each of those devices will be discussed, as well as the symptoms and repair techniques involved.

For more information contact NPEC, 2708 W. Berry St., Fort Worth, TX 76109: 817-921-9061.

Seminars planned for ETA convention

The Professional Electronics Technicians Association will hold its 1984 convention on May 24-27 in Clearwater, FL. Seminars planned for the convention are aimed at working technicians, service business owners, electronics teachers and electronics technology students. The convention will include workshops on "Managing the service business," "Computer servicing procedures," "Test equipment of the '80s" and "Advancing your career as a technician."

For more information contact the ETA, R.R. 3, Box 564, Greencastle, IN 46135; 317-653-8458.

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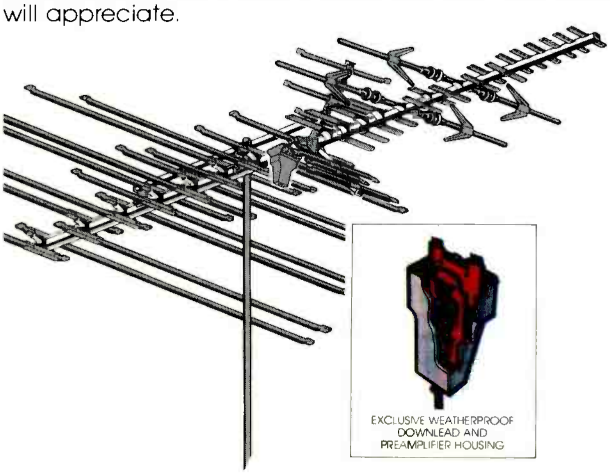

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Inside a microcomputer

Part II

When your personal computer fails, what's the problem? A knowledge of what's happening inside the black box will give you some insights that can enhance orderly troubleshooting.

By Bernard Daien

The first part of this article discussed the architecture of a microcomputer, why the various sections are needed, and how they interrelate. This part of the article discusses how information is entered, programming, coupling to teletypewriters and telephone lines, and so forth and how information is output to readouts and other devices. Remember, the microcomputer is useless without inputs and outputs, therefore provisions for them are really an integral part of any microcomputer-based system.

Memories are also an essential part of microcomputer-based systems. Accordingly, this article covers the relationship of the microprocessor (MPU) and the memory and touches on memory organization.

Communicating with the computer

Because the microcomputer performs all of its internal operations in binary form, instructions must be in binary form. Unfortunately, English consists of a 26-letter alphabet, and our decimal system of numbers is not in binary either. Talking to the computer system requires the use of only ones and zeros (binary) because that is the computer's language (known as "machine code"). Writing information in machine code is tedious and error prone. As an example, using the typical 8-bit words employed by many microcomputer-based systems, you would input something like this: 00101011, 10110100. This is not easy to remember.

Several schemes have been developed to make things easier; some simply use what is known as *assembly language*. This is not a true language, but simply a series of *mnemonics* (memory joggers), usually in the form of abbreviations. For example, the words *no operation* become *NOP*. Although this helps, it is not time or cost effective, because in assembly language, each of the steps in a calculation must be stated one at a time.

How does the computer *know* assembly language if it runs in binary? The answer is that a program called an *assembler* is placed in the computer's memory banks and used like a look-up table or dictionary. The computer examines each mnemonic entered in the programming, and translates it into machine code. Remember, you can make the computer do many different tasks by merely entering a suitable program. Assembly language is considered a *lower level* language, because it causes one operation to be made for each program instruction entered. There are more powerful *higher level* languages that can cause an entire series of operations to be performed with only one, or a few, instructions. For example, you can enter a problem, order it solved, and, with a higher level language, the computer will perform all of the many steps required to solve the problem and state the answer.

Higher level languages such as BASIC, COBOL or FORTRAN, can do more with less effort, but to use them you must enter a longer program called an *interpreter,* or a *compiler* into the computer's random-access memory (RAM). Sometimes these are entered permanently in the form of a read-only memory (ROM). Many personal computers have BASIC included in ROM at the time of manufacture. In any event, assemblers, interpreters, and compilers are programs held in memory to enable the computer to understand human language and math. They are translation tables of one sort or another, usually in external memory. As a result, large amounts of memory are used up by these programs. The memory so used is unavailable for problem solving. If the computer has only a limited amount of memory, this may result in a major handicap. It is desirable that the computer have a capability of at least 32K of memory addressing if even a modest amount of programming is to be done, along with a BASIC language interpreter. This is one reason why some of the smallest and least expensive computers now on the market should be considered as little more than toys.

The microcomputer revolution, which started only a few years ago, has already progressed to a state of maturity that few could possibly have foreseen. From those early days when a microcomputer (no one called them personal computers yet) was a PC board stuffed with ICs, with a hexadecimal keypad input, an LED readout and "roll your own" software, the technology has progressed to the point where personal computers of today rival the sophistication and ease of use of their larger counterparts.

There are *real* computers available today for a few thousand dollars. The accompanying article is the second of two designed to give a general idea of the design of these units to help make their servicing less of a mystery. This section describes a recently introduced real-world computer that offers advanced features at reasonable cost.

The Z-100 PC series by Zenith Data Systems is compatible with the IBM PC and is available in two basic configurations—the Z-150 series desktop and Z-160 series portable models. Standard features of the Zenith PC series include:

- 128K bytes of RAM, expandable on the existing board to 320K, and with one expansion board, expandable to 640K. The built-in board will also accept 256K chips.
- Monitor outputs for RGB color and composite "grayscale" monochrome video.
- Built-in menu-driven diagnostic software.
- Three scrolling modes: basic, smooth and jump.
- High-speed text and graphics display.

"Zenith has also included special features to make troubleshooting easier," according to Randall E. Griffin, vice president for product management and planning. "For example, Zenith's basic power-up diagnostics execute in less than five seconds, compared to as long as 60 seconds on many other systems. If a problem is identified, the user can invoke a comprehensive menu-driven set of diagnostics to perform more rigorous testing of the system."

The ROM also includes a powerful monitor/debugger, with which users can "single step" through programs to modify them or troubleshoot.

"We're going to provide disc-based test systems, which are intended to be used by kit builders, technicians and original equipment manufacturers," Griffin said. "These provide more extensive testing than the ROM-based diagnostics."

The Z-100 PCs are designed for easy servicing. "All of the basic operating systems—the boards, power supply and disc drives—are interchangeable on all five models, and all are readily accessible through the top of the cabinet." To aid service technicians, the Z-100 PC has six LED indicators to monitor power on the bus.

The five models in the Z-100 PC line are essentially the same internally except for the type and number of drives, Griffin said. The desktop units are available in three configurations: single or dual 5¼-inch soft-sector floppy disc drive, and a dual-drive system in which one of the drives is a Winchester 10.6Mb hard disc drive.

This problem cannot be solved by merely adding memory because the MPU must have the ability to address the amount of memory added. Remember, a 16-bit addressing capability will handle a 64K memory, but if the MPU does not have a 16-bit address bus, you simply cannot add that much memory. Some of the lowest priced MPU-based computers only have limited add-on memory handling ability and will never be able to do some of the tasks requiring more memory. It is advisable to purchase an MPU-based computer with the capability of handling 64K of solid-state memory, or alternately, one of the disc drives for magnetic disc memory. The disc is slower, but can handle a great deal of memory. Another popular way to go is to buy a system that can be interfaced with one of the inexpensive magnetic tape cassette recorders and, although slower than disc, you'll have lots of memory ability, even with an assembler, interpreter, or compiler held in memory.

Of course, in order to use the higher language capability of the system in programming, you will have to learn the vocabulary of the language used. BASIC is the most common language used now with small computer systems and the easiest to learn. The computer has a limited vocabulary; it cannot understand all, or even most, of the common words in the English language. It does understand a relatively few, and you will be limited to those few. There are also some rules about the form in which you address the computer, but this is no more difficult than learning the form in which you write a business letter. Finally, the MPU can handle common math in BASIC, using math equations with some symbols changed a little or restricted. Again, these are easy rules to learn and pose no difficulty because the computer is doing most of the work of translation. Remember, software replaces hardware, and the computer can do many tasks if it is programmed to do them.

Interfacing

It was just mentioned that the computer can handle a magnetic disc drive, but only if there is a proper disc controller interface between the computer and the disc drive mechanism. This is needed because there has to be some way to start and stop the drive motors, select the proper location on the magnetic disc itself (addressing), and either record or play back the information. This sort of situation occurs with other external devices and links to other digital systems. However, there is still another problem that must be overcome by means of the interfacing, or the input or output device used.

The MPU system moves information around in 8-bit *parallel* format, or even 16-bit *parallel* format. This means that all the information is delivered simultaneously, like a rubber stamp printing all the words on it at the same time. Many of the external devices are *serial* format, in which the information is delivered a little at a time, the way a typewriter prints information. Further, there is no probability that the two systems are even running at the same speed. The MPU is synchronous, slaved to the clock frequency, while a teletype runs at a much slower speed: the MPU running at a frequency in megahertz, and the teletype at only a few hertz. In some way serial must be converted to parallel for inputs, and parallel to serial for outputs. The differences in speed of operation must also be overcome in order to have a practical working system.

Much of the usefulness of computers lies in their ability to communicate with other digital devices via teletype or telephone. This eliminates the need for everything to be at the same location, which is important.

Data transmission

The Asynchronous Interface Adapter is one of the interface devices in common use (also known as the Asynchronous Communications Interface Adapter, or ACIA). This is capable of converting serial to parallel/parallel to serial, all with the two systems running at different speeds. It does this by taking serial information one bit at a time and storing it in a register until 8-bits are stored, then dumping them out in parallel form. The timing is controlled by the clock on the MPU, for outputting the information to the MPU, thus getting into "sync" with the MPU. If the input serial device is slower than the MPU, the information is simply stored until 8-bits are present and dumped at the proper part of the clock cycle. Going the other way, the register in the ACIA is loaded in parallel (all at once) and released in serial form into the output line.

Another versatile and common device for interfacing is the Peripheral Interface Adapter (PIA). The word peripheral means roughly the same as I/O. This device connects to the 8-bit data bus and uses the bus to input and output in the 8-bit parallel format used by the MPU. The PIA also connects to two separate 8-bit buses going to other I/O devices. Thus, the PIA can handle 16-bits from the outside world and deliver them as two 8-bit words, in sequence, to the 8-bit bidirectional data bus. Or, it can take two sequential 8-bit data words from the MPU and output them as a single 16-bit word to an outside 16-bit bus, connecting to other devices. It can connect to two independent 8-bit external data buses or to any combination of the above. Of course, the PIA does this by means of internal registers like the ACIA.

Both the PIA and the ACIA are under control of the MPU via the control bus. This enables the MPU to ascertain if the PIA or ACIA is busy or available and turn it on or off in the output or input mode by means of the control bus.

Stated another way, because the computer has no control over the source of input information, in order to make a useful system, the computer must be able to interface with that source, whatever it is. The interface device accomplishes

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Circle (7) on Reply Card

this task, and although it is not, strictly speaking, part of the computer, it is an essential part of the computer-based system.

Now look at some of these input and output devices, now that you can interface with them via the PIA, ACIA, or a number of other specialized interface devices that are available for most commonly encountered I/Os.

A *terminal* is nothing but a keyboard with the alphabet, numbers, punctuation marks and symbols. If the terminal is electromechanical with a printout capability using standard teletype format, it is called a teletypewriter. Most terminals are electronic and work in conjunction with some form of separate display, like a cathode ray tube, on the less expensive small systems. Terminals may therefore be strictly an input device, or an input and output device, depending on their design.

Telephone couplers can be used as input or output devices in conjunction with the telephone lines. Many of them are acoustic devices, which use a small speaker and a microphone to put information into the telephone handset. Both the terminal and the acoustic coupler are serial devices.

Cathode ray displays, such as TV sets and monitors, pose another problem. Because of their sweep systems, the data to be displayed must be repeated for each frame scanned if the image is to appear stationary. This requires that the data from the MPU must be stored in some rather large memory and read out over and over, for every frame displayed, for as long as the image is to remain on the screen. This uses quite a bit of memory if a large amount of information is to be displayed, and requires a complex interface subsystem.

Even the lowly LED or LCD display requires that there be a decoder, which can decode binary into the seven segments used for each character in the display. Because the computer must read out in decimal numbers, it must decode binary into a 7-segment decimal. Fortunately, some of this decoding is done on the LED or LCD display chip, but some of it is often done in other interfacing circuitry as well, either internal or external to the MPU system.

About memories

Memory is vital to the operation of the system. There are many forms of memory, but the fastest, most inexpensive, most reliable memory for small systems is the solid-state memory. Years ago magnetic core memories were standard, but although they were reliable, they were bulky, had low output, and for small systems, have been almost entirely replaced by other memories.

Tape cassette memories offer fairly large memory capability. The cassettes can be mailed, are inexpensive and are probably the second most popular form of bulk memory used with small systems. Disc systems, using a magnetic disc much like a 45 rpm phono record, are more expensive, more complex, and are the third choice in small systems, but they are used extensively in business and professional machines today.

This article will be confined to the solid-state systems that in home computers are usually limited to 64,000 word memories. Note that the term *word* is used, because each address in a solid-state memory contains an 8-bit word. Be careful because sometimes memories are rated as to word-storing capability, at other times as to the total number of bits stored. Obviously a 64K word memory storing 8-bit words is really storing 64,000 x 8 bits, which equals 512,000 bits. If the system were using the simplest flip-flops to store this data, the flip-flops alone in the memory system would require more than a million transistors inside the chips.

In order to make this clear, it is common to refer to memories as, for example, a 4K x 8, which means 4000 words of 8 bits each. Some of the smaller, older MPUs used 4-bit data words, and in that case you might be using a 16K x 4; 16,000 words of four bits each. When you address such a memory you can only select the word you want, not the individual bits of the word. You get *all* of the bits of the word stored all at once.

Unfortunately, many of the solid-state memories are *volatile:* the contents of the memory are lost if the power source is lost, even momentarily. This can be partially avoided by using a rechargeable battery as backup power, or better yet, by placing memory that is needed repeatedly in a permanent ROM, which is not volatile.

Solid-state memories are not usually on one large chip because, as was already noted, a 64K x 8 RAM would require much more than a million transistors. It is customary to use a number of smaller, readily available and inexpensive RAM chips to organize a large memory. For example, if 16K x 8 memory were needed for a small home system, you would use 16 RAM chips of 1K x 8 each; or just as readily, 16 chips of 2K x 4 each. They both have the capability of storing 128,000 bits total. This is illustrated in Figure 1, which, as a simple example, shows two alternate ways to organize a memory of 1K x 4.

Notice that because the computer uses several memory RAM (or ROM) chips, you need to be able to select the particular chip or chips that have the desired word in them, as well as the location of that word in the chip selected. Therefore, the memory address bus has some of its wires assigned to word location, and others to chip selection. The way the 16-bit address bus is divided depends on the organization of the memory. It all adds up to the same addressing capability, however, because 64K is 64K, no matter how you divide it, just as the number 100 is 5 x 20, or 10 x 10, or 25 x 4. It all amounts to the same total. The whole point of this discussion so far is to make the point that the address bus may have 3 chip select wires and 13 address selects, as just one possibility, but it is a 16-wire (bit) address bus.

Circle (8) on Reply Card

In essence, what has been said is that the way devices external to the MPU, such as memory, I/Os and interfaces are set up affects the way the bus system is organized. Again, the MPU is a flexible device; it can do many things depending on how it is programmed and interconnected. This is undoubtedly part of the fascination of the MPU; it's almost like a chess game with all the possibilities and variations.

Now, back to memories. In addition to the address bus, the memory is tied to one of the lines in the control bus, which is used to input the *read/write* signal that determines whether information is being entered in the memory or retrieved. Thus, it is possible to select a chip, select an address in the chip, and read out of or write into the memory. Sometimes the memory has internal or external buffers, which are frequently tri-state. These can be enabled or disabled as required, which gives the ability to input and output the contents of the memory into the 8-bit bidirectional data bus. This is essential in the case of memories because all the memory chips are connected to the bidirectional data bus all of the time. The chips that have been selected are active; the others are not. Because outputting and inputting takes place on the same 8-bit bidirectional data bus,

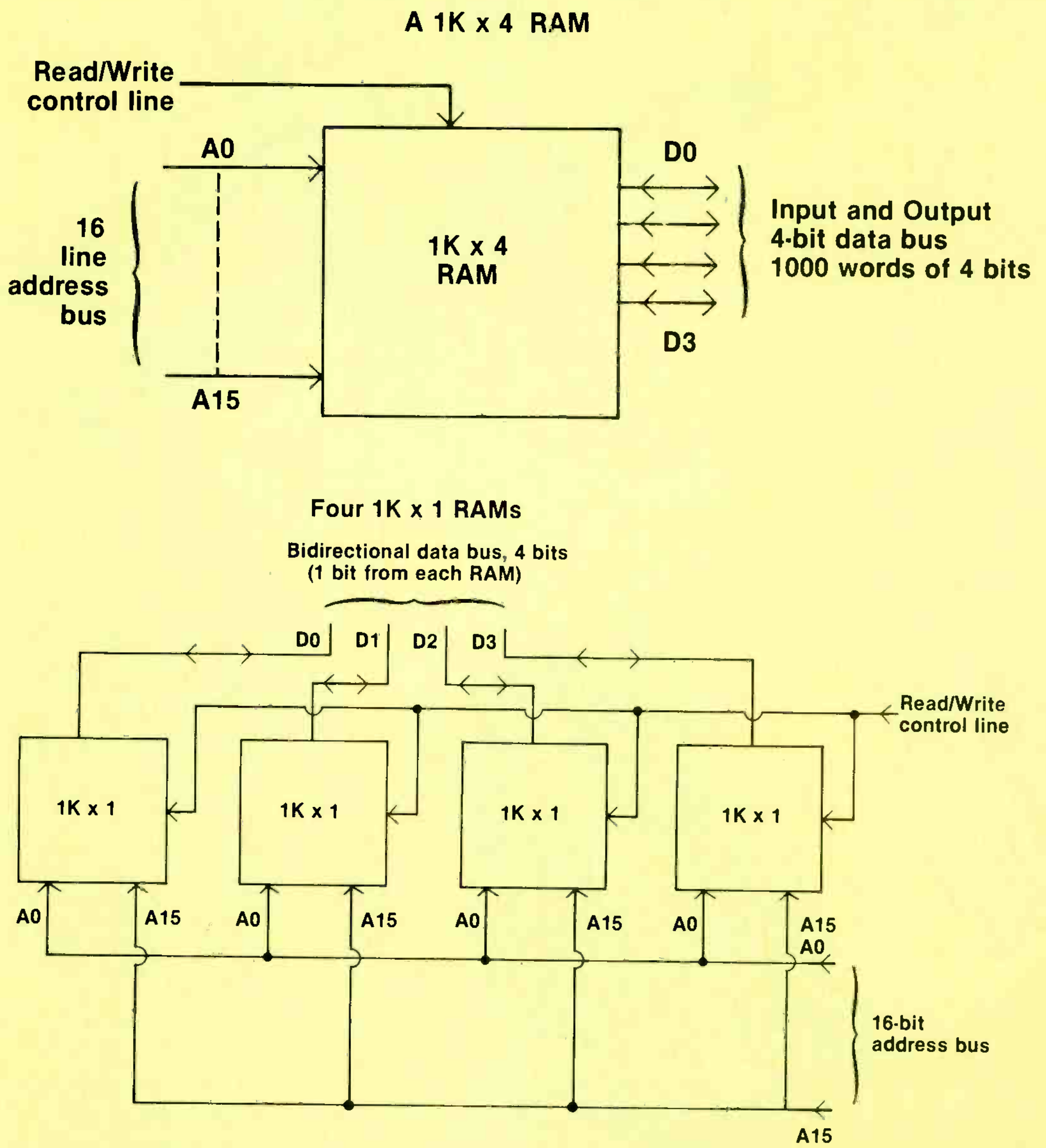

Figure 1. Computer memory may be organized in a number of different ways depending on the available technology and the desired addressing scheme.

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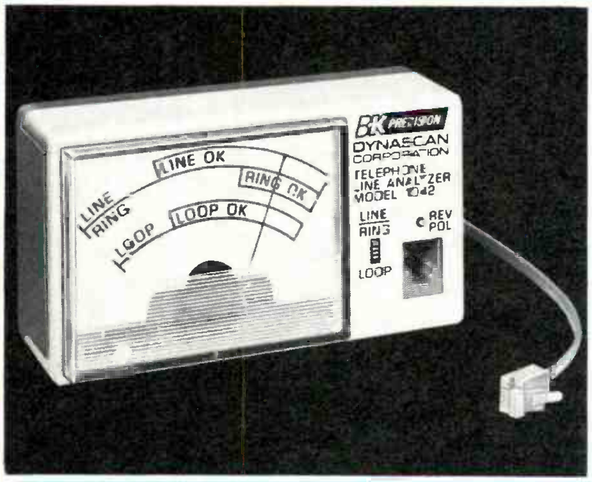

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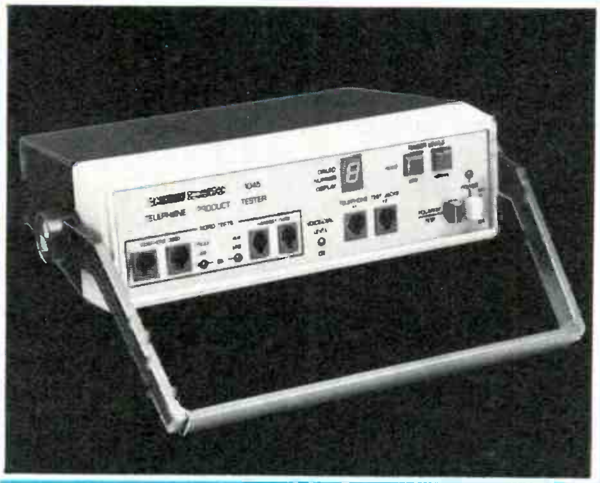

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Circle (9) on Reply Card

some way must be provided to *disconnect* the chips that are not intended to output to the bus. Figure 2 shows the use of a typical memory, with the connects to address bus, control bus and data bus. The RAM incorporates tri-state logic buffers inside the chip for use with the bidirectional bus system.

