Special report: Computer servicing

1987 Article Index • Voltage Regulators
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- Continuity beeper
- Built-in bail
- Anti-skid pads
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FEATURES

8 Voltage regulators
By Greg Carey, CET
This last part of a 3-part series on horizontal output circuits shows how to isolate problems related to the power supply and regulator circuits.

62 Index of 1987 articles
Need help using a piece of equipment or solving a servicing dilemma? The index may lead you right to the article you need.

SPECIAL REPORT

Computer servicing

15 Special report introduction
By Conrad Persson
As personal computer use grows, so will opportunities to service them. This special report shows you how to service specific products and what equipment to use.

16 Troubleshooting microprocessor-based circuits—Part I
By Tom Allen
This first part of a 2-part article discusses how microprocessor-based systems differ from analog or digital systems, and gives a run-down on the best equipment to use for this new application.

24 Servicing the Apple II+ computer
By Michael J. Zoiss
Digital troubleshooting skills are as useful for computer servicing as they are for any other application. These five case histories of actual service experiences show how to apply these principles to the Apple II+ computer.

49 Servicing the Commodore 1541 disk drive
By Andy Balogh
The 1541 is a good introduction to disk drive servicing because it uses common methods to store and retrieve data. However, there are a few tricks to this trade.

52 Break-out boxes: Active vs. passive
By Manfred R. Will and Cindi L. Kemper
The break-out box is a useful tool for testing serial interfaces between computers and peripherals, but whether to use an active device or a passive device depends on the situation.

54 Logic probes: Troubleshooting to the component level
By Conrad Persson
If troubleshooting to the PC-board level and replacing the problem board isn't the best solution, the logic probe may help you troubleshoot all the way to the component level.

DEPARTMENTS

4 Editorial
6 News
14 Products
35 Profax
54 What do you know about electronics?
We get letters
60 Test your electronics knowledge
67 Literature
68 Audio Corner
More on audio servos
70 Computer Corner
Accessing read-only memory
72 Video Corner
Operation of the Newvicon pickup tube
74 Readers' Exchange
76 Advertisers' Index

ON THE COVER

As uses for computers increase and prices decrease, sales of personal computers to consumers should rise, along with opportunities to service PCs. The 3.8 million PCs sold for home use, as reported by the EIA, attest to the profitable future of computer servicing.

(Photo courtesy of Beckman Industrial.)
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Happy New Year, and welcome to a new modern look for Electronic Servicing & Technology.

We figured you couldn't help but notice that we have a new look, so we might as well call attention to it. We have made a number of changes, all of which are designed to make the magazine both more attractive and easier to read.

For starters, we changed the typeface. For those of you who are into type, for years our magazine was printed in a typeface called "Century." Starting with this issue, we will be printing the magazine in a typeface called "English Times." We didn't make the change just to make the magazine look different. The only reason we changed the typeface is that English Times is much easier to read.

You'll also note that we've changed the heads of the departments—News, Books, Products, etc. Again, we didn't make the change just for the fun of it. We felt that this change would make the pages look more consistent and streamlined, and, again, it will make the magazine easier to read.

Finally, we've changed the table of contents in a way that we feel not only makes it more attractive, but will help you find the articles that interest you more easily. We've also made a few other subtle changes throughout the magazine, but I won't detail them all here.

Most important, the change in the look of the magazine doesn't signal any change in the content. We are still the how-to magazine of consumer electronics servicing, and that's what we will continue to be.

Thanks for responding

In our September issue, we included a reader opinion survey in which we asked for information about you and your opinions about the magazine. To the 420 of you who took the time to fill out the card and return it to us, thank you. The information will be extremely valuable to us in planning future issues. Here's a sample of what those people who responded told us. (Please keep in mind that the numbers and percentages reported apply only to those 420 people who responded and, because of the nature of the survey, can't be considered to be representative of all of the readers of the magazine.)

I won't burden you with all of the results here, but the information that we found most useful came from the responses to the questions, "What kind of information do you want to read about in ES&T?" and "What kind of information is the most useful to you?"

Although these numbers are not considered statistically significant because the survey sample was not selected on a scientific basis, they are in line with the kind of feedback we have been getting from readers through other methods, and so we will use this as one of the information sources on which to base decisions for future article coverage. That means lots of TV and VCR servicing articles, and significant coverage of audio, CD and computers.

Nile Conrad Pearson

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<td>49.3%</td>
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NASD offers seminars

NASD (National Association of Service Dealers) is offering seminars geared toward owners and managers of product sales, rent-to-own and rental businesses. During a typical 1-day, 7-hour program, participants listen to in-depth discussions about financial planning, service advertising, strategic planning and customer relations. The 2-day, 14-hour service seminars cover the same topics more in depth.

NASD will also be sponsoring its School of Service Management in Daytona Beach, FL, February 6-9, at the Indigo Lakes Resort and Conference Center.

Anyone interested in more information on NASD’s programs may contact NASD at 10 E. 22nd St., Lombard, IL 60148; 302-953-8950.

Maxtec completes buyout

Maxtec International has completed its buyout of Dynascan’s Industrial Electronic Products Group. Maxtec was created by the management of Dynascan’s former B&K-Precision test instruments and Telemotive industrial remote-control groups, which are both now part of Maxtec. Maxtec has signed a multi-year lease with Dynascan to remain in its existing Chicago facilities. All the company’s Telemotive products are manufactured in Chicago. About 60% of the B&K-Precision products are manufactured in Chicago.