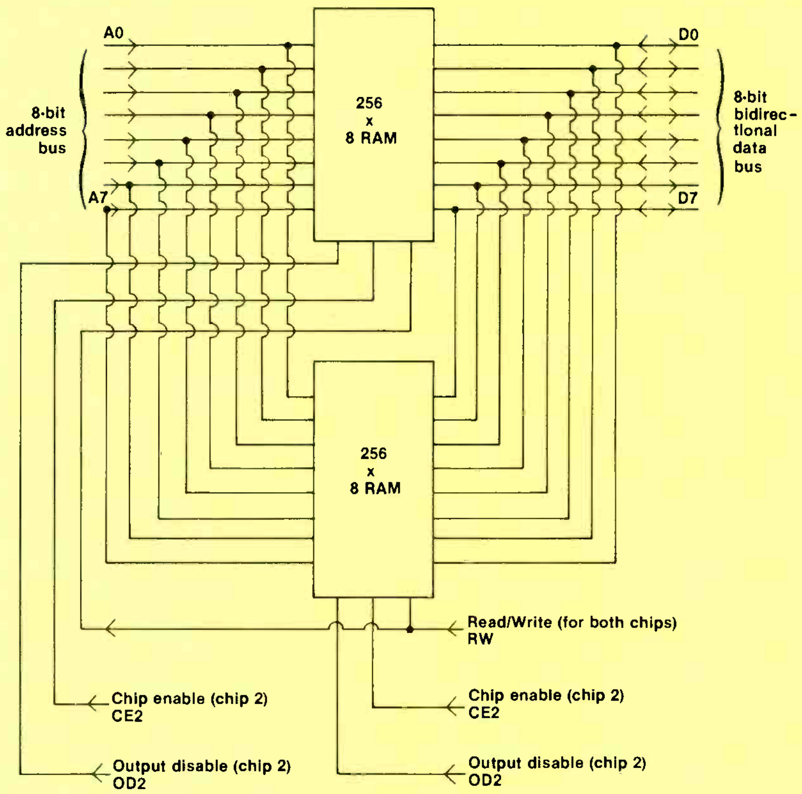
Programming

As stressed earlier, the MPU can do little without some instructions in a written program. All of the internal operations of the MPU have been designed to make the MPU responsive to programming and to make work easier for the programmer. If you decide to get your own computing system, you will soon discover that you need a library of programs for commonly encountered problems, and that you need to learn to make up your own programs for the less common problems. At that time you will want to learn how to write your own programs. A good language to learn for general programming is BASIC; for business use, COBOL; and for scientific math work, FORTRAN. BASIC is a good language to learn because it is the easiest, most flexible and most widely used with small systems.

Remember, the computer is useless without a program and programs can be expensive. You will save a lot of money if you learn to do your own programming. It has been repeatedly and reliably estimated that the original cost of a small computer is only 10 percent of the total cost of owning the system. The other 90 percent over the life of the computer is programming costs.

Some of the smallest systems, especially kits, do not provide a terminal and cannot therefore be used for programming in BASIC or any of the other higher level languages. They usually provide a *keypad* that does not have all 26 letters of the alphabet, or all of the punctuation marks and symbols required. The keypad is limited to assembly language programming, which is simply not practical for any reasonable amount of programming. Similarly, avoid any MPU training course that does not include the use of a terminal and the introduction to higher language programming as an integral part of the course. You will simply have to pay someone else to teach you how to use a terminal and do programming in BASIC or COBOL later on at extra cost. You will also have to pay extra for an interpreter program if your small computer does not have one in order to program in a higher language. Thus, you need an alphanumeric keyboard, an interpreter, and some instruction in programming as essentials to doing any practical work with a small computer. That in turn may require some extra memory if you have less than 32K. If you are not going to use assembly language and a keypad, it is sometimes possible to avoid the use of an assembler program, thereby freeing up some memory for other use. This is not always possible; it depends on how the MPU is organized in manufacture.

Diagram of a 512 x 8 RAM, organized with two 256 x 8 RAMs

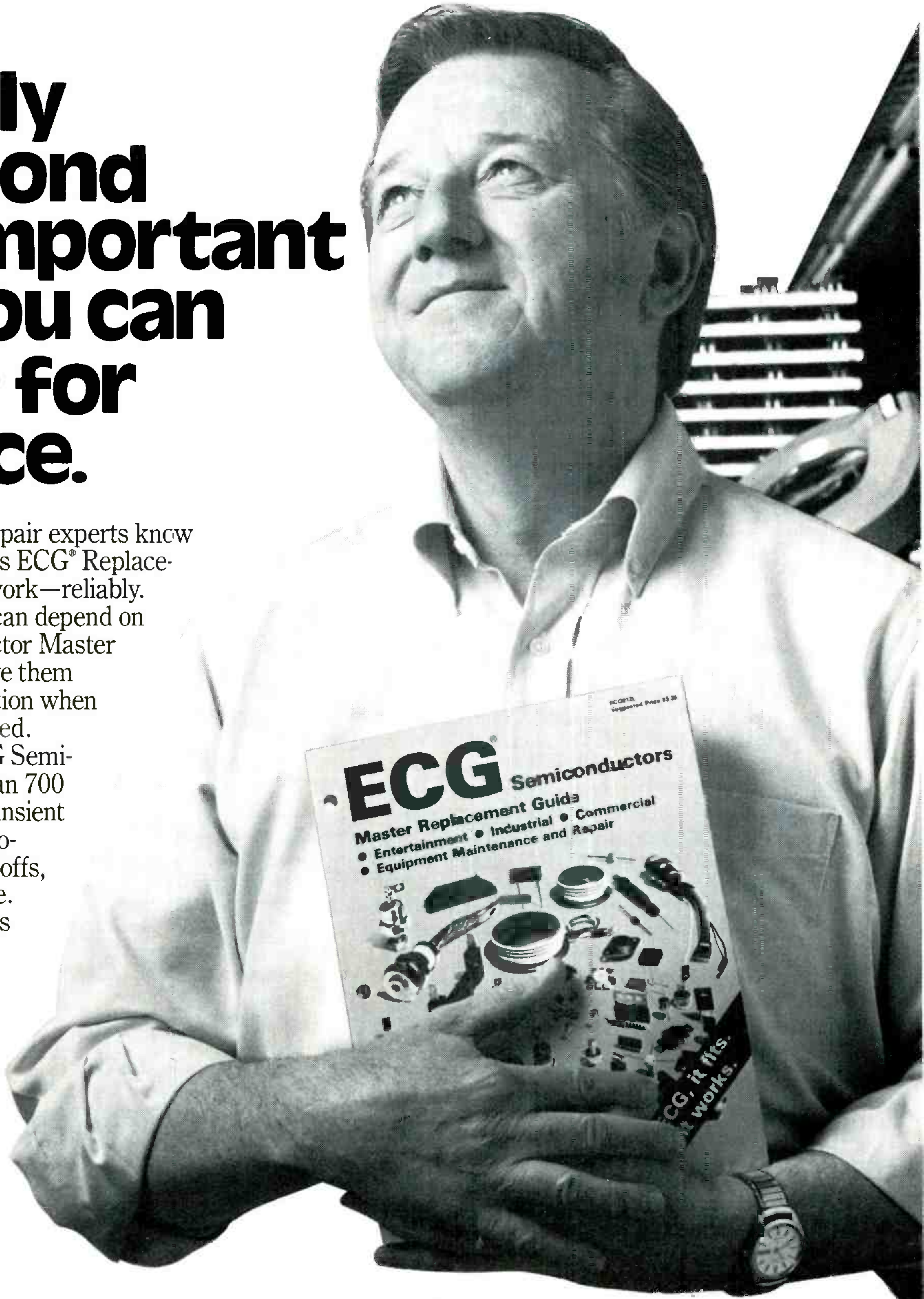


Note: The chip enable inputs are used as "chip select" bits. The output disable signal disables the internal tri-state output buffers. The CE, OD and RW signals are control signals. The 8-bit data bus carries data inputs when in the write mode, and data outputs when in the read mode.

Figure 2. Data is read into or out of a memory by first selecting the desired memory chip, then the particular word locations on that chip.

Fixing them

Personal computers have made undreamed of calculating, filing, sorting power available to small companies, schools and homes. They are indeed complex and require a great deal of study for a thorough understanding. Because of their design, construction and logical operation, however, a general idea of how they work, knowledge of some specific failure modes, and a few appropriate tools and test equipment can make many repairs possible by someone with a good general knowledge of electronics. ES&T



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TIPS for servicing GE'S AB/AC chassis

By Homer L. Davidson

A list of typical or recurrent failures of a TV receiver can be one of the most valuable tools in diagnosis and repair. After the problem areas have been identified, those solutions should be examined first. This is particularly important with erratic or intermittent symptoms. Use sophisticated equipment and techniques only after these typical failures have been checked and found not to apply.

The AB and AC chassis receivers were manufactured by General Electric for use in 10-inch and 13-inch color receivers. They also can be found under Montgomery Ward and J.C. Penney brand names. The source of schematics used here was Photofact 1904-1.

Intermittent griplets

Most intermittent problems with General Electric AB and AC chassis color-TV receivers have been traced to erratic connections at the rivet-like eyelets (called griplets) that connect top-of-the-board wiring with bottom-board wiring (Figure 1). Some intermittent troubles are difficult to locate when they are not affected by physical pressure. Fortunately, these eyelets often restore normal operation when the circuit board is twisted or moved slightly. Conversely, when the receiver is working normally, movement of the board often triggers the intermittent so the defect appears.

These erratic contacts can affect operation of sound, color, vertical sweep or raster and high voltage, depending on which is erratic. A temporary repair can be made sometimes by resoldering all suspected eyelets at top and bottom. A better method is to insert a short length of bare hookup wire through the eyelet and solder it to the copper wiring on both sides of the circuit board. However, *the best way is to connect together each pair of eyelets,* using a length of insulated hookup wire by running the wire ends through each eyelet and soldering the connections securely at top and bottom to the board's copper wiring. This insulated wire should be placed on top of the board in the approximate path of the original etched wiring when the wiring is in critical circuits such as chroma and video. Two eyelets are involved for each wire added. Wires added in power-supply or horizontal circuits can be located on the board's bottom side (Figure 2) without causing any problems.

After the primary defect has been found and repaired, it is excellent insurance against a recurrence of the problem to add jumper wires to many other pairs of eyelets. Figure 3 shows where jumpers should be added to the various dcV supplies. If these originally were erratic, the symptoms would be a dead or intermittently dead receiver. Notice that W17A is jumpered to W17B, and so on. Table 1 also lists other symptoms vs. pairs of eyelets.

No raster or sound

First, check fuses F900 (4A line fuse) and F950 (0.75A). Replace any that test open. Measure the dc voltage at the horizontal-output transistor's collector. A zero voltage reading indicates a bad eyelet or an open C700. A reading of about +169V hints at an open Q700 output transistor. Therefore, jumper W32A to W32B, W41A to W41B and W42A to W42B, using the bottom-foil side of the board. Zero voltage at the Q700 horizontal-output transistor's collector now indicates an open in retrace-tuning capacitor C700 or an open in the power supply (Figure 4). If C700 is open, *use only an original*

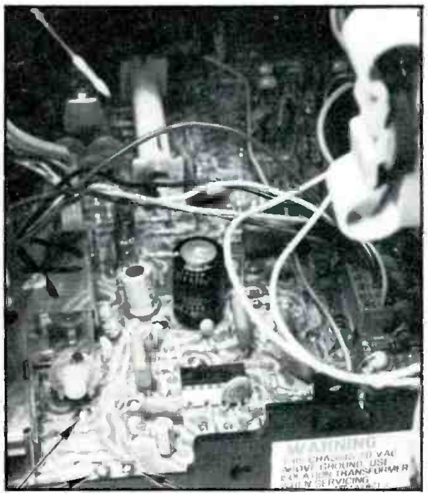


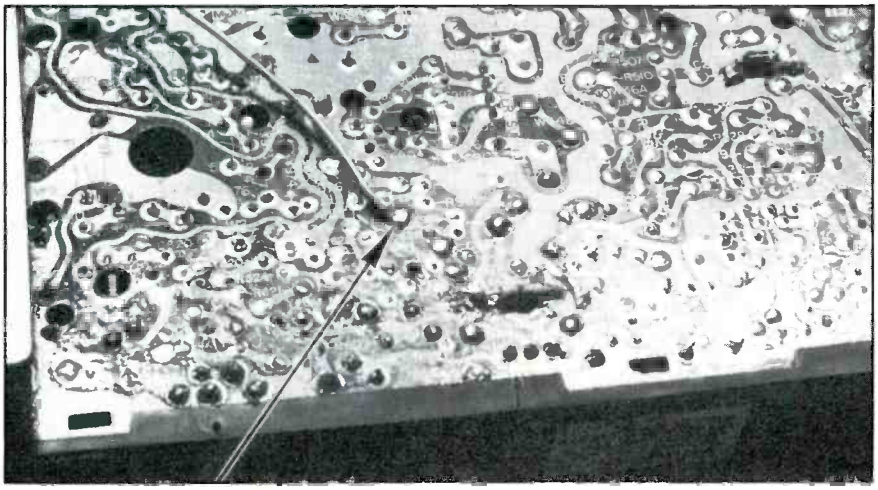
Figure 1. Rivet-like eyelets (griplets) on General Electric AB and AC chassis circuit boards connect top wiring with bottom wiring. Arrows point to three that have been resoldered. These eyelets have a tendency to become intermittent, thus causing various symptoms depending upon which eyelets are affected.

Figure 2. Jumpers can be added to the bottom or foil side of the circuit board when they are added to the less sensitive circuits, such as power and horizontal. Jumpers in sensitive circuits, such as video and color, should be dressed over the copper foil path on the top side of the board.

replacement; this is a critical safety capacitor.

When fuse F950 opens immediately as power is applied and (although the power is turned off after only a few seconds of operation) the horizontal-output transistor feels warm, the two suspects are the output transistor and the flyback (HV) transformer. Remove Q700 output transformer and test it out-of-circuit. If the transistor is replaced, always use a new mica insulator. *Warning:* do not use more than one insulator because excessive heat buildup and delayed failure of the output transistor may result.

A defective flyback is the most likely cause of a ruined output transistor. Incidentally, a present-day flyback is called an integrated high-voltage transformer (IHVT) or integrated flyback transformer (IFT) because several high-voltage diode rectifiers are placed inside



TIPS
for servicing GE'S AB/AC chassis

each, thereby eliminating external triplers. Therefore, shorted diodes inside the flyback can give the same symptoms and ringing readings as another flyback with shorted turns in the HV winding (Figure 5).

After a new horizontal-output transistor has been installed, protect it during the next tests by reducing the power applied to it. One method of doing so is to remove fuse F950 and temporarily connect a 100W incandescent lamp bulb across the fuse clips. The bulb functions as both a current indicator and a current limiter. If the lamp lights brightly when power is applied, the current is excessive. Test for overloads and then repeat this test. Repair and test as many times as necessary. Do not apply full power until the bulb glows more dimly.

An alternative method of achieving this limitation is to power the chassis from a variable-voltage transformer. Start with a low ac voltage, such as 30V rms, and check supply voltages for signs of overload (such as abnormally low dc voltages or excessive heating of resistors or the horizontal-output transistor). If the chassis condition appears to be normal, increase the line voltage 10V or 20V per step until 120V is reached. Stop at any point that appears to cause an overload. If care is used, these tests can be made without ruining a replacement horizontal-output transistor or other major part.

A defective IC530 oscillator/vertical-horizontal-countdown IC can eliminate the horizontal sweep and all dc voltages obtained from it. Also, IC530 should be replaced when the horizontal frequency is incorrect and proper locking cannot be obtained. Good results have

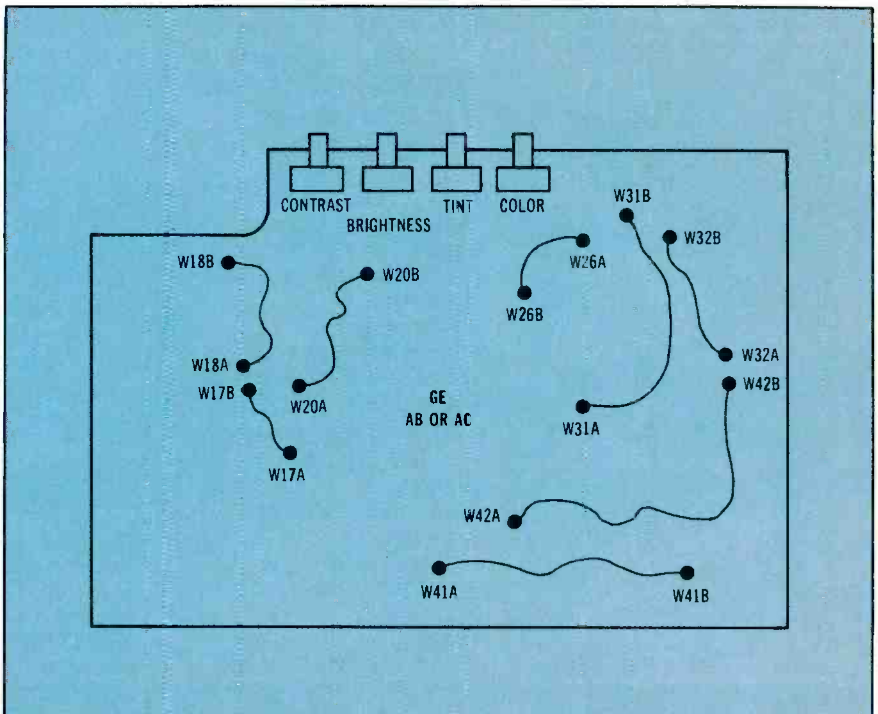


Figure 3.

Figure 3. Critical griplets on GE AB and AC chassis.

Table 1. This table shows what symptoms can be caused by certain bad griplet connections.

SYMPTOM	ADD JUMPERS
Intermittent or no raster and sound	W32A to W32B W41A to W41B W42A to W42B
Intermittent or no sound	W17A to W17B W18A to W18B
Intermittent or no color	W20A to W20B W26A to W26B W31A to W31B
Intermittent or insufficient vertical height	W32A to W32B W41A to W41B W42A to W42B

Figure 4. An intermittent open in one of the four C700 lead wires will open the emitter or collector circuit and thus eliminate all horizontal sweep along with most dcV power, when the open is occurring.

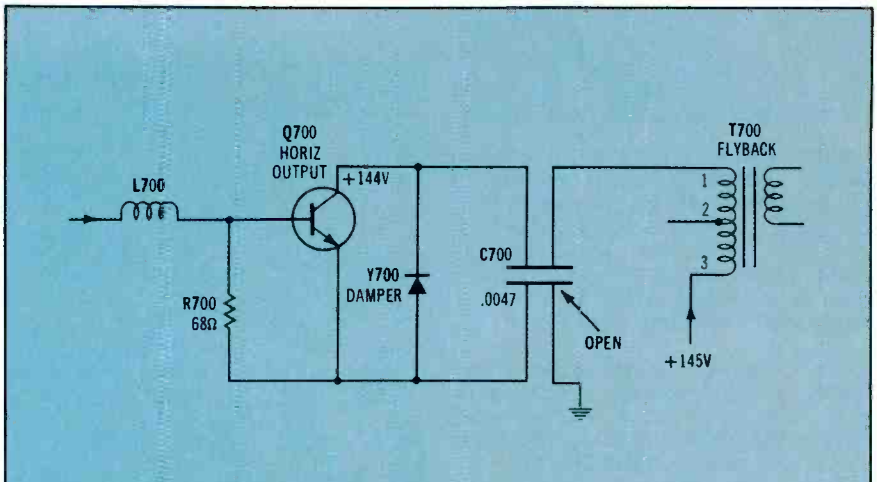


Figure 4.

been obtained using the EP84X82 General Electric replacements in several cases. No universal replacement IC is listed in Photofact 1904-1.

When the symptom is horizontal-frequency drift, replace C523, a 120pF capacitor in the oscillator circuit. For no-raster/no-sound/no-sweep problems, check Q551 horizontal-driver transistor and Q980 start-up SCR. Check all Q980 dc voltages, and make certain pin 9 of IC530 has the proper ±8.7V. Scope the signal, then trace the horizontal and vertical countdown waveforms coming from IC530 as they travel through the horizontal and vertical deflection stages. Failure to find the expected voltages or waveforms will indicate a problem upstream from that point.

Intermittent raster

Intermittent sound often is accompanied by an intermittent raster. First, jumper together W32A and W32B, W41A and W41B, and W42A and W42B. Bad connections at W32 connections might have been causing R980 (750Ω 3W) to operate very hot. Replace R980 (in the start-up circuit) if it has been damaged.

Intermittent continuity inside C700 (the 4-lead retrace-tuning capacitor, mentioned before) has been known to cause erratic raster and sound. Connect the probe of a dc meter to the Q700 collector as a monitor. If the dc voltage disappears along with the raster, the capacitor is almost certain to be the defective component.

Erratic loss of low-voltage power sometimes can be traced to bad solder joints at R904 (3Ω 18W) or R906 (50Ω 15W in Figure 6). Heat from the resistors can crystallize and thus ruin the solder joints. It is wise to check these joints on all AB and AC chassis that you service.

Raster, but no picture and sound

When the receiver has a white screen without picture or sound, the first suspect is IC120, the IF/AGC IC. Measure all dc voltages at the various pins, and compare the readings with the schematic values. Scope pin 12 looking for a negative-going video signal. If a clean signal of about the usual 1.8VPP is found there, the problem is likely to be found in the following video stages. Check the video waveforms until one is missing, and then make additional measurements to find the bad component. Test all video transistors in-circuit.

If the loss of picture and sound is erratic, connect the probes of a dual-trace scope at two points in the video circuit and notice where the signals disappear or remain steady when the picture tube loses its video.

Excessive brightness

Excessive brightness that cannot be reduced sufficiently by the brightness control is likely to be produced by a problem in the video stages or picture-tube circuits and voltages. One defect that has been encountered several times is an

TIPS for servicing GE'S AB/AC chassis

open R756 (270KΩ in Figure 7); the resistor that connects the low-voltage ends of the screen controls to ground. When it opens, the screen-grid voltages rise far above normal and the usual range of bias adjustments is not sufficient to reduce the brightness to a desirable level. This situation is easy to find by testing all picture-tube grid, cathode and screen-grid dc voltages and comparing the results against the schematic.

A partial short between control grid and screen or cathode in the picture tube will increase the brightness, but only the brightness of one color. Therefore, the main symptom will be a radical change of b&w screen color. A few light taps on the neck of the picture tube sometimes will dislodge loose particles and relieve the problem.

A collector-to-emitter short in video driver Q404 brightens the picture, while an open in any junction darkens the picture greatly. Defects in IC300 chroma IC or its supply voltage or certain defects in the video transistors can cause excessive brightness. Because of the many direct-coupled stages, in-circuit tests of all suspected transistors should be performed before any analysis is made by measuring their dc voltages.

Intermittent color

Before any tests are performed, connect insulated wire between W20A and W20B, W26A and W26B, and W31A and W31B. These eyelets are located near the front of the chassis around color IC300, and they give so much trouble (sometimes several weeks after other repairs have been made) that *these jumpers should be added following any other repairs.*

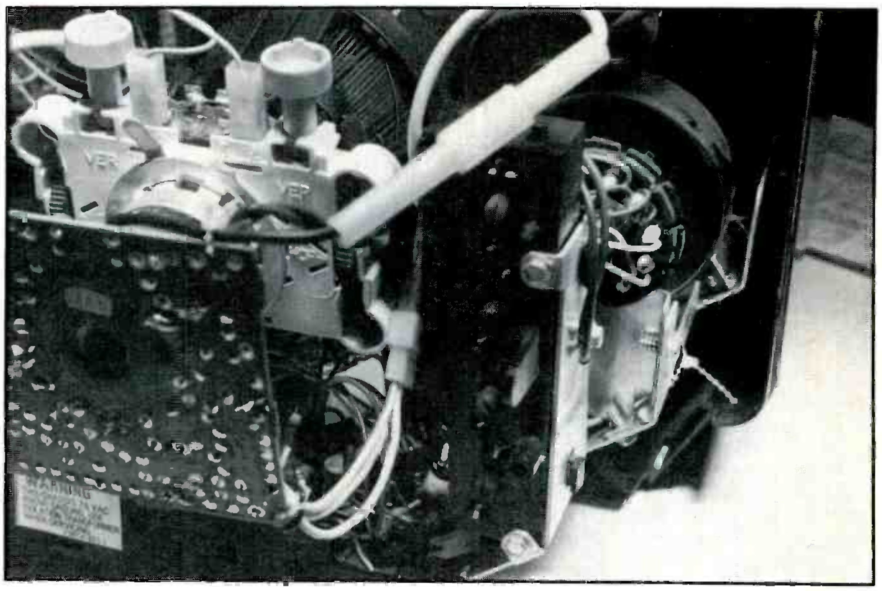


Figure 5. The integrated flyback (hockey-puck shaped object at the right) is the first suspect when a horizontal-output transistor has been ruined. These flybacks have the high-voltage diodes located inside; there is no HV tripler.

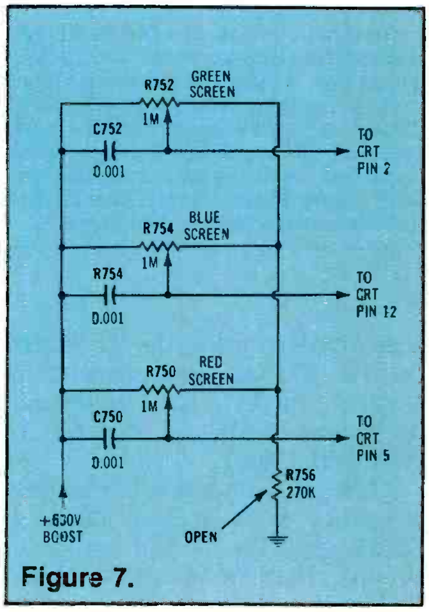
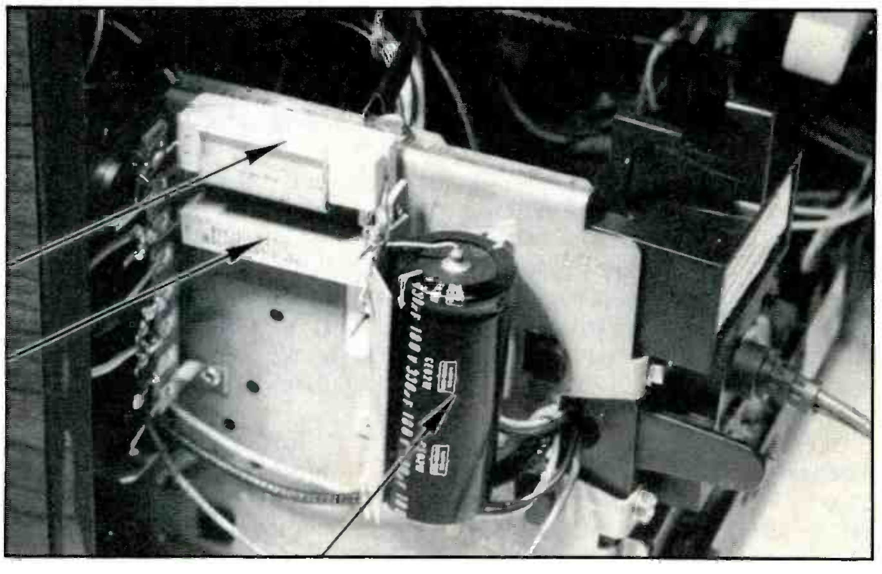


Figure 7.

Figure 7. One cause of excessive brightness is an open R756, which increases the screen-grid voltages sufficiently that the normal brightness control operation cannot reduce the visual brightness to the desired level.

Figure 6. Heat from the two large high-wattage resistors (R906 above and R904 below) can ruin soldered joints on the terminal strips. Check these soldered joints when the +145V supply is intermittent. Input filter capacitor C920 is shown at the right of the power resistors.



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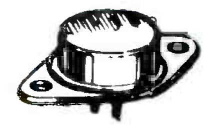

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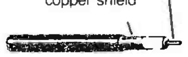

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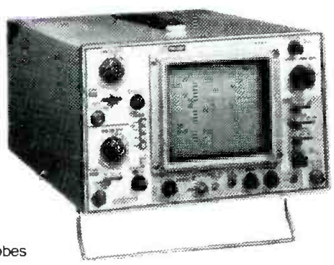

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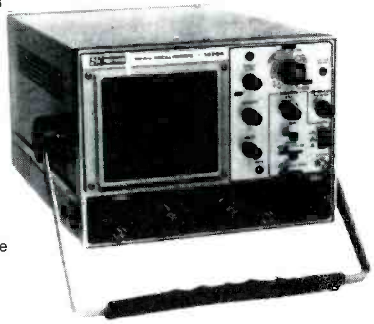

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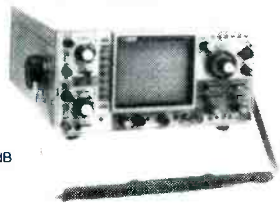

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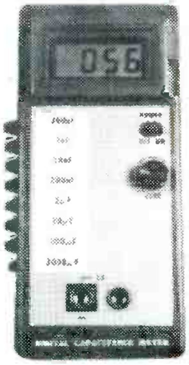

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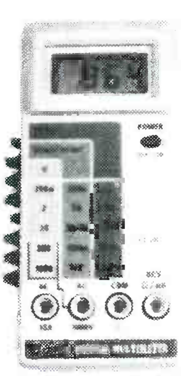

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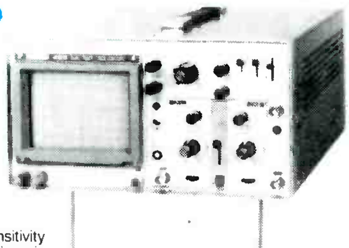

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TIPS for servicing GE'S AB/AC chassis

If color is not obtained after the jumpers are installed, suspect IC300. Scope the input signal at pin 15 and the three demodulated color signals (use color bars in the generator) at pin 1 (G – Y signal), pin 23 (B – Y signal) and pin 24 (R – Y signal). If the pin-15 input signal is normal, but the three – Y signals are missing, check for a 3.58MHz CW carrier at pin 8. The carrier proves the color oscillator is operating; the absence indicates a dead color oscillator. Before replacing IC300, compare the dc-voltage measurements at all pins with those shown on the schematic, and make certain the proper + 11.6V of supply voltage is present at pin 22. Also, check the resistance of L338 and substitute color crystal X300 if all other tests and substitutions fail to restore the color.

Picture has only one bright color

A shorted picture tube is one possible cause of a predominant color in the raster and picture. Check the picture tube in a good tester, and be certain to test for shorts and leakages. Moderate and careful tapping on the CRT neck when the receiver is operating sometimes shows by flashes of color or brightness changes that the picture tube has an intermittent condition. With an in-circuit transistor tester, check Q400, Q410 and Q420. A shorted or open junction in one can produce a tinted b&w screen, and a severe short can cause one color to become so bright that the picture might bloom out. Incidentally, an open L411, L401 or L421 peaking coil can blur the picture in one color.

Height problems

Before any tests or repairs are made, add jumpers from W41A to W41B, from W42A to W42B, and from W32A to W32B. Poor connections at these eyelets can cause incorrect dc voltages at the vertical-output transistors and bad height, so they should be corrected first.

One typical defect is a burned or open R650 4.7Ω resistor (Figure 8). R650 is located near the back edge of the chassis, and sometimes is so burned the color code is obscured.

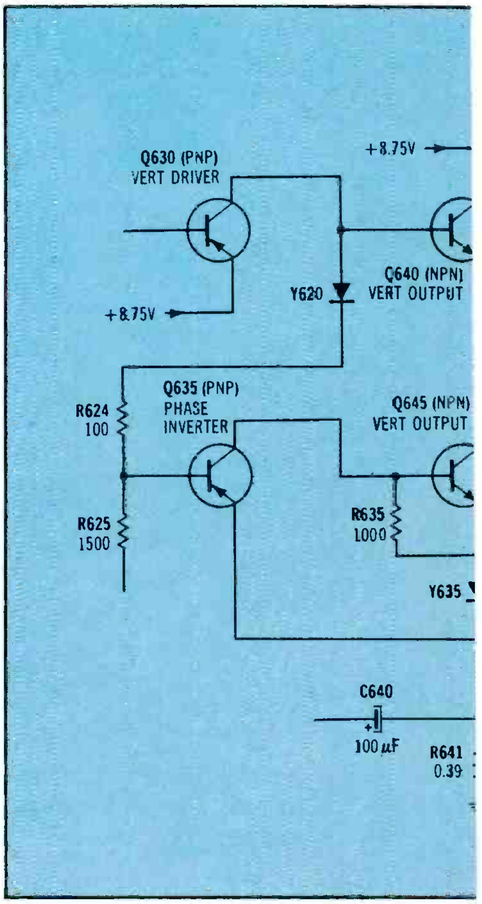
After the jumpers are installed and R650 is replaced but the vertical problems remain, the vertical-output transistors should be tested next. They are driven by direct-coupled transistors, so a problem in a previous stage can produce erroneous voltages and resistances. Therefore, the base lead of each output transistor should be disconnected from the circuit before the output transistors are tested. Replace both output transistors if even one has an open or a leaky junction.

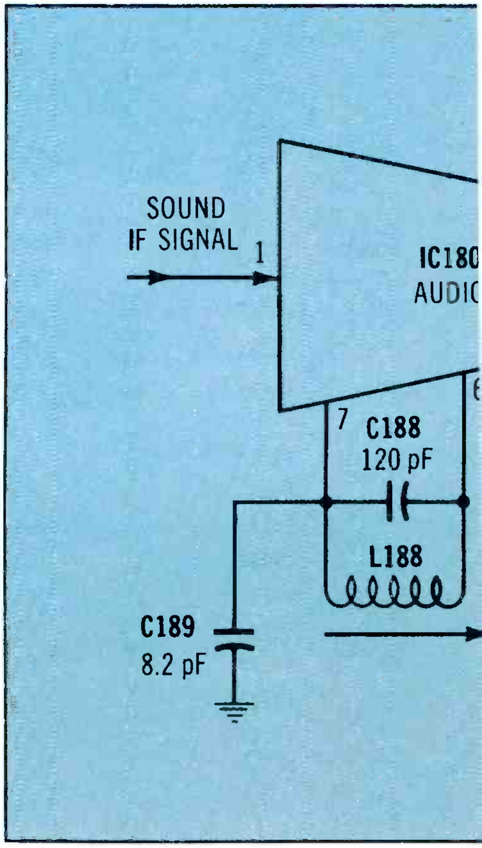
Do not overlook the various voltage sources that power the vertical stages. Sweep power from the integrated flyback is rectified, producing separate positive and negative supplies for the complementary symmetry vertical-output stage. Rectifier Y946 and 1000µF C947 produce +8.75V for Q640, while rectifier Y942 and 1000µF filter capacitor C943 produce –9.17V for Q646. Check these components when the supply voltages are out of tolerance.

Distorted sound

When the sound is intermittent or distorted, pull the chassis completely out (the sound circuits are in the front-left corner near the tuner) and add jumpers from W11A to W11B and between W18A and W18B. Often the jumpers will eliminate the intermittent-sound problem. A loud hum with some distortion can be caused by an open or broken 10Ω R175B resistor at IC180 pin 15 (Figure 9).

Before testing audio-circuit components to find the cause of distor-





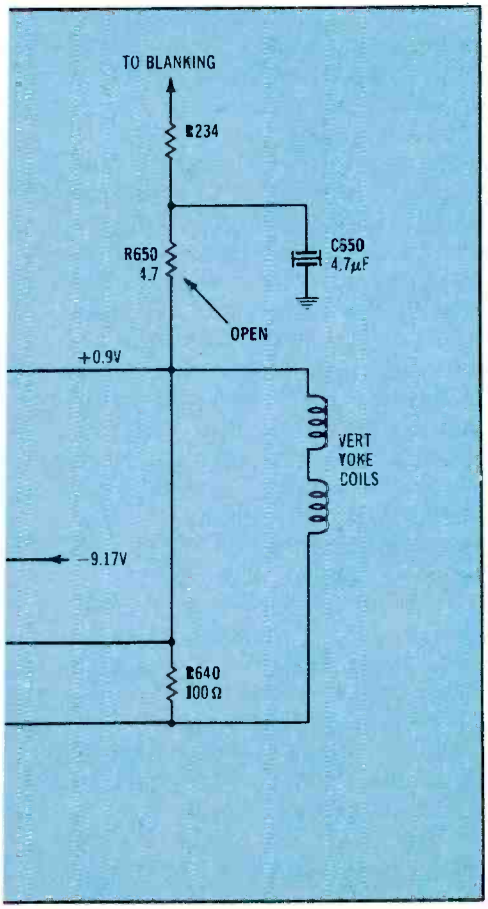


Figure 8. Defective Q640 and Q645 vertical-output transistors and an open R650 resistor are the most likely cause of insufficient height.

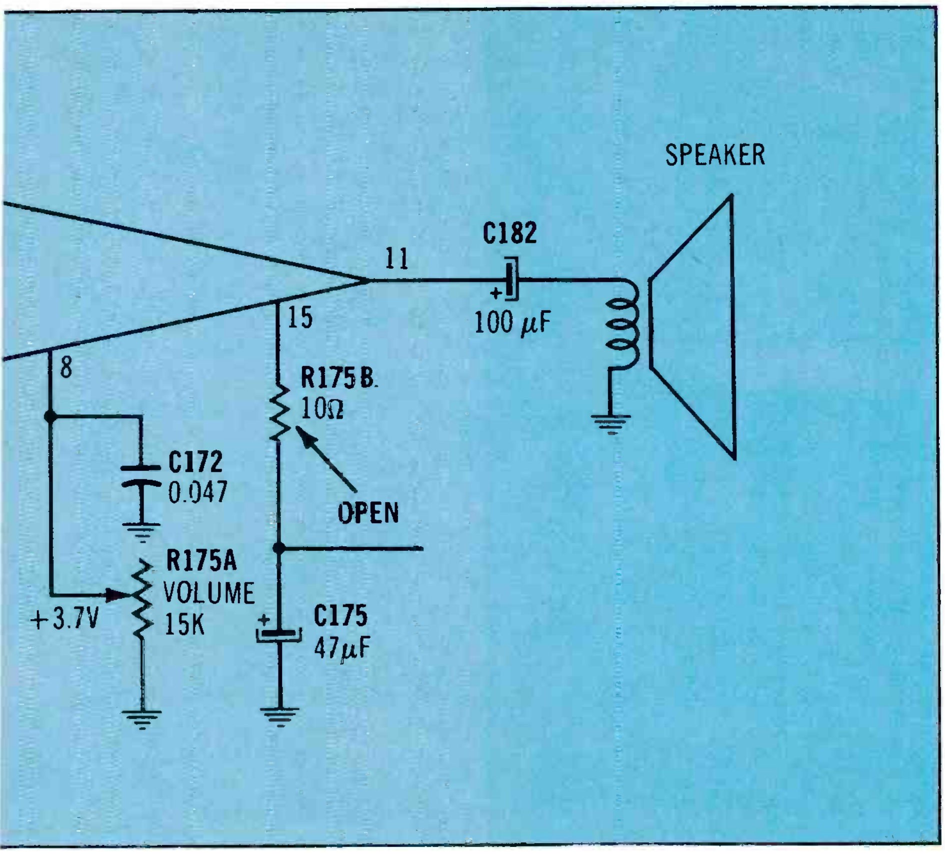


Figure 9. Drifting-value C188 and C189 capacitors, IC180 failures and an open R175B resistor are common causes of distortion or intermittent sound.

tion, substitute a test speaker externally. Notice that the GE speaker has 32Ω impedance. If the speaker is normal, touch up the L188 adjustment. Better sound after L188 has been adjusted usually means another component nearby has changed. Locate C188 and C189. Tap them gently with a plastic rod. Apply alternate heating and cooling to the two capacitors. Replace any capacitor that shows the slightest sign of being erratic. Finally, adjust L188 as the last step.

If none of the previous tests improve the sound, check all dc voltages at the IC180 pins and compare the measurements against the schematic. Incorrect voltages (that are not caused by a bad supply voltage) indicate IC180 should be changed. Always touch up L188 after another IC180 is installed. These tests, replacements and adjustments should locate and eliminate most typical sound problems in GE AB and AC chassis.

Sync/locking problems

When there is weak horizontal locking, scope the Q510 sync-separator collector. A lack of 22VPP vertical and horizontal sync points to a problem in the Q510 stage or in the signal at the Q510 base. When the collector signal is normal, scope IC530 pin 14 for the presence of 7VPP of horizontal-frequency differentiated sync. Also, scope pin 10 for 8VPP of vertical-frequency integrated sync. Lack of either is abnormal, and might be caused by a defective component between Q510 and IC530. Of course, leakage or a short inside IC530 can remove one of the signals.

If all IC530 dc voltages are within tolerance (including +8.74V at pin 9) but the sync at pin 14 or 10 is improper, IC530 should be replaced. Experience has shown that replacing IC530 solves most vertical and horizontal sync problems.

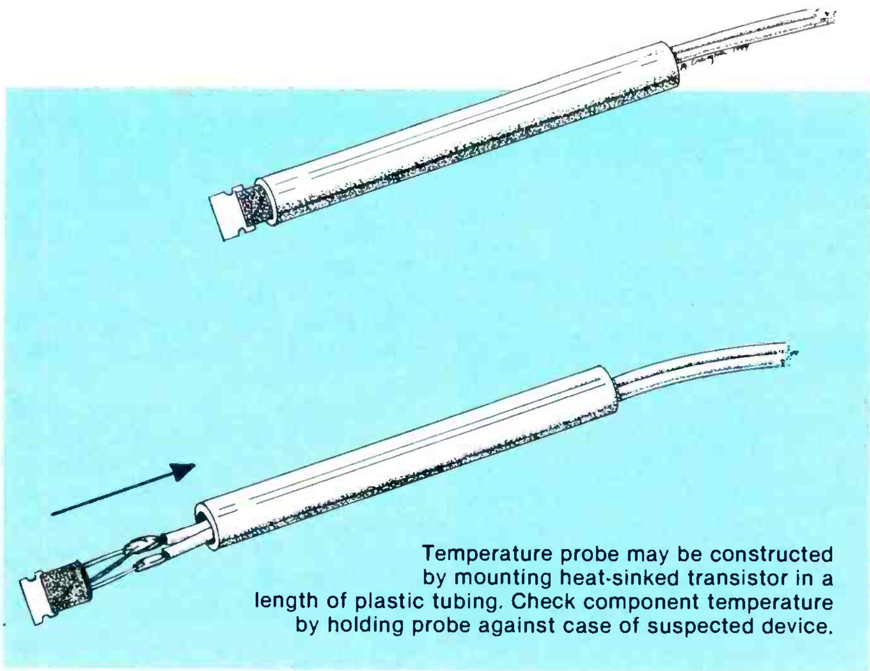
Check for a 2.2VPP horizontal-frequency sawtooth at IC530 pin 1. This is the sample of horizontal-sweep that is compared against the sync in a phase detector inside IC530. If this sawtooth is weak, distorted or missing, solid horizontal locking will be impossible. In several cases, resistor R517 was found to be burned or increased in resistance. Check R517 first.

Comments

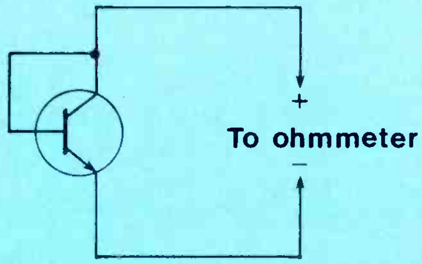
All known common or recurrent problems of the General Electric AB and AC TV chassis have been described. The most important problem has been the eyelets or griplets. I strongly advise you to place jumpers between all eyelets mentioned in this article, regardless of the original symptoms. While the color receiver is apart, the jumper installations require little time, and they may save you from having to open the set up again soon. ES&T

Build this simple DMM temperature probe

By Michael A. Covington



Temperature probe may be constructed by mounting heat-sinked transistor in a length of plastic tubing. Check component temperature by holding probe against case of suspected device.



Temperature-probe transistor is connected as shown. A PNP transistor may be used, but polarity of connections to ohmmeter must be reversed.

A temperature probe for a digital multimeter normally costs about $100. You can make a serviceable one out of a couple of dollars' worth of parts – a silicon transistor, some wire, and a piece of plastic tubing.

The key to the low price is that most of the time a temperature probe is used to compare temperatures rather than measure them outright, and therefore does not need to be calibrated. Its main uses are to identify ICs that are running much hotter than their neighbors and to determine whether the temperature of a component rises excessively when power is applied. Unlike your finger, a probe will not mistake pressure, texture, or greasiness for heat; nor will it get burned or shocked if temperatures or voltages are higher than you expect.

The probe described here uses a transistor, with base tied to collector, as a temperature sensor. It is connected to a 3½-digit digital multimeter set on the 2MΩ or 20MΩ range, whichever gives a reading near the middle of the scale. It is sensitive enough to detect a puff of warm breath. Although the probe does, in principle, work with an analog meter, the movement of the meter needle for a small temperature change is almost imperceptible.

The case style of the transistor is more important than any of its other characteristics. Use a small plastic-encapsulated transistor with a heat sink sticking out of it (the "TO-92 power tab") such as the Radio Shack 276-2030. The heat sink helps conduct heat into the transistor junction. A second choice is a plastic-encapsulated transistor without a heat sink. The smaller the transistor, the quicker its response. Large power transistors are relatively insensitive. The diagram shows an NPN transistor, but a PNP unit can be used if polarity is reversed.

The transistor is mounted in a piece of plastic tubing and, in use, is held against the object whose temperature is to be measured, preferably coupled to it by a dab of heat sink grease. Lower ohmmeter readings indicate higher temperatures. ES&T

Photofact

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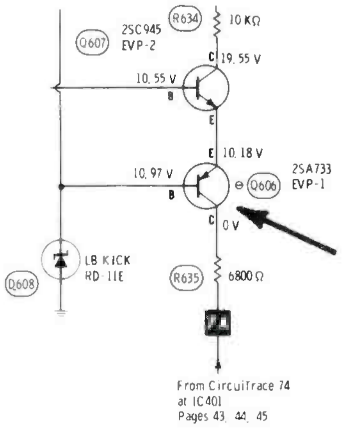
Troubleshooting Tips

Black cloud in picture
Sony KV-1711 chassis SCC-63A
(Photofact 1503-1 or 1625-2)

After operation of about five minutes, a moving black cloud would appear on the top half of the screen. This cloud changed size erratically, moving vertically while varying in width. The receiver was obtained from a shop that had given up after three months.

The moving black cloud appeared after the chassis was powered on my test bench for the usual five minutes. Because excessive supply voltage sometimes causes video limiting to occur, I first checked the +130V supply. It was a steady +124.6V, so it could not be the cause of the cloud.

IC401 and its signals also were suspect because it handles video amplification, ABL function, ACR and H/V blanking. All IC401 dc voltages were nominal, but scope waveforms showed erratic blanking in the video output signal at pin 14 of IC401, and the movements were synchronized with the vertical sweep. By contrast, the input video at pin 17 showed



normal video without any erratic sections.

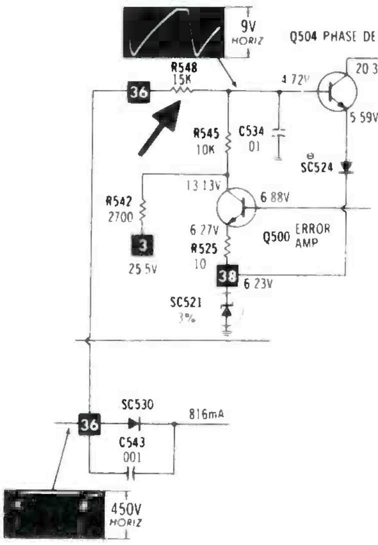
Next, the blanking signals were checked at IC401. Horizontal blanking at pin 12 was stable and normal, but the vertical blanking at pin 11 showed an intermittent random square-wave pulse train that seemed to be synchronized with movement of the black cloud. Evidently, this was the circuit to be tested.

The signal for vertical blanking comes from the vertical-output stage through R546 and C524 before R548 and C525 parallels the signal to ground, then it goes through R345 to IC401 pin 11, with zener diode D302 connected from pin 11 to ground. R546 and C524 appeared to be the most likely suspects, but they were replaced without giving any improvement. Then I noticed a signal or voltage brought to R345 (and pin 11) from CircuiTrace 74 in the power-supply section. This voltage comes from the collector of Q606 transistor. The Q606 base/collector junction appeared to have an intermittent breakdown or avalanche, so I replaced Q606 and the black cloud was gone permanently.

Dr. Paul L. Poehler
Satellite Beach, FL

Multiple triggering and then shut-down
Philco and Sylvania E31 and Wards GGY-12913A
(Photofact 2083-2)

When power was applied, the rustle of high voltage could be heard, but the chassis immediately went into shut-down. I connected a variable-voltage ac transformer and, starting at a very low voltage, slowly increased the ac voltage applied to the chassis. However, the flyback HV/transformer squealed loudly (as though the horizontal frequency



was wrong, or the windings were arcing) long before normal line voltage was reached.

I replaced the flyback, but there was no improvement. After going over the horizontal sweep and the various power supplies without much success, I finally found 15K R548 was open. This is difficult to find unless one end is disconnected because other circuit resistances parallel it. A new R548 solved the problem. Since that one repair, I have had the same resistor open in two other chassis.

Don Mendenhall
Parker, AZ

Editor's Note: Before this tip was processed for publication, a similar one was received. Evidently this resistor is a frequent cause of failure. The second tip follows, since it provides additional information.

After buying and installing a new flyback and an SCR513 switching-regulator SCR in the power supply, I found no change of symptoms. After thinking a long time about how to test this without disconnecting the fail-safe circuit, I decided to substitute the regulated +112V supply. I connected power from a variable-voltage transformer to an external bridge rectifier and, without using the receiver's ac cable, connected the bridge output to the +112V source and ground. First, I brought the ac slowly up to 80V, obtaining a stable picture without any danger signs, and I increased the voltage until +112V was measured at that supply. The operation appeared to be normal, so I started testing the switching-regulator circuit. Input pulses to SC503's anode measured more than 400VPP, but at the base of Q504 there was no horizontal sawtooth. R548 (15K) was open, and installation of a new one provided normal operation (after the S3 jumper was reinstalled to connect regulator and +112V supply).

William F. Springman
North Liberty, IN

Testing diodes
All late-model color receivers

Regarding the troubleshooting tip on page 37 of the February 1984 ES&T, I too have been testing diodes on my Sencore LC53 by connecting the LC53 red lead to cathode and the black lead to the anode. This applies reverse polarity, so a normal non-defective diode draws no current during leakage tests. Then, I select a peak-reverse voltage that the diode is expected to withstand, and switch to 100μA leakage range. When the capacitor leakage button is pressed, a non-defective silicon diode will read 000 (or no leakage).

A reading of almost any leakage indicates the diode is defective and should be replaced. Next, I check the diode's capacitance. If you use a different capacitance meter, the reading might be different from the ones I usually see. Just test a half dozen or so good diodes and use the average as a standard for later tests.

Also, I use reverse-polarity voltage with transistors, SCRs and triacs to determine if they have breakdown current when the base or gate is not connected. And I test dual diodes with forward current at 3V to determine whether or not they are balanced. Then they are tested for reverse leakage and capacitance.

In reference to Mr. Houser's test, it seems logical, since we might consider a diode to be similar to a disc capacitor in that larger voltage rating demands a thicker slab, which reduces the capacitance. During the two years I have owned an LC53, I have found all these tests to be effective for finding borderline or erratic conditions in addition to the more usual characteristics.

Eugene Spooner, CET
Charlotte, NC

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KNOW YOUR Oscilloscope

The word *oscilloscope* can be separated into two parts, *oscillo* and *scope*. The first is short for oscillations and the second means to view or see. Thus, if we take the word literally, it describes an instrument for viewing oscillations. Conventional oscilloscopes display electrical signals that vary with time, such as sine waves. When used with a suitable transducer, a conventional oscilloscope will provide a visual display of any physical quantity that can be reproduced as a voltage. For example, in a hospital, the heartbeat of a patient can be displayed on a CRT screen. This is exemplified by the "biomedical test" waveform shown in Chart 1. With the advent of the digital revolution, specialized oscilloscopes have been made that provide displays of data fields, as exemplified in Figure 1.

The basic distinction between a digital data-field display and a sine-wave display is that the former presents sequences of digital events with respect to clock time, whereas the latter presents an analog variation of an electrical quantity with respect to real time. (The "clock" in a digital system is a crystal-controlled oscillator that synchronizes system operation; on the other hand, "real time" has to do with the actual time in which physical events occur.)

A schematic for the simplest type of an oscilloscope is depicted

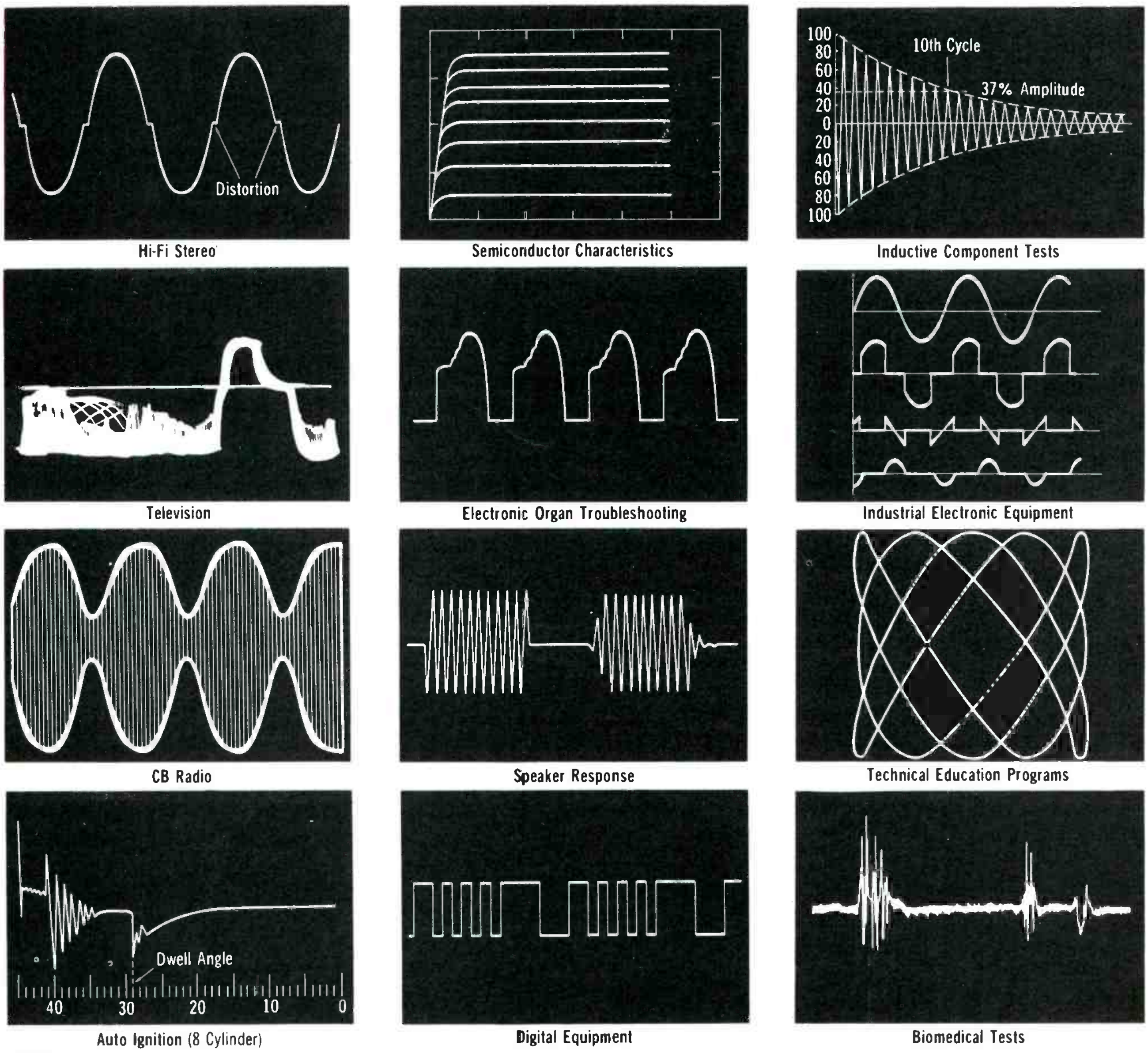

Chart 1.

in Figure 2. It consists of a cathode-ray tube, a power supply, and two RC coupling circuits. The components are illustrated in Figure 3. Although this elementary arrangement can be used in certain applications, such as modulation monitoring and for the display of vectorgrams in high-level chroma circuits, it has various disadvantages. These are:

1. A directly driven CRT is comparatively insensitive; a typical CRT requires approximately 300 volts peak-to-peak for full-screen deflection.

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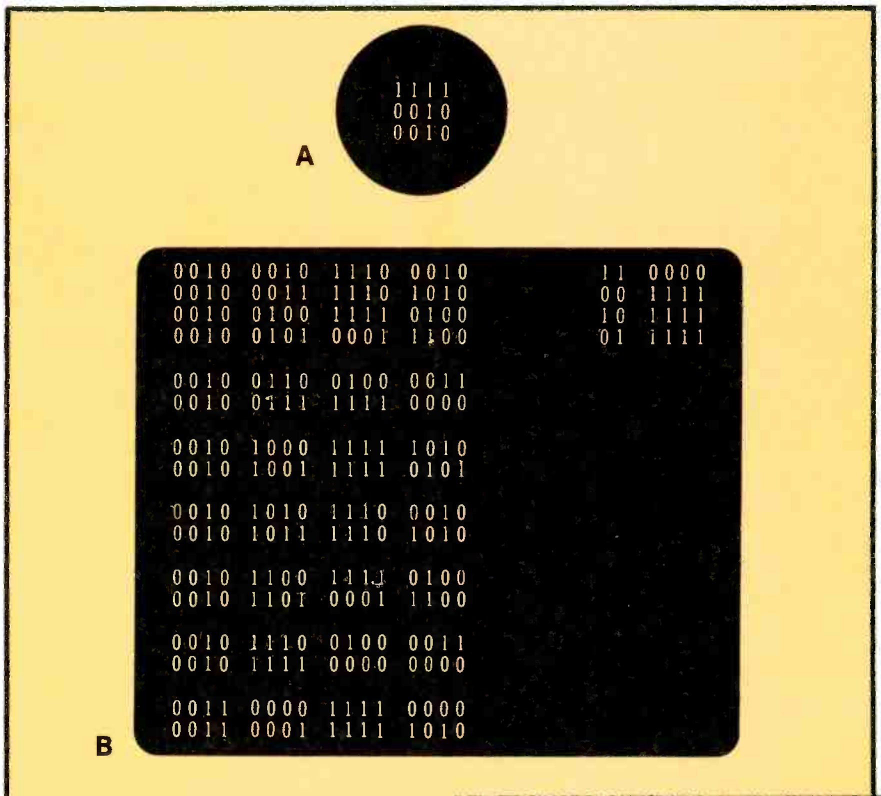


Figure 1

Figure 1. Data-domain displays. (A) Elementary display pattern. (B) Check of a dual-clock operation displayed on screen of a data-domain analyzer.

Figure 2. The schematic for a simple type of oscilloscope.

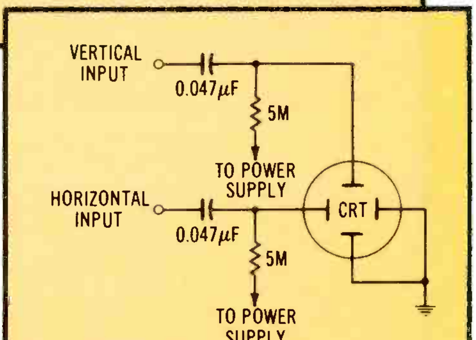


Figure 2

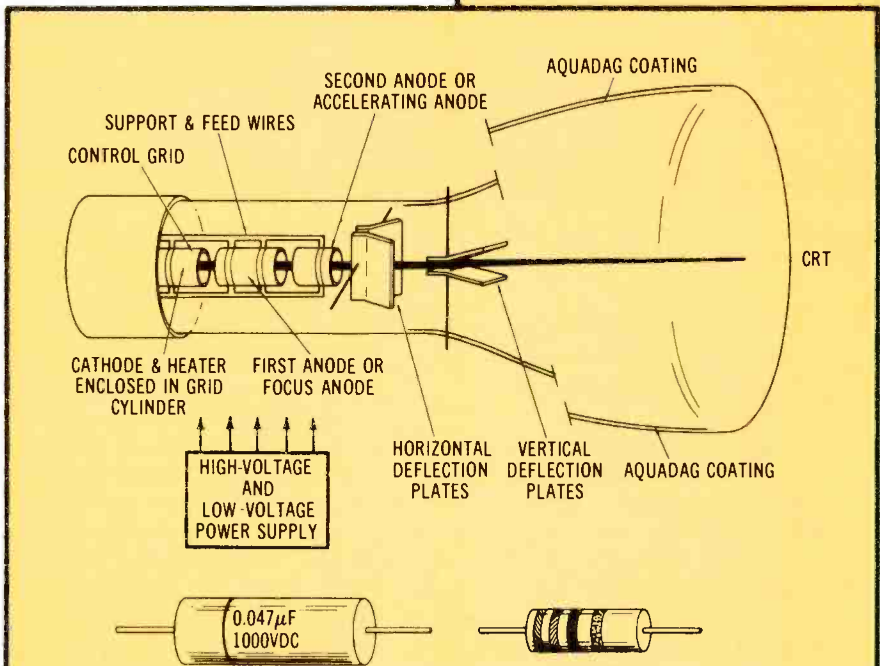
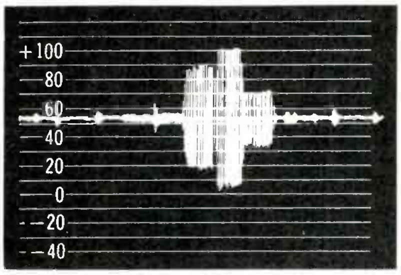
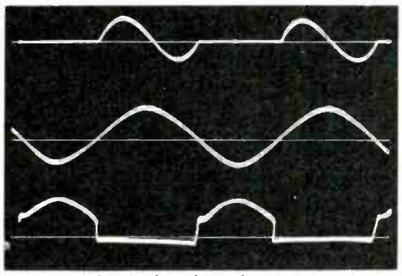


Figure 3

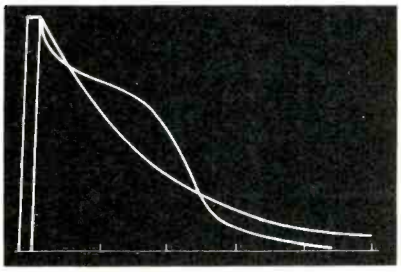
Figure 3. The components needed for the circuit in Figure 2.



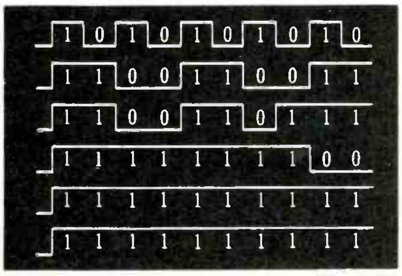
TV Station Maintenance



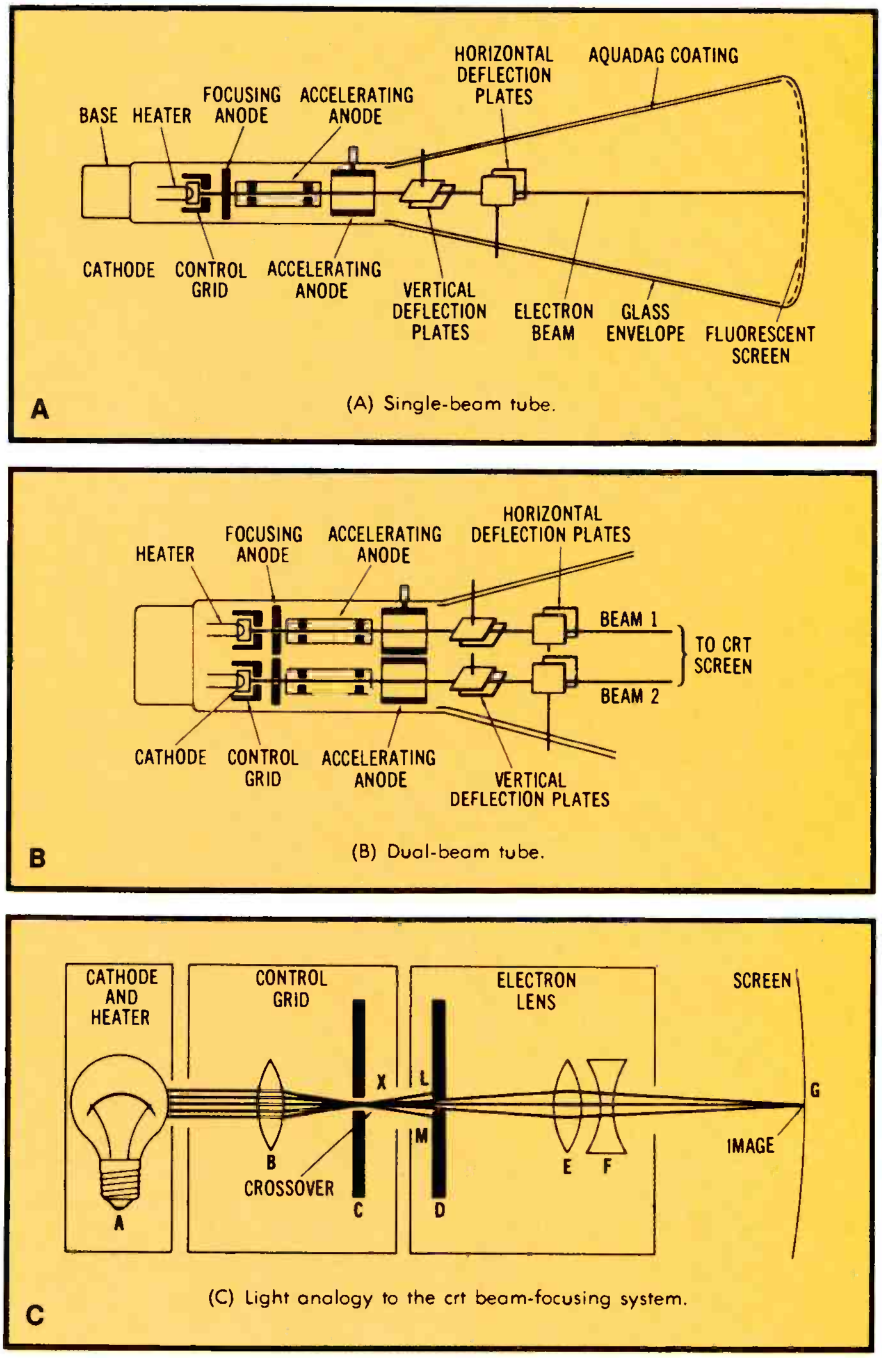
Research and Development



Acoustic Environmental Measurements



Data Signals and Digital Data Fields



(A) Single-beam tube.
(B) Dual-beam tube.
(C) Light analogy to the crt beam-focusing system.

Figure 4. Two basic types of a CRT. (A) Single-beam tube. (B) Dual-beam tube. (C) Light analogy to the CRT beam-focusing system.

Therefore, vertical and horizontal amplifiers *are required* in the great majority of applications.

2. Single-ended drive to a CRT results in variation of the focus (astigmatism) from one region of the screen to another. Accordingly, good focus *requires* push-pull (balanced or double-ended) drive to the CRT deflection plates.
3. Unless an external sawtooth generator is used, the arrangement in Figure 2 can display only Lissajous patterns and related waveforms. Because most applications use voltage-time displays, *it is desirable or necessary* to include a linear time base in the oscilloscope arrangement.
4. Although Lissajous figures are often self-synchronized, most voltage-time displays will not be synchronized (locked) on the CRT screen unless the time base is automatically kept in step with the displayed waveform. In turn, *it is desirable or necessary* to include a synchronizing network in the oscilloscope arrangement.
5. In many applications, it is helpful or necessary to move the pattern about on the CRT screen, in order to adjust the height of the pattern, or to adjust the length of the pattern. Hence, a general-purpose oscilloscope *must include* vertical and horizontal-positioning controls, vertical-gain control(s), and horizontal-gain control(s).
6. Applications in state-of-the-art electronic circuitry often require that a selected interval of a waveform be "picked out" and expanded on the CRT screen. Therefore, modern oscilloscopes *generally have* triggered sweeps.
7. Service data generally specify peak-to-peak voltage values of waveforms, and some applications require time measurements from one point on a waveform to another (for example, rise-time measurements are sometimes required). Accordingly, modern oscilloscopes *generally provide* calibrated vertical-step attenuators, and calibrated time bases.
8. Some applications are facilitated by simultaneous display of input/output waveforms, by simultaneous display of a complete waveform and, also, an expanded portion of a selected interval, or by simultaneous display of a reference waveform and related waveforms within a system. In turn, *it is sometimes desirable or necessary* to provide dual-trace display in an oscilloscope. Moreover, in digital-electronic applications, multichannel displays *are provided* by data-domain-type oscilloscopes.

Cathode-ray tubes

Two basic types of cathode-ray tubes are used in the majority of oscilloscopes, as depicted in Figure 4. The most common type is the single-beam tube, comprising an electron gun with a cathode, heater and control grid, followed by a focusing anode, an accelerating anode, vertical-deflection plates, horizontal-deflection plates, and a fluorescent screen.

The electron beam is electrostatically focused and deflected in this design. Lab-type oscilloscopes may employ a dual-beam tube, which includes two electron guns, two sets of anodes, and two sets of deflecting plates (Figure 4B). Each basic type of CRT has certain advantages in particular applications. When a dual-beam CRT is used, two patterns can be displayed on the screen just as if two separate oscilloscopes were being employed. On the other hand, when a single-beam CRT is used, two patterns must be time-shared in order to have a simultaneous display, as shown in Figure 5. In alternate-channel operation, one complete waveform is traced on the screen; then, another complete waveform is traced; the first waveform is then completely retraced, and so on. However, in chopped operation (Figure 5B), the two waveforms are rapidly sampled, and successive samples are displayed on the screen, as indicated.

High-frequency waveforms are displayed to their best advantage by alternate-channel operation in the dual-trace mode; conversely, low-frequency waveforms can be displayed with less flicker by chopped operation in the dual-trace mode. When precise phase measurements are made between Channel A and Channel B displays, a single-beam CRT provides better accuracy than a dual-beam CRT. In addition, *persistence* is a factor that enters into consideration. As the CRT beam moves across the face of the tube in response to voltages on the deflection plates, the corresponding spot of light also moves. If this movement is fast enough, the spot (or succession of dots) appears as a continuous trace or line of light. The blending of successive positions of the spot into an apparently continuous trace is due to two factors:

1. Persistence of the phosphor used in fabrication of the screen.
2. Persistence of vision.

Persistence of vision is the ability of the human eye to see any object or spot of light at its original position for a fraction of a second after it has moved. Similarly, the persistence of phosphor is its brief glow after the electron beam has left its initial spot.

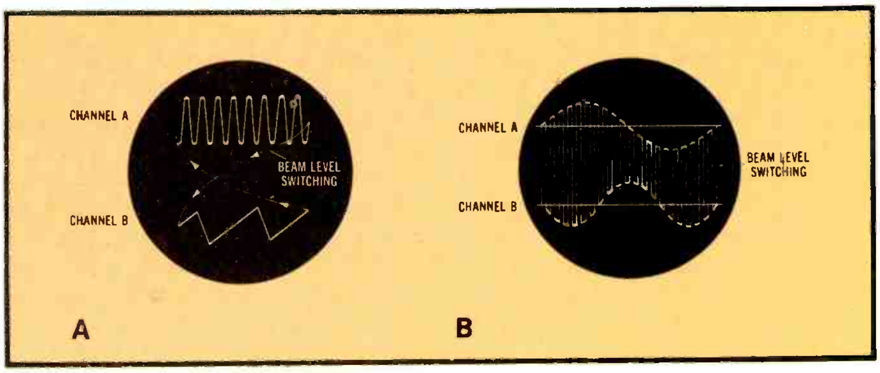


Figure 5. Dual-trace modes of operation. (A) Alternate channel operation. (B) Chopped operation.

In general-purpose oscilloscopes, the blending of the spot into a line is due almost entirely to the persistence of vision. In special-purpose oscilloscopes, a CRT with a long-persistence phosphor may be used, and electrical phenomena of short duration and nonrepetitive form can be displayed. (Special storage-type oscilloscopes can retain a selected pattern on-screen for an hour or more; the stored pattern can be erased at any desired time.)

The phosphor most commonly used in the CRT of an oscilloscope is termed P1, and is rated for medium persistence. P5 is a phosphor of short persistence; P7 has a long persistence. Some phosphors, such as P4 (commonly used in TV picture tubes) and P11 (which provides a blue trace that is easily photographed) are widely used. Other types of phosphors produce green traces and red traces. These are used in color-TV picture tubes. Colored traces also find an application in special-purpose CRTs for particular military operations.

One of the special CRTs used in storage-type oscilloscopes uses a metal mesh construction behind the fluorescent screen, as shown in Figure 6. The intensity of the electrostatic field in the apertures of the metal mesh determines whether the flood-gun electron emission will penetrate to the fluorescent screen. The metal mesh is usually operated at zero volts so that the flood-gun emission cannot go through to the fluorescent screen. However, the radiation from the trace that has been *written* on the screen modifies the electrostatic field intensity in the apertures of the metal mesh. The field intensity in the apertures that are behind the pattern on the screen has less repelling action on the electrons from the flood gun. In turn, the flood-gun electrons can pass through these apertures. The aluminized coating behind the phosphor viewing screen, in turn, accelerates the flood-gun electrons, and these electrons maintain the pattern that is glowing on the screen for an indefinite period. If the operator wishes to erase the pattern, he pushes a bias control that biases off the metal mesh so that no flood-gun electrons can pass. In turn, the glowing pattern disappears from the screen. Note that the flood-gun electrons that do not pass through the metal mesh are collected by the collector mesh.

Storage-type oscilloscopes provide improved displays in various applications. Even a brief nonrepetitive transient can be captured and "frozen" on the screen of a storage-type CRT. The storage mode of operation is advantageous for observing changes in a signal, to compare the result of making a circuit adjustment, to compare the performance of two or more equipment setups, to compare an arbitrary waveform against a standard waveform, for reducing flicker in the display of waveforms with low repetition rates, for effectively displaying digital signals that have a low duty cycle, for reducing noise interference on a recurrent waveform, and for monitoring intermittent conditions.

Graph patterns

To use a simple analogy, the electron beam can be considered as pencil writing upon the screen of the CRT according to the voltage on the deflection plates. When a horizontal-deflection system is used (and practically no oscilloscope is built without one), the trace on the screen is really a graph. Graphs are now so commonplace that hardly a person has not seen one. Some examples are the temperature graphs and electrocardiographs used in hospitals, or the sales graphs of a business office.

The reader probably has drawn graphs in school; he will remember that they show two sets of data with the values of one set varying in some fashion as the other set varies. One set of values is plotted along the horizontal or X-axis on the graph paper, and the other set is plotted along the vertical or Y-axis. The located points are then connected to form a continuous graph. The action of the oscilloscope in tracing a response curve is so similar to this that some oscilloscopes even have inputs marked "X-amplifier" and "Y-amplifier."

This comparison is a good point to remember. When confusing indications are seen on the oscilloscope screen, it may help if the operator remembers that the oscilloscope is plotting time horizontally and voltage vertically to produce a graphical account of the operating conditions of the circuit. Usually it is unnecessary to know exactly how much time is represented by the horizontal travel of the trace, as long as the beam is uniform in its rate of travel; but, if necessary, this time can be determined accurately and for very short intervals.

Figure 7 shows a graph of one cycle of voltage having a frequency of 60Hz. Instantaneous voltage is plotted above or below the X or horizontal axis; elapsed time is plotted to the right of the vertical axis *(Y)* and measured in fractions of a second. The peak voltage is taken as 1 to simplify plotting the graph. This curve is called a sine curve because the amplitude or Y value at any point on the curve equals the maximum value of E (in this case, 1) times the sine of the X value at that point. *(X* must be converted to degrees, with one com-

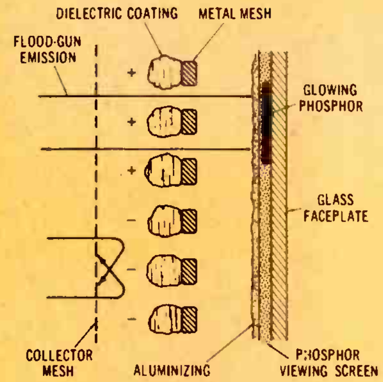


Figure 6. The metal mesh design of a storage-type CRT.

plete cycle equaling 360 degrees.)

Practically all oscilloscopes have a graticule mounted in front of the face of the CRT. The graticule is commonly ruled like a sheet of graph paper. The vertical intervals are used to measure voltage, and the horizontal intervals are used to measure time in typical applications. Because the plastic graticule is mounted in front of the fluorescent screen in most oscilloscopes, you must view the pattern in a line exactly perpendicular to the screen to minimize parallax error. If you view the screen obliquely, the parallax error can be appreciable in using the graticule. To avoid this source of evaluation error, some modern CRTs have parallax-free graticules. This is done by having the graticule ruled on the *inner* surface of the CRT face.

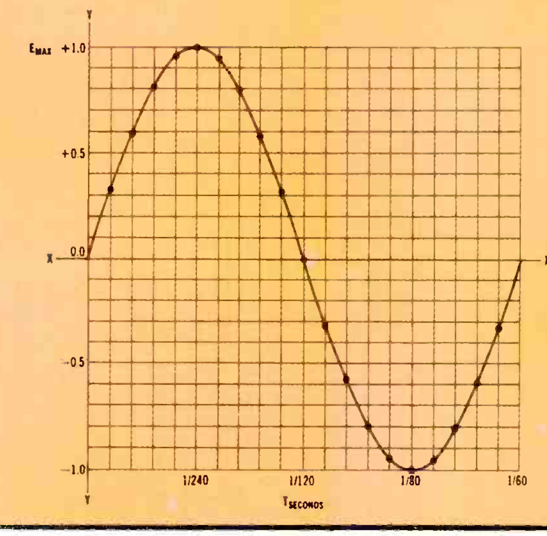


Figure 7. Graph of one cycle of power-line voltage. Frequency is 60Hz.

Even when a parallax-free graticule is used in a CRT, there remains a practical limit to the precision with which the operator can read the scale. Therefore, some lab-type oscilloscopes are provided with a *digital readout.* This function employs *microprocessor circuitry* to "spell-out" highly precise waveform data automatically, either on an LED panel located below the CRT, or as numerals "written" on the CRT screen. For example, a CRT readout can tell the operator precisely what vertical sensitivity is being used, what time-base speed is in use, what pulse width is being displayed, what the precise rise time may be, what repetition rate is being displayed, and so on. In other words, a CRT readout "does the figuring" for the scope operator, and displays a more precise answer. It also reduces measurement setup time, and avoids the possibility of a calculation error. In other words, a digital readout, as illustrated in Figure 8, combines the function of a conventional oscilloscope with that of a digital counter for an elapsed-time

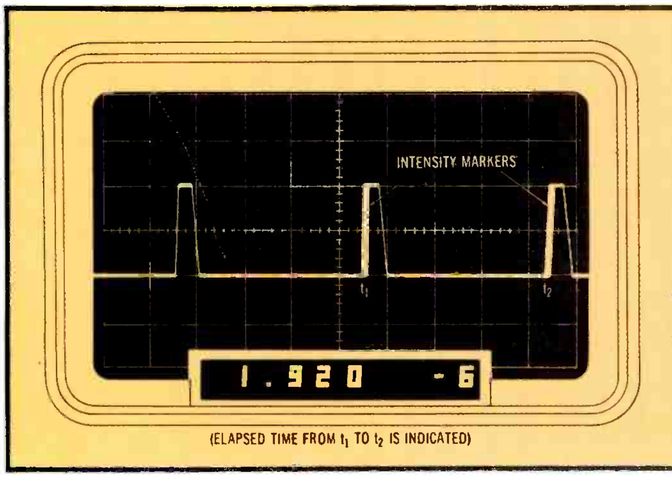


Figure 8. An example of a digital readout for the elapsed time between two intensity markers in an oscilloscope pattern.

indication. In this example, the readout is 1.920 −6, indicating 1.920 microseconds (1.920 × 10^{-6} second).

An oscilloscope with a CRT readout features on-screen numerical displays that are produced by scanning action under the control of integrated-circuit character generators. To display a number on the CRT screen, the electron beam must be turned on and off during appropriate intervals. It is standard practice to use 7-segment digits, as shown in Figure 9.

The total number of time intervals that are employed for digit formation determines the complexity of the IC character generator(s). The 7-segment digits are produced as shown in Figure 9B. Each segment of a digit is comprised of straight lines that fall along either the horizontal or the vertical axis. Thus, four vertical segments occupy two time periods during the horizontal-scanning sequence; they occur at the same time on every line. Note that the three horizontal segments also occupy the same time periods on the horizontal scan. Observe in Figure 9B that the adjoining segments may be proportioned so that their ends overlap, thereby avoiding "breaks" in the character display. Both the horizontal and the vertical scanning periods of each digit are divided into eight *time slots* (Figure 9C). Each of the vertical time slots comprises an even number of horizontal scan lines, in a typical design. The first two horizontal time slots and the first vertical time slot in each digit are blank in this example. The top, center and lower horizontal segments occupy the third through the eighth horizontal time slots during the second, fifth and eighth vertical time slots. The left and right vertical segments occupy the third and eighth horizontal time slots. Also, the left and right vertical segments occupy the second through the fifth time slots, and the fifth through the eighth time slots, with an overlap during the fifth time slot.

The more elaborate oscilloscopes often have *edge-lighted* graticules. The graticule is fabricated from lucite, and several red light bulbs are mounted around the edge of the graticule. A control is provided for varying the light intensity. When the scale-illumination control is turned down, the graticule is almost invisible, and only the green fluorescent pattern is in evidence. On the other hand, when the scale-illumination control is turned up, the graticule rulings are displayed as red lines over the green waveform. The adjustable light intensity facilitates the photography of waveforms. The distinction between lab-type and service-type oscilloscopes has become less marked than in the past. State-of-the-art, service-type scopes have display and operating features that were formerly provided only by lab-type scopes. Also, modern lab-type scopes are far more sophisticated and versatile than their predecessors.

Writing speed

An important characteristic of all oscilloscopes should be mentioned – the reaction speed of the electron beam to any applied voltage. The beam possesses very little inertia. For all practical purposes, it can be said to have no inertia; consequently, it responds almost instantaneously to the impulse of the deflection voltages. This is the property that enables the trace to follow every variation of the applied signal, no matter how suddenly the signal may change direction or amplitude.

How readily the beam changes direction while moving at high speed can be shown by the following example. Assume an oscilloscope has a sweep frequency of 30kHz and a horizontal amplification capable of expanding the trace to four times the screen width. (Many oscilloscopes will exceed both specifications.) For a 5-inch oscilloscope, this means the trace is equal to 20 inches in length although only five inches of the center can be seen. The beam

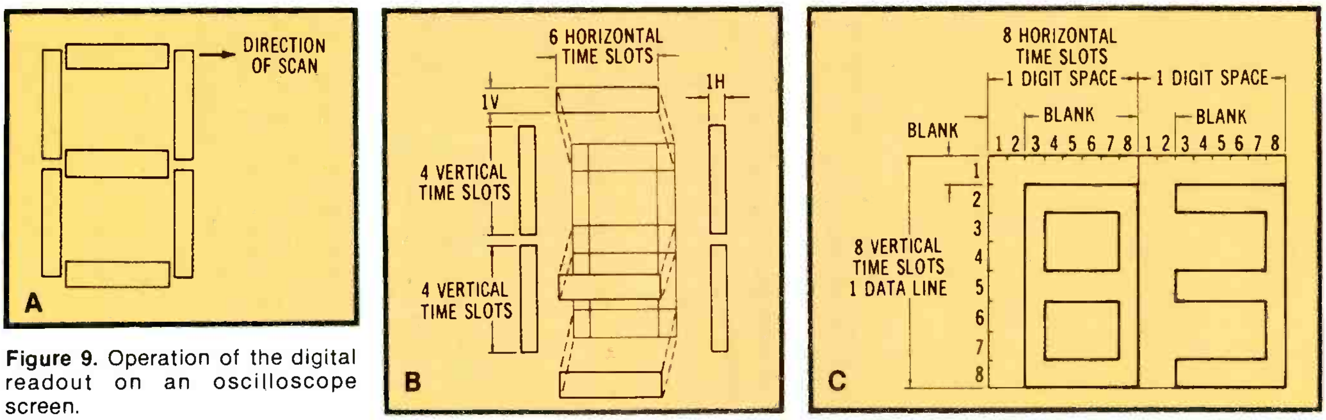


Figure 9. Operation of the digital readout on an oscilloscope screen.

sweeps these 20 inches in 1/30,000 second – actually, in even less time since some time is lost in retrace. Thus, the beam is sweeping the tube at a "writing speed" of 600,000 inches per second, or a little faster than 34,000 miles per hour. The retrace time usually is less than trace time; accordingly, the retrace speed would be much greater. However, the retrace is seldom used for viewing and, therefore, is not considered when discussing writing speed.

Input impedance

Another important characteristic of the oscilloscope is its high input impedance. This is desirable in any voltage-measuring instrument, for it means the instrument will have a minimum loading or disturbing effect on any circuit to which it is connected. The vertical amplifier input impedance of a conventional oscilloscope may have any value from 1 to 5MΩ shunted by 25 to 50pF. If connected directly to the deflection plates, the impedance may be as high as 10MΩ shunted by 15pF. The input impedance at the vertical amplifier can be increased by the use of high-impedance probes.

A block diagram of a general-purpose oscilloscope is shown in Figure 10. This is a greatly simplified diagram with several features combined in each section. The focus, intensity, and positioning circuits are not shown; they have been considered as part of the low-voltage power supply. The step and vernier attenuators usually are associated with the vertical and horizontal amplifiers. Triggering and synchronizing of the sweep oscillator are considered part of the sweep oscillator.

As noted previously, an oscilloscope could be made of a CRT and a power supply only. Such an oscilloscope would be extremely limited in the ways it could be used. The signal input would have to be made directly to the deflection plates, and a comparatively strong signal would be necessary to deflect the electron beam a usable amount. After adding vertical and horizontal amplifiers and a horizontal-deflection system to provide a time base, the oscilloscope may be used for an increased number of applications. The oscilloscope can respond to very weak input signals, and general-purpose oscilloscopes sometimes have a vertical-deflection sensitivity of 15 millivolts rms per inch or less.

The appearance of the front panel of a basic oscilloscope is shown in Figure 11. Although numerous controls are provided on the front panel, the instrument is not difficult to operate. To anticipate any subsequent discussion, a half dozen, or even more, of the controls may remain at reference settings during a series of tests. Therefore, do not jump to the conclusion that an oscilloscope is more difficult to operate than a TV receiver, for example. In fact, a service-type oscilloscope is easier to operate than a color-TV receiver.

When the oscilloscope is properly connected and adjusted, it gives a visible indication of the amplitude, frequency, phase, and waveform of the signal at any particular point in a circuit. An instrument providing as much information as this to a knowledgeable user is a powerful tool indeed. There is probably no phase of electronics where it has not proved useful for designing, testing, or servicing.

Cathode-ray tube operation

Although a CRT operates at a comparatively high voltage (in the range from 1kV to 5kV, depending upon the particular design), the CRT *draws comparatively little current* from the high-voltage supply, even with the beam-intensity control advanced substantially. Thus, the current demand from the high-voltage power supply in a service-type oscilloscope never exceeds 2mA or 3mA. The normal operating voltages for a CRT in a top-performance lab-type oscilloscope are noted in Figure 12.

A modern 5-inch CRT has, externally, four parts: the base, the neck, the bulb and a face or screen. Inside the neck is the gun structure. The gun contains all the electrodes for forming, shaping and directing the electron beam that strikes the fluorescent screen of the tube.

Applying the proper voltage to the various electrodes of the gun produces a beam that is brought to a focus in a small spot on the tube screen. The beam intensity is controlled by the voltage on the control grid. Figure 13 is a perspective drawing showing how the electron beam passes through the space between the deflection plates on its path to the screen. With all deflection plates at the same electrical potential, the beam will pass along the axis of the deflection-plate assembly and strike the center of the screen.

If one plate of a pair of deflection plates is made more positive or negative than the other, the electron beam is attracted toward the positive plate and repelled from the negative plate (Figure 14), because unlike electrical charges attract and like charges repel each other. The electron beam is always negative and, therefore, is always attracted to the positive plate. The amount of deflection varies directly with the magnitude of the voltage on the deflection plates. For example, if a potential difference of 50 volts between a pair of plates moves the beam one inch at the screen, 100 volts will move it two inches (Figure 15).

Applying an alternating voltage to the vertical plates moves the beam and produces a vertical line from top to bottom of the screen. Similarly, the proper voltage applied to the horizontal plates produces a horizontal line across the screen. With proper voltages for both sets of plates, the beam can

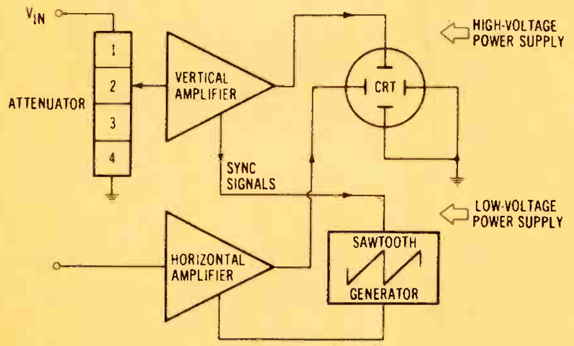


Figure 10. Block diagram of a general-purpose oscilloscope.

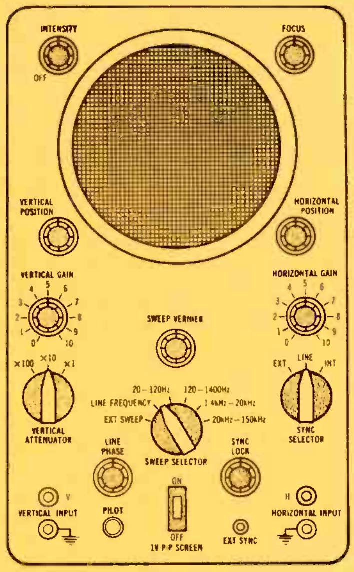


Figure 11. Appearance of the front panel on a basic oscilloscope.

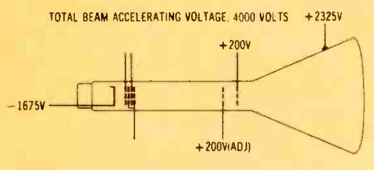


Figure 12. Terminal voltages for a CRT in a high-performance lab-type oscilloscope.

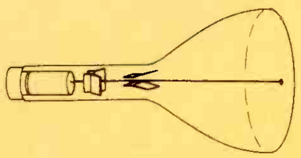


Figure 13. Path of electron beam through deflection-plate assembly.

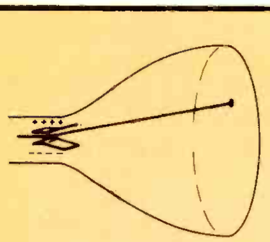


Figure 14. The electron beam, being negative, is always attracted by the positive-charged deflection plate and repelled by the negative-charged deflection plate.

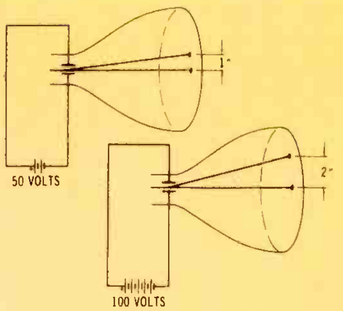


Figure 15. The amount of deflection is directly proportional to the voltage applied to the plates.

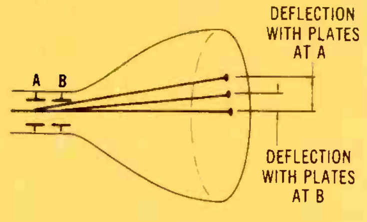


Figure 16. Given equal deflection voltages, deflection plates set nearest the base of the CRT will have a greater deflection sensitivity than those farther away.

be made to move anywhere on the screen.

Deflection sensitivity

The deflection sensitivity of a CRT and of the entire oscilloscope determines the weakest signal that can be viewed successfully with the instrument. Anyone who has consulted a tube manual about CRTs may have noticed that deflection sensitivities can cover a wide range, depending on the voltages used. The sensitivities also differ for the two pairs of deflection plates, one sensitivity being greater than the other. For example, one tube manual lists the following sensitivities for a 5CP1-A CRT. When the voltage of anode No. 3 is twice that of anode No. 2, the sensitivity is 39 to 53 volts (dc) per inch for every thousand volts supplied to anode No. 2. This range applies to one set of deflection plates. For the other set under the same voltage conditions, the sensitivity is 33 to 45 volts (dc) per inch per thousand volts supplied to anode No. 2.

The pair of deflection plates having the greater sensitivity (that is, requiring the smaller number of volts per inch of deflection) is always the pair nearest the base of the tube. The reason can be readily seen by examining Figure 16. In this illustration, a pair of deflection plates is shown in two different positions, one (position A) being nearer the tube base than the other. If the applied voltage is the same for both positions, the electron beam will be deflected through an equal angle each time. With equal deflection angles, the deflection plates at position A swing a longer beam, thus giving a longer trace.

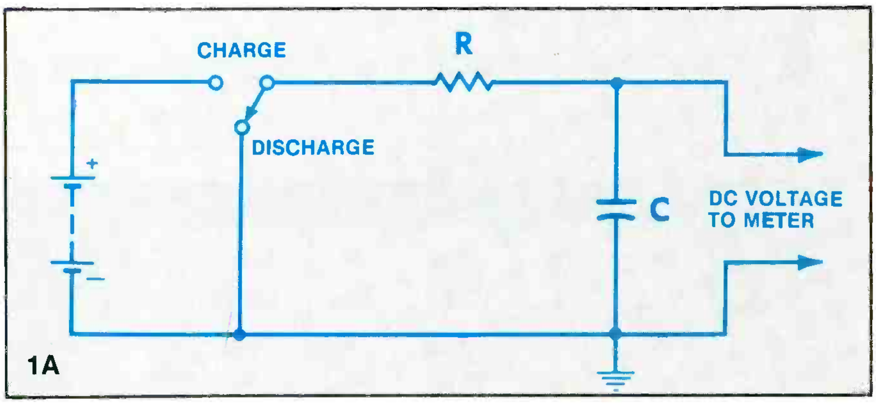
Either pair of plates can be used for the vertical system; the rotational position of the tube about its long axis determines which pair. To obtain the highest possible deflection sensitivity for the vertical system, the CRT normally is positioned so that the pair of plates closest to the base produce the vertical deflection. The horizontal-deflection plates usually are driven by a stronger signal and are farther from the base than the vertical-deflection plates.

PART 2

Interpreting waveforms

By Carl Babcoke, CET

The approximate frequency response of an audio amplifier can be determined by using square waves as a test signal, and then comparing the input signal with the distorted output signal, using a dual-trace scope. This fast test is made possible by a practical application of *time constants.* A thorough understanding of time constants can explain capacitive reactance, and why some lines of square waves are bent into curves as they pass through certain time-constant filters. Time constants deserve more than the minor coverage usually given in most textbooks.



CAPACITOR INSTANTANEOUS VOLTAGES

AFTER 1T, CHARGE VOLTAGE = 63.2% (OR DISCHARGE = 36.8%)
AFTER 2T, CHARGE VOLTAGE = 86.5% (OR DISCHARGE = 13.5%)
AFTER 3T, CHARGE VOLTAGE = 95% (OR DISCHARGE = 5%)
AFTER 4T, CHARGE VOLTAGE = 98.2% (OR DISCHARGE = 1.8)
AFTER 5T, CHARGE VOLTAGE = 99.3% (OR DISCHARGE = 0.7%)

1B

Figure 1. Time constants can be studied using this circuit. (A) With the switch at the *discharge* position, the capacitor is completely discharged. When the switch is changed to *charge* position, the battery causes current through the resistor and into the capacitor, which at this time is equivalent to a short circuit. Current is maximum, with the amount depending on the voltage and the resistance. Then the current flowing into the capacitor rapidly begins to develop a positive voltage that opposes current through the resistor. At the end of five time constants, the capacitor voltage virtually equals the supply voltage, and the current is zero. *The capacitor now is completely charged.* When the switch is changed to *discharge* position, charge that had been stored in the capacitor flows back out through the resistor to ground. At the end of 10 total time constants, the capacitor again has zero voltage and zero current; it is discharged. (B) These are the capacitor voltages (in percentage of the supply voltage) at the end of each five charging time constants and the end of five discharging time constants. By definition, a one-time-constant RC filter will provide those voltages.

Time-constant basics

When dc power is switched through a resistor to a capacitor (Figure 1), the voltage increase at the capacitor is not instantaneous. The time constant of resistance and capacitance (T = RC) determines how rapidly the voltage rises. Maximum capacitor voltage is not attained during the first time constant, nor does the voltage increase at a linear rate. When the voltage rise is graphed, a curve whose voltage approaches the source voltage is formed.

During capacitor charging, one time constant is the time required for the capacitor voltage to increase from zero to 63.2% of the supply voltage. During the second time constant, the voltage increases 63.2% of the remaining 36.8% (or 23.3%), bringing the voltage up to 86.5% at the end of the second time constant. The remaining difference between source and capacitor voltage now is 13.5% of the source voltage. In one more time constant the capacitor voltage increases 63.2% of the 13.5%, producing 8.5% that is added to the previous 86.5% to provide 95% of the supply voltage at the capacitor after the first three time constants. The final two time constants are calculated by the same 63.2% increase of the remaining voltage, so after five time constants, the capacitor-charging voltage is 99.3%, and it is considered completely charged for all practical purposes. According to theory, the voltage on the capacitor will never quite reach the source voltage but approaches closer and closer as long as it is connected.

A second method of studying time constants is based on capacitor-discharge voltage. If a charged capacitor is discharged through a resistor, its voltage will drop by 36.8% after the first time constant (Figure 1). Also, time constants can be specified in capacitor-charging or capacitor-discharging *current*. The current curve will be the inverse of the voltage curve.

Incidentally, the mathematics of time constants is simplified if you assume a supply voltage of 100Vdc, thus using one voltage and one percentage figure for each calculation.

TIME-CONSTANT FORMULAS

T = R times C R = T/C C = T/R

RESISTANCE		CAPACITANCE		TIME CONSTANT
ohms	times	farads	equals	seconds
ohms	times	microfarads	equals	microseconds
kilohms	times	microfarads	equals	milliseconds
megohms	times	microfarads	equals	seconds
megohms	times	picofarads	equals	microseconds

DIVISIONS OF A SECOND

one millisecond equals 0.001s
one microsecond equals 0.000001s
one nanosecond equals 0.000000001s
one picosecond equals 0.000000000001s

Table 1. These time-constant formulas and conversions are needed for calculations.

Time-constant formulas

The time constant (T in seconds) equals the resistance (R in ohms) times the capacitance (C in farads). Briefly, this is T = RC. However, the formula can be rewritten as R = T/C or C = T/R.

Time constants are unwieldy when expressed in seconds, ohms and farads. Table 1 shows several alternate specifications. For the time constants used later in this article, the formula becomes: T (time in microseconds) equals R (resistance in ohms) times C (capacitance in microfarads). Most calculators can handle these figures easily.

Electronics books usually show drawings of capacitor-charging and capacitor-discharging curves. In this article, however, the drawing is performed by a B&K-Precision oscilloscope (Figure 2). (The light and dark values of the trace are reversed for clarity.) Each horizontal graticule division represents one time constant, while each vertical division represents 24% of the input voltage.

Ac or dc pulses?

Someone might question the use of switched dc voltage (zero or positive) in Figure 1 and the substitution of ac square waves in Figure 2. It certainly is true that the Figure 1 switching produces dc square waves having zero voltage at the bottom and maximum supply voltage at the waveform's top (Figure 3A). This can be an advantage if you wanted to verify the voltage at the end of each time constant; the time constant could be made so long that an electrostatic voltmeter could actually measure the constantly changing voltage.

Fortunately, the use of ac square waves (Figure 3B) allows convenient and rapid measurements of reasonable accuracy by viewing them on a scope screen. Actually, the presence or absence of dc with the square waves does not affect the waveform on the scope. This was proved in a practical test that added dc voltages (varied from zero to double the waveform amplitude) to ac square waves. No change was noted on the scope screen, even when dc coupling was used.

Voltage and current relationships

Figure 4 shows the relationships between voltage and current over 10 time constants. Repetition rate of the square waves and the precise time constant were chosen

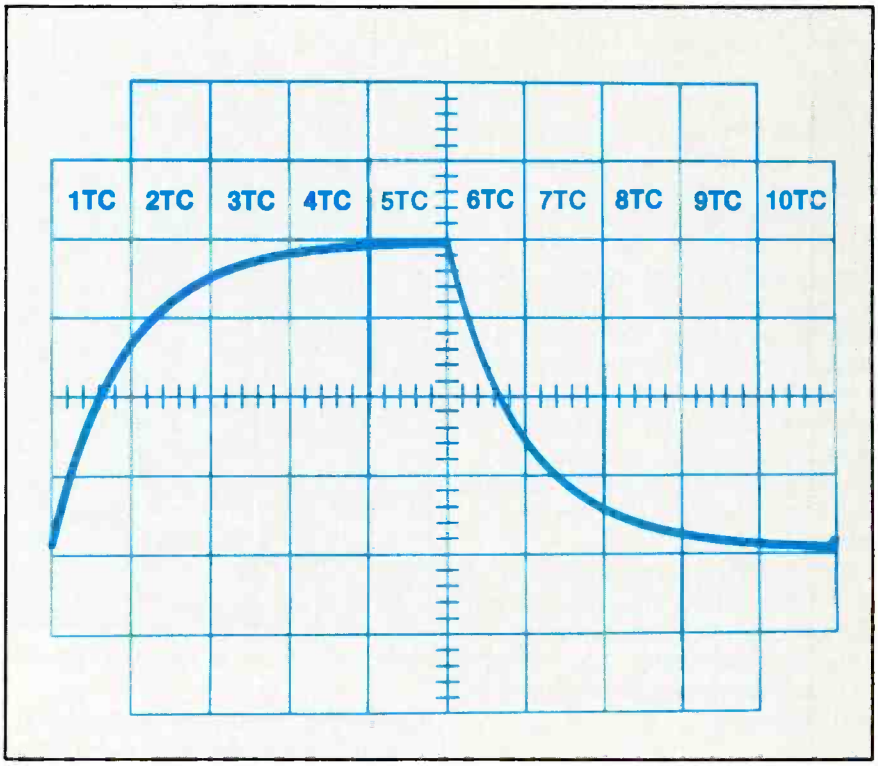


Figure 2. This textbook curve shows capacitor-charging voltage at the left and capacitor-discharging voltage at the right. Each horizontal graticule division represents one time constant. A 500μs time constant was used. Compare the voltages at the end of each time constant against the theoretical list in Figure 1. The accuracy of the scope curve is very good.

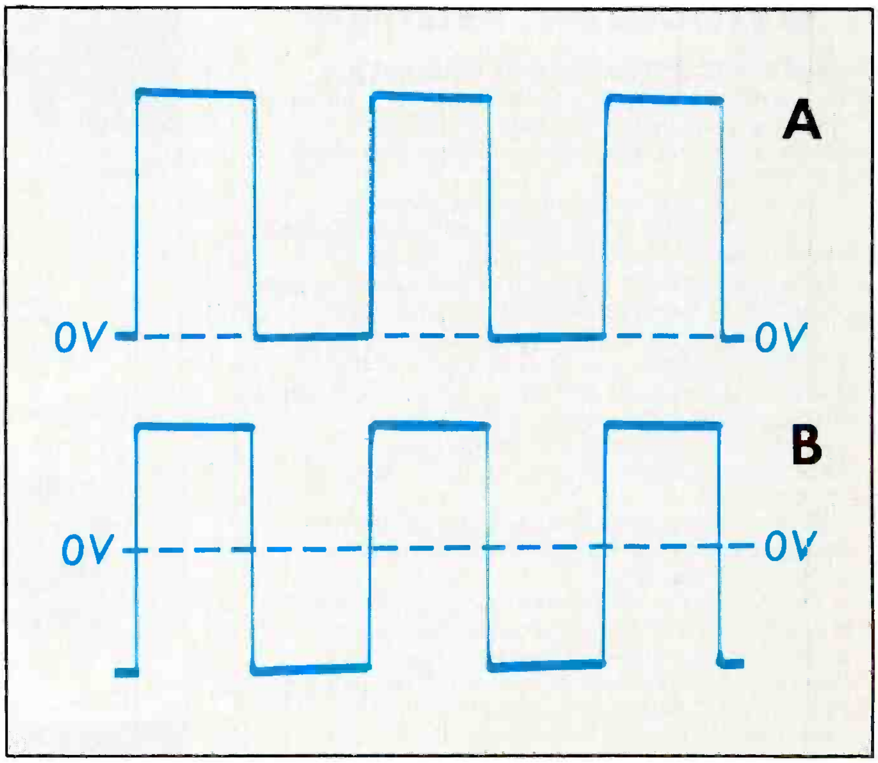


Figure 3. Adjustable dc voltages were added to the test square waves to verify that dc voltage did not affect the filtered waveforms. (A) These are dc square waves, such as found in digital circuits. No differences were noted in the waveforms from lowpass and highpass filters when dc square waves were used or (B) when the dc voltages were removed. (Invisible vertical lines have been touched up.)

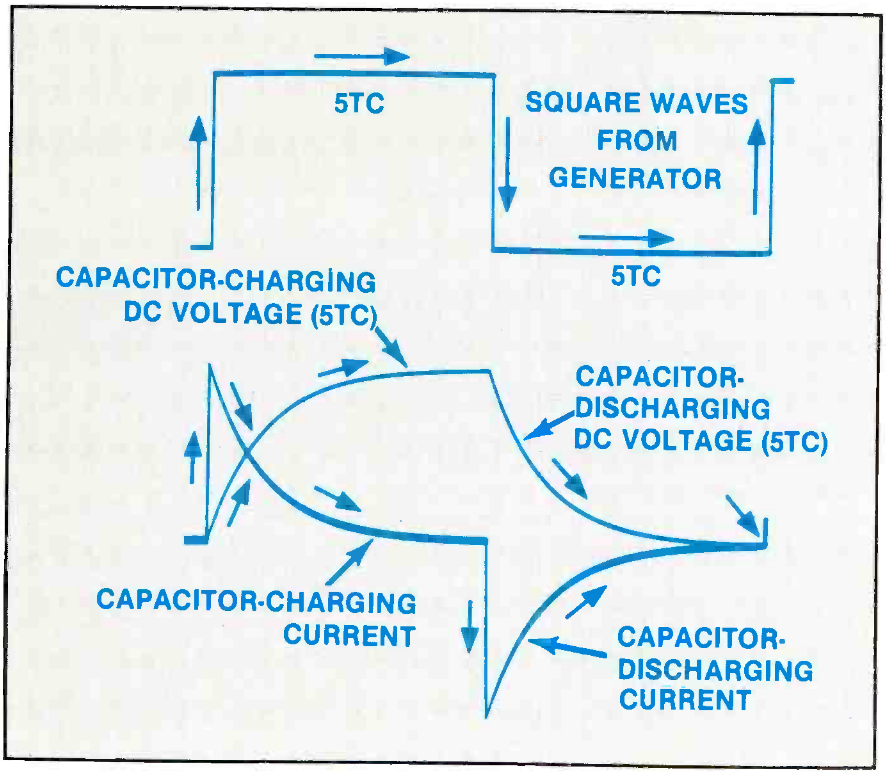


Figure 4. Voltage and current curves during five charging time constants and five discharging time constants are shown. Arrows show movement of the scope beam.

to provide the classical charge/discharge waveshape. Of course, many other variations of curves are produced by time constants of different durations and by square waves of other repetition rates. Specific combinations can clarify capacitive reactance and other important subjects. Before examining these, let's look at a sequence of waveforms from a progression of time constants.

Lowpass filters and square waves

A series of time constants can be obtained by varying both the resistor and the capacitor values. Or one capacitor can be used and the resistance changed for each time constant. Alternatively, a fixed resistor can be used for all filters, while the time constant is varied by selecting a different capacitance. Also, the *effects* of various time constants can be obtained by using one time constant while changing the repetition rate of the square waves; a method that

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was not used in Figure 5 because the generator's waveshape varied slightly over the required band of repetition rates.

All waveforms in this article and most of the data were produced using a precision 20K 1% resistor (constructed from several paralleled resistors), various capacitances of appropriate values, and 200Hz repetition-rate square waves.

All capacitances were measured by a B&K-Precision model 820 digital capacitance meter. The 200Hz square waves came from a B&K-Precision E-310B sine-square generator. A Sencore SC61 waveform analyzer measured the signal frequencies so they could be maintained to better than 0.4% accuracy. (The SC61 counter has much higher accuracy, but the generator drifted slightly.) All waveforms were photographed from a model 1535 B&K-Precision scope with attached scope camera.

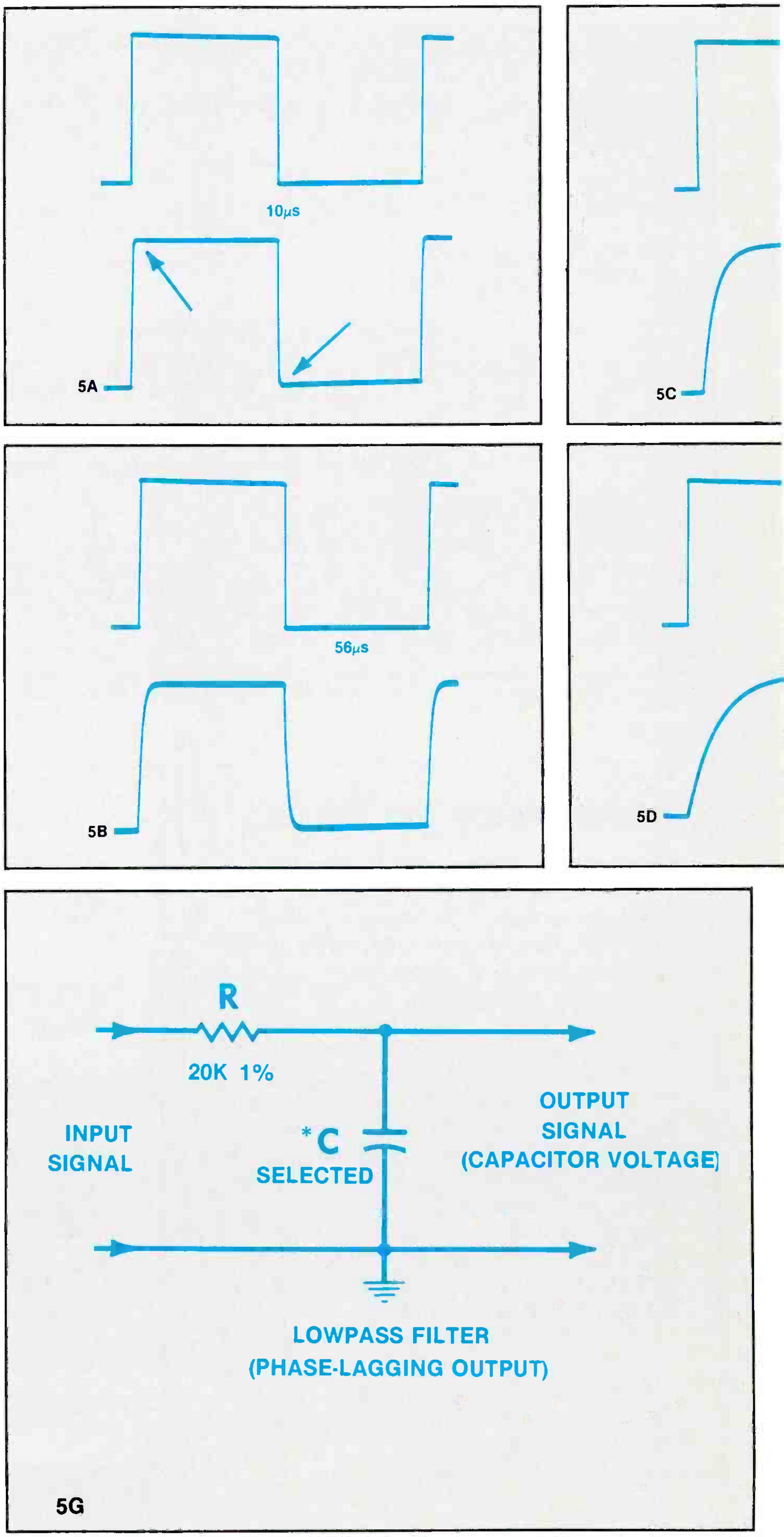
Figure 5 shows six pairs of waveform photographs. All vertical lines have been touched up to make them visible. In each photograph, the top trace shows the generator's square wave, while the output of the time-constant lowpass filter is shown by the bottom trace. The same precision 20kΩ resistor was used for these six tests. The measured capacitances are listed, along with the time constants in microseconds.

Additional information in Figure 5 includes the repetition frequency that would produce a similar waveform *if the time constant was* 500μs. As a reminder that the effect of filters on square wave waveforms depends both on the repetition rate and on the time constant of the filter, the time constants are listed that can provide identical waveforms (to those shown) when the repetition rate is changed to 2000Hz. A table lists the sine wave frequency responses of the six filters.

A short summary of lowpass filter effects (and how to evaluate the waveshapes) is provided in Figure 6, which shows four curves superimposed on one cycle of a square wave.

Visual perspectives

In actual servicing, most



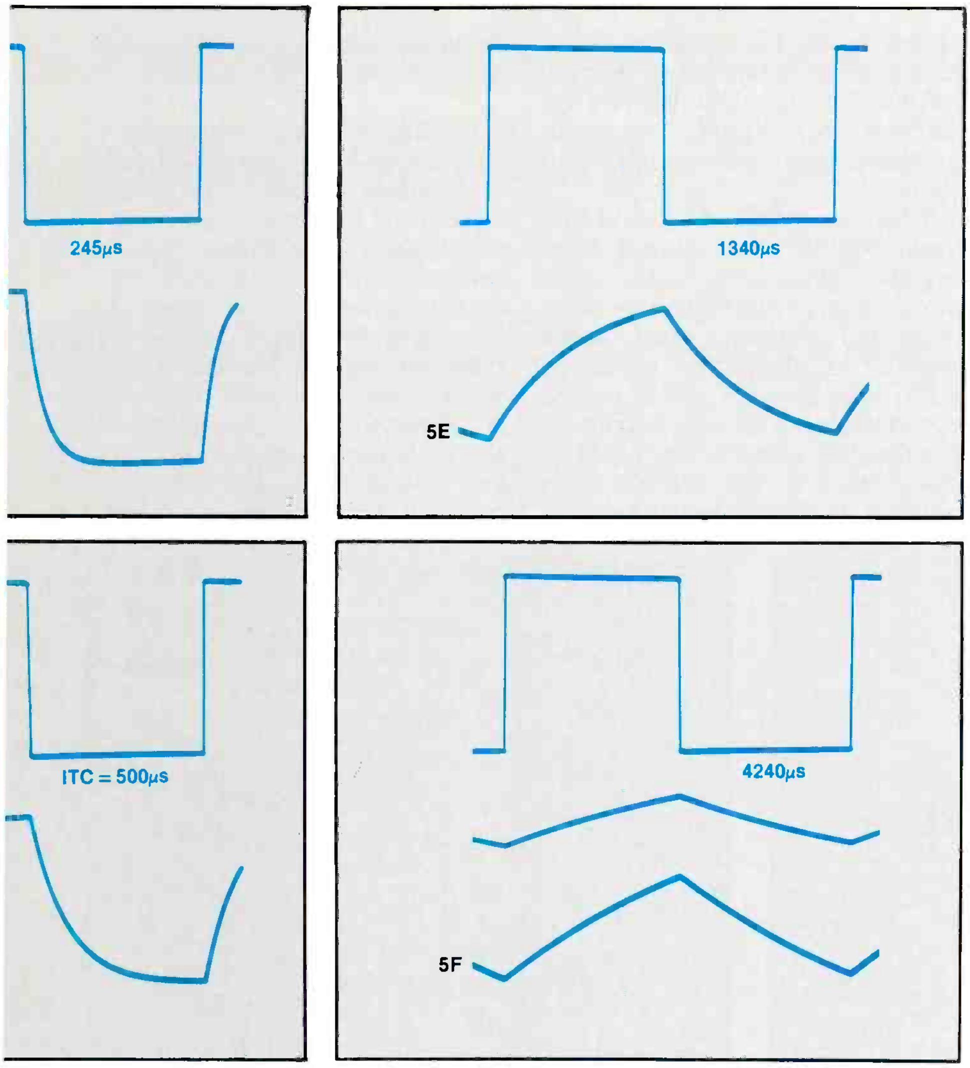


Figure 5. Six lowpass filters show how square waves change as the time constant is increased in steps. Remember, these waveforms will resemble the voltage charging/discharging curves of Figure 4. (A) A 0.0005μF capacitance have a 10μs time constant and barely rounded two corners (marked with arrows). Watch these corners as the time constant is increased. 10μs with 200Hz square waves gave the same waveform as 500μs would at 4Hz. Also, the same waveshape can be obtained at 2000Hz with a 1μs time constant. (B) Increasing to 0.0028μF and 56μs time constant rounded the two corners even more. The same waveshape can be obtained with 500μs at 22.4Hz, and a time constant of 5.6μs would give the same waveshape at 2000Hz repetition rate. (C) With the time constant at 245μs, the curve begins to resemble the classic textbook time-constant curve of Figure 2. A rep rate of 98Hz would give the same waveform with 500μs TC. At 2000Hz, 24.5μs is needed for an identical waveshape. (D) A 500μs time constant provides 10 time constants (totaling 5000μs) and forms the classic voltage charging/discharging curves that are used in most explanations about time constants. No loss of output waveform height occurred in these four examples because full voltage was attained before the end of the positive peak. The same 2000Hz waveshape can be obtained with a 50μs time constant. (E) A long 1340μs time constant slowed the rise of charging voltage until the positive peak had passed, thus the height is reduced to 72% of the input amplitude. The same waveshape can be obtained at 536Hz with a 500μs time constant, or at 2000Hz with a 134μs time constant. (F) Increasing the time constant to 4240μs produced a triangular waveshape having almost perfectly straight lines. The actual amplitude relative to the input signal is shown by the center trace, while the lower trace has had the amplitude increased by increasing the scope gain. Such strong filtering also produces huge phase shifts when sine waves are used to replace square waves. A rep rate of 1696Hz produces the same waveshape with a 500μs time constant. Also, 2000Hz with 42μs gives an identical waveshape. (G) The lowpass-filter schematic is similar to the test setup in Figure 1 with square waves used instead of a dcV source. (H) These are actual frequency response readings of the six TC filters. They show the areas where maximum phase shifts occur (attenuation of 1dB or more).

FREQUENCY RESPONSE OF TIME-CONSTANT LOWPASS FILTERS

All readings in decibels

Sine wave test frequency	Figure numbers					
	5A	5B	5C	5D	5E	5F
20Hz	0	0	0	0	– 0.1	– 1.2
40Hz	0	0	0	0	– 0.5	– 3.4
60Hz	0	0	0	0	– 0.8	– 5.3
100Hz	0	0	0	– 0.5	– 2.3	– 8.6
150Hz	0	0	0	0.8	– 3.8	– 12.2
200Hz	0	– 0.2	– 0.4	– 1.5	– 5.6	– 15.3
400Hz	0	– 0.2	– 1.5	– 4.0	– 10.6	– 20.3
800Hz	0	– 0.4	– 3.6	– 8.3	– 16.1	– 26.1
1600Hz	– 0.2	– 1.3	– 7.8	– 13.8	– 22.0	– 32.1
3200Hz	– 0.4	– 3.6	– 13.2	– 19.8	– 27.8	– 38.0
6400Hz	– 1.5	– 7.8	– 18.8	– 26.8	– 34.1	– 44.2
12800Hz	– 3.8	– 13.3	– 24.8	– 31.8	– 40.5	– 50.0
16000Hz	– 5.1	– 15.8	– 26.8	– 34.2	– 42.0	– 52.0
5H	0.02TC	0.11TC	0.5TC	1TC	2.7TC	8.5TC

waveforms are given only a cursory glance. However, first impressions can be misleading unless some precautions are taken. Examine the three scope traces in Figure 7. Would you suspect that all three waveshapes might be identical? The top trace shows only slightly more than one cycle of a filtered square wave, but the height is very low, making analysis difficult. Three classical charge/discharge curves are shown by the center trace. They are easy to recognize because the height of each separate curve is about equal to the width. When shown on the bottom trace, these same charge/discharge curves have sufficient height but are too narrow for rapid, accurate analysis, since there are about 15 there.

With exceptions of musical and vocal sounds that do not have regular repetition, and some digital signals that have no short repetition pattern, most scope waveforms should be examined with only one or two complete cycles visible, and with height approximately equal to the width of one cycle. If the waveform is unusual, these suggestions can be modified slightly to make the waveform easier to examine.

Dealing with dc components

Here's an important principle to remember about filtering waveforms that have a dc component (dc waveforms). All dc voltmeters, by their basic natures, operate as integrators. Therefore, dc pulses or square waves will show an appropriate dc voltage when measured by a dc voltmeter. It follows that a dc voltmeter will show identical readings at input and output of a lowpass filter (when all output loads are discon-

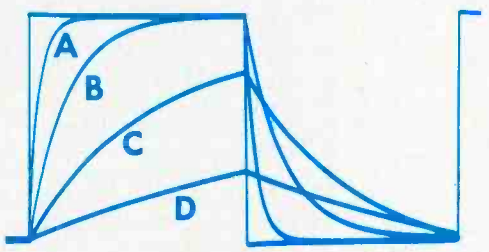


Figure 6. Four different time-constant curves superimposed on one square-wave cycle illustrate the effects of lowpass filters. (A) One cycle of a 200Hz square wave requires 500μs of time, and 10 time constants are needed (five charge and five discharge) to show time-constant operation properly. Therefore, a time constant of 500μs is needed to provide the classic capacitor charging/discharging curve of B. However, curve A was produced by a 150μs time constant, which is 0.3 (or 30%) of the required 500μs. Therefore, curve A should be identical to curve B but compressed laterally onto 30% of the square wave's positive peak. Visually, this appears to be correct. (B) As stated, this is the classic curve from a 500μs time constant, so it follows the instantaneous capacitor voltages listed in Figure 1. These two curves show that the time constant can be estimated by noting where during the square-wave cycle the capacitor-charging voltage reaches virtually 100%. Curve 1 reaches the goal at 30% of the peak. Therefore, it had 30% of 500μs, or 150μs time constant. Other values of less than one time constant can be estimated the same way. Obviously, the method is not practical where the full supply voltage never is reached (as with curves three and four). (C) Clearly, curve C was formed by a much longer time constant. The filter's actual time constant can be found approximately by measuring the percentage of the square-wave peak that was traced horizontally before the voltage rose 63.2%. This horizontal distance represents one time constant, and the ratio of that to the square-wave peak provides the appoximate time in microseconds. One waveform was measured that way, and the answer was about 15% too high because it is difficult to know exactly where 63.2% is. (D) Curve D cannot be analyzed for time constant by the previous method because the capacitor-charging voltage does not rise to 63.2% before the positive peak has passed. Instead, the time constant can be determined by reducing the generator frequency until a classic charging/discharging curve (such as B) is produced. Then the time constant is one-tenth of the time for one square-wave cycle. Fair accuracy can be obtained by this method.

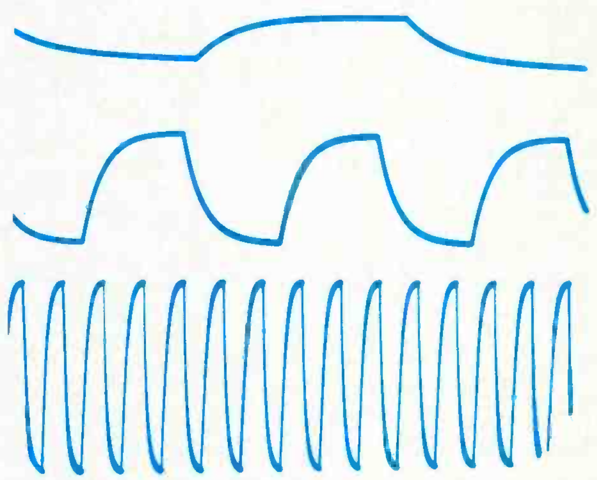


Figure 7. All three scope traces show the same charging/discharging waveshape. Only the center trace is easy to recognize and analyze. This illustrates the importance of adjusting the scope waveform from the optimum height and number of cycles.

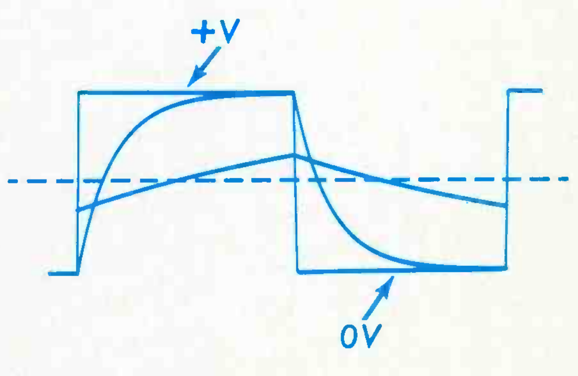


Figure 8. When dc square waves (those with zero voltage at the bottom peaks) are filtered, the dc-voltage readings obtained from voltmeters will be identical for the unfiltered square waves and for all the filtered waveforms. That is because all dc waveforms have the same average voltage (dotted line).

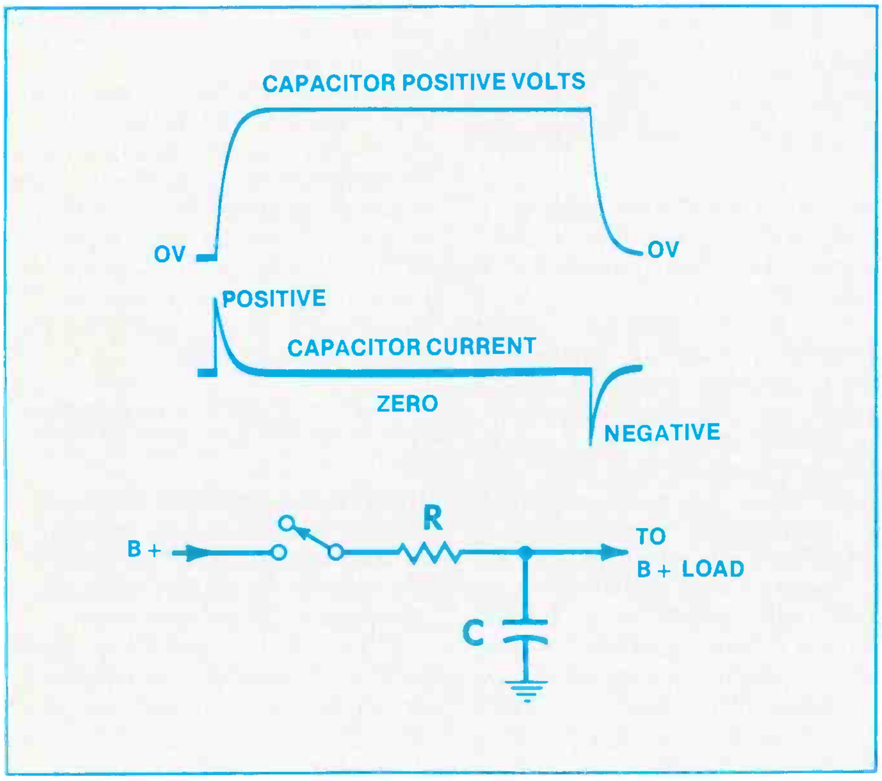


Figure 9. A strong time-constant lowpass filter can reduce or eliminate switch-on and switch-off popping noises when B+ is turned on and off. Also, a large value capacitor (relative to the load) has a short-term voltage regulation action.

nected). *Lowpass filters do not change the average dcV level of dc waveforms.* This statement was verified by dc-voltmeter readings and dc-scope waveforms.

The Figure 8 waveforms were made with the scope adjusted to dc coupling. Zero voltage is at the bottom of the waveform, and the dc voltage measured half of the square-wave amplitude (no math is needed for that). After the signal passed through a one-time-constant lowpass filter, the dc-voltage reading at the filter's output was exactly the same voltage as the square waves alone.

Next, a 4240μs filter was used, and the output dc voltage again was equal to the square waves dc voltage. Notice the low amplitude of the triangular waveform. All three test conditions produced the same dc voltage reading.

Symmetrical waveshapes (triangles, square waves and sine waves) with zero at the bottom and positive dcV at the top have their average positive voltage exactly at the vertical center of the waveshape. A dotted line has been added to mark this average-voltage location in Figure 8.

At first glance, it seems impossible that the input square wave and the filtered charge/discharge curves could produce the same dc voltage. After all, one whole corner is missing from the charge curve. Remember, this is dc, not ac, and so all parts of the waveform above the zero line contribute to the dc voltage. A dc square wave has full voltage for half a cycle and then zero voltage for the other half cycle, but the charge/discharge curves have partial voltage for a half cycle and a lower partial voltage for the other half cycle. In other words, both curves contribute dc voltage, not just one as is true with square waves. If you were to cut out the voltage-discharging part of the Figure 8 waveform and attempt to insert it into the missing corner of the voltage-charging curve, it would fit perfectly, and the two sections together would form a new square wave.

Switching transients

Lowpass filters can be useful in circuits other than audio amplifiers. For example, a lowpass filter might be included in B+ circuits to minimize clicks or pops at turn-on or turn-off. Figure 9 shows the waveshape obtained by such a circuit. Optimum values probably would be determined by experimentation, but such circuits can definitely reduce all instantaneous voltage changes on the B+ line.

Notice that the time-constant capacitor has *positive* charging current at switch-on and then *negative* capacitor-discharging current at switch-off. In practice, the discharging current merely is added to the load current.

Incidentally, the words positive and negative do not mean positive and negative voltage and current. Remember, nothing actually passes *through* any capacitor. Current comes in to charge the capacitor with voltage (positive current), and then during discharge, those same electrons move in the opposite direction out of the capacitor (negative current) to discharge the capacitor voltage into the load resistance.

Notice that power is taken from the B+ supply at switch-on to charge the filter capacitor, thus gradually applying voltage to the filtered B+. Then at switch-off, this power stored in the capacitor attempts to supply the load. In fact, the capacitor-stored power softens the otherwise abrupt drop to zero.

This also explains how a large electrolytic capacitor that is floated on a low-current B+ supply can produce some degree of voltage regulation. The capacitor draws current and becomes charged. Then it waits, drawing no current until the voltage changes. If the voltage rises, the capacitor charges to the new voltage level, drawing charging current that helps reduce the voltage rise to a more moderate amount. However, when the voltage decreases, the capacitor discharges part of its current into the load, which minimizes the amount of voltage drop. ES&T

The final installment of this *Waveforms* series of articles will be published in a future issue. That segment will cover the effects of highpass filters on square waves and current voltage relationships in capacitive circuits. Part 1 of this series appeared in the December 1983 **ES&T**.

Books

Satellite Communications, by Stan Prentiss; Tab Books; 288 pages; $16.95 hardbound, $10.95 paperback.

This book covers the various disciplines of satellite communications, including practical data on uplink and downlink transceivers and TVRO stations. Earth station basing diagrams, focal and Cassegrain feeds, low-noise amplifiers, downconverters, receivers and installation instructions are covered.

Chapters cover satellites in orbit and under construction, satellite signals, fixed satellite service, DBS service, transmitters and trapping, TVRO receivers, TVRO considerations and design, interference and mounting constraints, security and scrambling devices, and CATV satellites.

Published by Tab Books, Blue Ridge Summit, PA 17214.

Television: Theory and Servicing, by Charles G. Buscombe; Reston Publishing Company; 838 pages; $34.95 hardbound.

In this textbook, theory and practice are treated with equal importance, and every effort has been made to keep it current with the latest trends in receiver design and troubleshooting techniques. Up-to-date circuits are described and analyzed along with the troubleshooting procedures for each. The author treats all subjects in a logical and straightforward manner progressing gradually from the simple to the complex.

At the end of each chapter, important points are condensed and summarized along with numerous thought-provoking review questions. Most chapters also include a troubleshooting questionnaire to stimulate analytical reading. Troubleshooting flow drawings and trouble symptoms charts are included with step-by-step procedures.

Prerequisites to the course of study include knowledge of electronic fundamentals and solid-state devices; some review is included where necessary. Some of the chapters include a brief introduction to TV basics, receiver fundamentals (b&w and color), information on all types of test equipment and accessories, and troubleshooting procedures. This textbook is designed to serve the needs of teachers and students. With its many practical servicing hints and short-cut procedures, it should also prove useful to the technician in the field.

Published by Reston Publishing Company, 11480 Sunset Hills Road, Reston, VA 22090.

How to Maintain and Service your Small Computer, by John G. Stephenson and Bob Cahill; Howard W. Sams & Company; 224 pages; $17.95 softcover.

This book explains some straightforward maintenance guidelines and procedures that help microcomputer owners prevent service problems from happening. Should repairs and downtime become imminent, easy-to-use flow charts lead users through diagnosis and troubleshooting to isolate the problem area. The entire computer system is covered, including printers, disk drives, and other peripherals.

Some knowledge of electronics, such as how to use a VOM and oscilloscope, is needed for troubleshooting, but no special understanding of digital theory is necessary.

Published by Howard W. Sams & Company, 4300 W. 62nd St., Indianapolis, IN. 46268.

1984 Radio Amateur's Handbook; American Radio Relay League; 640 pages; $17.75 clothbound, $12 paperback.

This revised, 61st edition of the handbook presents everything from electrical laws and circuits to sophisticated communications techniques. Some of the chapters include amateur radio, radio design techniques and language, solid-state fundamentals, ac-operated power supplies, frequency modulation and repeaters, interference, and test equipment and measurements.

Published by the American Radio Relay League, 225 Main St., Newington, CT 06111.

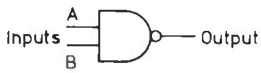
Answers to quiz

(from page 6)

1. *B*. The high positive voltage on the collector will produce a destructive emitter-base current.
2. *D*. The test *should* produce a straight-line display.
3. *B*. Moving the plates farther apart decreases the capacity. That, in turn, increases the resonant frequency so that it matches the dial reading.
4. *D*.
5. *A*. Think of it this way – if the arm is at point x the circuit is equivalent to a piece of wire.
6. *B*.
7. *B*. Maximum power occurs when the load resistance (across terminals x and y) equals the internal resistance (R_i). With 1Ω across the output terminals, the *total* power dissipated is 18W. Half is dissipated in the (output) load resistor.
8. *D*. The total is 1111_2, which is the same as 15_{10}.
9. *A*. The sample and hold circuit operates on a command pulse. When the command is presented, a charged capacitor holds a voltage that is proportional to the analog input signal at that instant. That capacitor voltage usually controls the output of an operational amplifier.
10. *C*. The rolloff of an operational amplifier should be linear.

Correction

In the article *An introduction to digital logic gates* in the March 1984 issue of **ES&T**, on page 49 we ran a symbol of a NAND gate and its Input/Output table. That table was incorrect. Please refer to the accompanying symbol and table for the correct conditions. (Thanks to Terry Mueller of Florida, Bill Lewis of New Jersey, Larry Griffin of Arkansas, Roger Snow of Maine, and several other readers for calling this to our attention.)



NAND GATE

A	B	Output
Lo	Lo	Hi
Lo	Hi	Hi
Hi	Lo	Hi
Hi	Hi	Lo

Input/Output Table

Coming in the June ELECTRONIC Servicing & Technology

Voltage regulators for circuit projects. Three-terminal integrated-circuit voltage regulators simplify power supply design. This article shows how to customize standard regulators to get nearly the precise voltage you need.

Components. There's frequently more to these fundamental building blocks than meets the eye. This fresh look at components may provide you with some new insights.

Readers' Exchange

For sale: Sencore VA48, mint condition with manual and probes, $775. *Henry C. Martin, 4 Mulberry Drive, Huntington, L.I., NY 11743; 516-427-5981.*

For sale: New B&K 1250 NTSC color pattern generator, make offer; new 1210 B&K portable generator, $100; B&K 820 capacitance meter, like new, make offer. *Jess J. Peck, 958 Lowell Blvd., Denver, CO 80204.*

Wanted: Lens for Sony KP-4000 color video projection system. Will pay $150 plus shipping costs. Call before shipping. *Edward L. Millerd, P.O. Box 292, Barbers Point, HI 96862; 808-672-9748.*

Needed: Schematic or service manual for Vornado color TV, model 15. *Mario Toscano, 20-07 Clintonville St., Whitestone, NY 11357.*

For sale: Sencore VA48 video analyzer, $735. Contact *Vernon Rondeau, 1315 Park Ave., Plainfield, NJ 07060; 201-753-6836.*

Wanted: Part #EP64X19 (73C180938-1) horizontal driver. *John Kehoe, 8 Market St., Rotterdam Junction, NY 12150.*

Wanted: Good used Heathkit CRT tester/rejuvenator with manuals. *Jim Sternad, 7121 34th Ave. N., St. Petersburg, FL 33710.*

For sale: Lincoln L550 CRT tester/rejuvenator, $30. *T.W. Benson, 204 Riverside Ave., Tallahassee, AL 36078.*

Needed: Hewlett-Packard CRT #5083-2752(51) for model 1707B oscilloscope. State condition. *Michael McKenna, 10109 S. Albany, Evergreen Park, IL 60642; 312-422-3011 after 3 p.m.*

For sale: Sencore VA48, mint condition with all manuals and probes, $850 includes shipping. *Eden L. Johnson Sr., 1801 Shaker Road, Franklin, OH 45005; 513-932-3117.*

For sale: Lafayette CRT tester/rejuvenator model 99-5018 with adapters, $22; tube tester TC1, $15; Scope Tektronix 514D with book, $90. *Leonard Duschenchuk, WA2KHK, 255 Stewart Ave., Bethpage, NY 11714.*

Needed: A source where I can buy a supply of ¼-inch channel knob inserts (springs). The half-moon flat-side type, and the flat-side type with the dimple. *Ellard TV, Box 37, Holly Pond, AL 35083.*

Wanted: Heathkit TV remote handunit for GR-900 color TV, will pay $15; complete remote control (receiver and transmitter) for Heathkit color TV GR-2001, will pay $40; yoke (part #24G102 50A09) for b&w Motorola chassis #TS-597, will pay $10. *Jim Young, 3502 Gondar Ave., Long Beach, CA 90808; 213-420-9832.*

Needed: Schematic, parts list and service manual for Pioneer SX-9000 stereo tuner. Will purchase or copy and return. Would also like to purchase 9-digit, metal cabinet frequency counter, Heathkit fine. *Lloyd Spivey Jr., WLLS AM/FM, Highway 231 S., Hartford, KY 42347; 502-298-3268.*

For sale: Eico model 944 flyback and yoke tester in VGC with manuals, $35. Will ship UPS collect. *J. McKenzie, Box 33, Wonewoc, WI 53968.*

Needed: Operating instruction manual for a Pioneer stereo tape deck model T-600. Will buy or copy and return. *Lynwood Wright, 1719 W. Nedro Ave., Philadelphia, PA 19141.*

For sale: Simpson 260 VOM with roll-top case and B&K model 2815 DMM, $75 each. *Ronald A. Jones, Box 89, Sequatchie, TN 37374; 615-942-5450.*

Needed: IF transformer, part #32-1313 for a Philco radio model #84. State price and shipping costs. *David Prevo, 21 River St., Windsor, VT 05089.*

Needed: Osborn's *Introduction to Microcomputers* Volume 3 Updates. These are out of print and I will purchase or pay to copy and return. *H. Juster, 1119 Granger, Ann Arbor, MI 48104; 313-668-8759.*

Wanted: A power transformer for Emerson TV chassis #120908A, Sams # 1048-1, model #19P84, part #T-8, 117Vac PR1, 128Vac sec., Mfg. part #730154-1, or a source where I can order this part. *Don Taylor, Radio & TV Service, 4707 Goodfellow Blvd., St. Louis, MO 63120.*

Wanted: Capacitor checker/analyzer in working order. Will pay reasonable price. *Gregory Inman, 2966 Norwood Ave., Slayton, MN 56172; 507-836-8831.*

For sale: UREI BL-40 "Modulimiter" audio processor for broadcast or studio use, with manual and spare semiconductor kit, $300; Beckman/Berkely model 7160-6 "Event Per Unit Time" (E/PUT) meter, circa 1956, working, with manual, make offer. Will also consider trade (especially AC or RF voltmeter) for either or both. *Michael W. Moran CET, Marlin Electric Company, 304 Ellison St., Horicon, WI 53032; 414-485-4463.*

For sale: Approximately 60 copies of **Electronic Servicing,** 1946-1951, $50; 60 copies of *Radio TV Maintenance,* 1946-51, $50; 110 copies of *Radio TV Service Dealer,* 1947-1958, $75; all plus freight or delivery free in NY metropolitan area. *Roy Berthold, 27 Cottonwood Road, Port Washington, NY 11050; 516-883-0914.*

Needed: Tube checker for all TV tubes. Prefer B&K, Sencore or IT-3117 Heathkit model. Please quote best price. *Frank Cowart, P.O. Box 727, Penney Farms, FL 32079.*

For sale: B&K model 415 sweep marker generator, $100; RCA model WR-89A crystal-calibrated marker generator, $35 and Precision series E-400 sweep signal generator, $35 with manuals and probes. Will ship UPS collect. *Wallen TV & Radio Service, 7049 E. 52nd St., Tulsa, OK 74145.*

For sale: B&K 1077B TV analyst in good condition with manual and leads, $200 plus shipping costs; Eico 460 scope with probes and manual, $50 plus shipping charges. *A & B Television Service, 1030 Fort Salonga Road, Northport, NY 11768; 516-757-6644.*

For sale: B&K 1077B TV analyst, $350; B&K 415 sweep and marker generator, $250; Sencore FE-27 Big Henry (field effect multimeter) $100 or best offer. Will ship UPS COD. *Vic's TV-CB Sales, 1024 Studewood, Houston, TX 77008; 713-864-6573.*

Needed: Schematic for Masterwork stereo/cassette player/recorder model M-400. Also need Solenoid DS-10B, DC100V, 800Ω model M-400. Need schematic and owner's manual for Masterwork SQ AM/FM 8-track, serial no. H340-03379, model number not known. Will buy schematics or copy and return. *M.J. Stanton, Rear 1725 Lafayette St., Scranton, PA 18504.*

Needed: TM transformer 22S25, also RCA field service guide #1. *Jiranek TV, Farmington, IA 52626.*

For sale: Obsolete radio and TV tubes, most any types available. Send list and quantity needed. Also, some other old radio items for sale. *Jeff Kraus, 424 Columbiana St., Navarre, OH 44662; 216-879-5083.*

For sale: Tektronix 7613 mainframe, $2550; Tektronix 465 with probes, $1525; Sams' Photofacts 704 through 1472 with full suspension files, $1000/best offer. Large assortment of late model tubes, mostly compactrons with caddys. *Charles S. Bryant, 3808 Via Palomino, Palos Verdes Estates, CA 90274.*

For sale: Complete correspondence TV repair course. Six binders including exams and answers Originally $1495, make offer. *Jan Poloske, 156 Highland Ave., Pennsville, NJ 08070; 609-678-7581.*

Needed: Schematic and parts listing for Electrobrand model #6542. *Homer McGuire, 1009 85th St. N., Birmingham, AL 35206.*

For sale: Align-Gen program (by Solas Products) converts Commodore 64 computer into a full-function color bar generator, 10 patterns including convergence, rainbow, centering, pincushion, etc., $30. *Mark Krause, I-12 Forge Gate, Lansdale, PA 19477; 215-362-5028.*

For sale: Sencore VA48 video analyzer, 1 year old, in mint condition with manuals and probes, $1000. *Ron West, 325 Allen Ave., West Chicago, IL 60185; 312-293-5898.*

Needed: Schematic or service manual for Percise model 300 oscilloscope, manufactured by Percise Development Co., Oceanside, NY. Will buy or copy and return. *Bill Cheakas, 4613 W. 43rd, Houston, TX 77092; 713-868-6610.*

Needed: Power transformer for an early "Scott" receiver, model # "All-Wave-15," and a speaker for same. Also need schematic, will purchase or copy and return. *George Wilder, Better Audio & TV, 138 W. Park, Elmhurst, IL 60126.*

For sale: B&K 747 tube tester, like new, $300; Hewlett-Packard 5300A/5303B 525MHz counter with hi-stability oscillator, $1100; Motorola/Measurements S-1329A-1 solid-state communication FM signal generator, $625. *Electronic Services Co., 2860 Highway K, Franksville, WI 53126; 414-835-4000.*

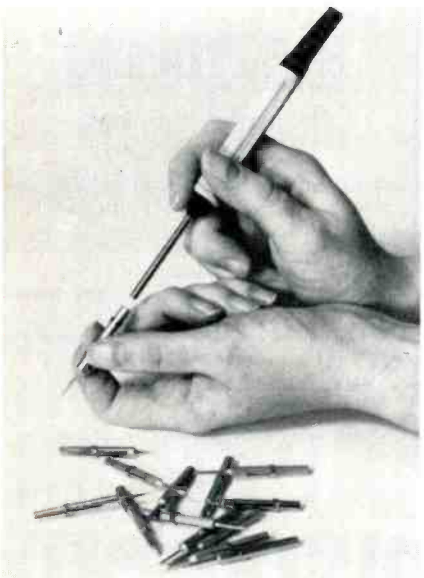
For sale: Sams' Photofacts in intermittent sequence from 10 through 700. Total of 300 folders, $200. Send SASE for listing. *Andy Burwell, 5709 Chapman Highway, Knoxville, TN 37920.*

Needed: Schematic or manufacturing information on Project One dc series stereo receiver, Mark 400. Will pay expenses. *D. Huisman, 837 Gardenia Lane, Palatine, IL 60074.*

Products

Miniature soldering irons

A wide selection of interchangeable slide-on tips for Antex miniature soldering irons is available from *M.M. Newman.* The tips come in more than 40 different shapes and sizes and are easily changed by sliding onto the heating element. There are no threads



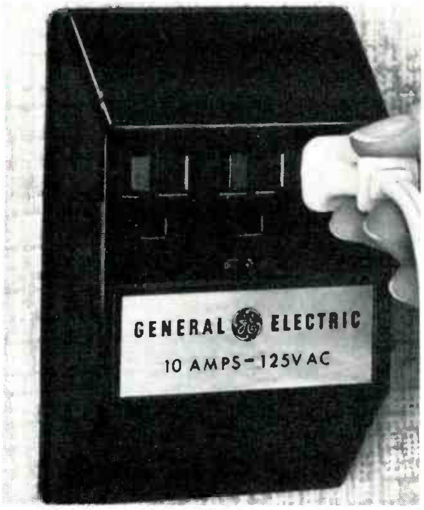
to bind or screws to freeze. The tips are made from a special copper alloy for maximum strength and heat conductivity and are nickel-, iron-, or gold-plated. Shapes include various spades, chisels, needles, cones, pyramids and blanks.

Circle (80) on Reply Card

Voltage spike protector

A voltage spike protector with built-in noise filtering capabilities – designed to protect high-tech computers, audio and video devices, and sensitive solid-state equipment – has been introduced by *General Electric.* The GESP-753 can save costly electronic equipment from sharp spikes in electrical voltage, the most damaging of which often occur during electrical storms.

The GESP-753 plugs into the upper outlet of any wall grounding receptacle. A stabilizing pin fits into the grounding contact of the unused outlet to hold the unit in place. Once plugged in, a built-in light indicates that protection circuits are working. The power cord of electronic equipment to be protected is plugged into one of the three grounded outlets.



The GE – MOV varistor, a metal-oxide semiconductor, is a critical component of the voltage surge suppressor and noise filter. These varistors (metal-oxide semiconductors) have been widely used in various circuit-protection devices.

Circle (81) on Reply Card

Oscilloscope

A 35MHz digital storage oscilloscope offering 4-channel display has been introduced by *Philips Test & Measuring Instruments.* The PM3305 has an 8K memory, half used for display and half for pre-trigger facilities. The maximum sample rate is 2MHz; for higher sampling rates – 100 us/div time base settings or faster – a sequential sampling system makes it possible to store repetitive signals up to the full 35MHz bandwidth.

In "direct display" or non-storage mode, the PM3305 provides 2-channel input with sensitivities from 2mV to 10V/div and time base speeds from 100ns to 0.5s/div. Triggering is highly flexible with a choice of A, B, composite or line sources: trigger modes include automatic, dc and ac. In storage operation, facilities include a 4096 x 8 bit digital memory, pre-trigger up to 4096 words, a time base extension to 5s/div and two additional input channels. The two extra channels are floating and can be adapted as 2 or 20mV inputs for mechanical transducers.

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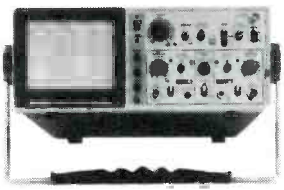

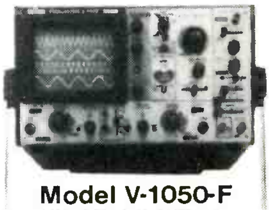

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Advertisers' Index

Reader Service Number		Page Number
9	B&K Precision, Dynascan Corp.	17
1	Consolidated Electronics, Inc.	IBC
24	Cook's Institute of Electronics Engineering	62
5	The Cooper Group	7
18	Dandy Manufacturing Co.	51
25	Diamondback Electronics Co.	62
15	Digitron Electronic	45
	ETA	59
20	Electronic Specialists, Inc.	57
22	Electronic Warehouse Corp.	59
	John Fluke Mfg. Co., Inc.	5
	Fordham Radio Supply	62
16	Global Specialties Corp.	47
4	MCM Electronics	1
17	Moody Tools	49
	NATESA	61
	NESDA	63
	New-Tone Electronics, Inc.	37
8	North American Philips	15
12	Omnitron Electronics	25
19	Optima Electronics	53
13	PTS Corp.	43
21,23	PanSon Electronics	57,61
	Philips ECG	19
14	Primefax	45
30	Satellite TV Week	62
2,3	Sencore, Inc.	BC
7	Simpson Electric Co.	13
28	Sony Video Communications	39
10,11	A.W. Sperry Instruments Inc.	21,23
26	Sperry Tech, Inc.	64
27	Spi-Ro Distributors	64
29	Test Probes, Inc.	49
6	Winegard Co.	9
	Zenith Radio Corp.	IFC

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