MTS TV sales rise in ‘87

Sales to dealers of color televisions with integral MTS rose almost 40% in 1987 compared to 1986, according to the Electronic Industries Association (EIA). As of the end of October, 3,448,934 were sold in 1987, compared to 2,468,058 in October 1986.

EIA/CES prepare for Winter Show

More than 100,000 trade attendees are expected to travel to Las Vegas for the International Winter Consumer Electronics show, to be held Thursday, Jan. 7, through Sunday, Jan. 10. The show will feature 1,400 exhibitors stationed in the Las Vegas Convention Center, the Hilton, the Riviera and the Sahara hotels.

Exhibits will showcase audio and video, computers and games, specialty audio, mobile electronics, cellular phones, home and auto security, watches and calculators.

Highlights of the show will include the Opening Session, which will discuss industry prospects and the national economic outlook for ’88; a Workshop Program, which includes sessions on DAT and high-definition television; an Advertising and Promotion Showcase; Publications and Trade Association Exhibits, featuring consumer electronics associations and publications; and the Electronic Product Locator, which will help attendees locate the products and companies in which they are interested.

Correction

The telephone number for Applied Research and Technology was listed incorrectly in the article “Power Conditioning,” which appeared in the November 1987 issue. ART’s correct address and telephone number are: The Pavilion, Suite 201, 5770 Powers Ferry Road N.W., Atlanta, GA 30327-4390; 800-624-4115 or 404-951-9556.
NEW SMD OSCILLOSCOPE PROBES AND TEST PROD KITS O.K. Industries introduces SMD oscilloscope probes and test prod kits. The SMD Oscilloscope Probes, designated the PS732 Series, are slim, precision probes designed for testing SMD circuits. The 0.003" tip and slim-body probe allow improved viewing angles necessary for testing circuitry.

Specifications range from 30MHz to 275MHz, x1 and x10 attenuation and are available with readout actuators. The new SMD tweezer probes, designated the TW300 (BNC connector) and TW310/H (banana cable connector), for SMD testing can adapt to most multimeters. The tip contact is gold beryllium copper; the rating is 600V rms, 3A, and the cable length is 1.2 meters.

The TK110 Test Pro Kit features ultra thin test probes to maximize testing accuracy. The rating is 250V rms, 3A, the tip is made of stainless steel at 0.8mm and the cable length is 1 meter.

List price for probes starts at $52.00. List price for Test Prods and Tweezers starts at $49.95 for tweezers and $42.95 for test prods.

Contact: O.K. Industries Inc., 1-800-523-0667. (In N.Y.S. call (914) 969-6890.)

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Uncontrolled...
Servicing
voltage regulators

If the main voltage malfunctions, it may keep the set from starting up, or it may cause the set to shut down. Here's how to determine if the regulator is the culprit.

By Gregory D. Carey, CET

This is the last of a 3-part series dealing with the horizontal output circuits of modern TV receivers. Part I explained how shutdown circuits operate and the best way to find the cause of shutdown. Part II discussed what to do if the circuits never get started in the first place. This time, we'll see how to isolate problems related to the power supply and regulator circuits. Combining all three should help you isolate any problem related to the output stages.

The first two installments of this series described how to troubleshoot problems in the startup and the safety shutdown circuits in modern TV receivers. This article will explain how the main voltage regulator can cause a shutdown or a startup problem. The first section explains how the troubleshooting from the first two articles isolates regulator problems. The second section explains how various kinds of regulators work. See Figure 1 for a diagram of the three loops that must work correctly for a modern TV set to operate.

How the regulator causes shutdown

The regulator is often the cause of shutdown. If it applies too high a voltage to the output transistor, the high voltage and the yoke current can climb too high. One of the safety detectors should sense this and cause a shutdown circuit to kill the horizontal output circuits.

The first article states that the best way to identify the cause of a shutdown is to monitor the collector of the horizontal output stage when you first apply power to the receiver. This calls for test equipment with enough protection to monitor voltages as high as 1,200V.

When the horizontal circuits operate correctly, the voltage reading at the collector should be the regulated dc level specified on the schematic. It should also have pulses, about 12µs wide, that repeat every 63.5µs. The pulse amplitude varies from one receiver to the next, but it is normally between 700Vp_p and 1,200Vp_p. A chassis with a shutdown problem produces flyback pulses until the safety circuits take over. The circuits either shut down the ac drive to the output transistor or its dc power supply.

After confirming a shutdown, separate the regulator from other possible problems. Reduce the ac line voltage to less than 90V with an isolated, adjustable ac power supply. The lowered voltage reduces the dc at the regulator input to a voltage below its normal output. Because the regulator cannot boost the voltage, this gives you manual control of the voltage powering the output stage. (See Figure 2.)

If the set operates at this lower voltage level, you can make some tests on the collector signal to eliminate ac conditions as the cause of the problem. If the scope CRT shows that the flyback pulse is less than 12µs, for example, a capacitor between the emitter and collector of the output stage is probably open. If the pulse is poorly shaped, suspect a bad flyback or a shorted flyback load. If the pulse has the correct waveshape, monitor it while increasing the ac line voltage.

Now, monitor the dc level while you observe the flyback pulse. The dc should increase as you raise the ac line voltage until it reaches its normal out-

Figure 1. For the horizontal circuits to operate, three loops must work correctly: the main power loop (solid line), the scan-derived loop with its startup circuits (dashed line), and the safety shutdown loop (dotted line). (Schematic courtesy of Sencore.)

---

Carey is an application engineer at Sencore. He has run more than 800 seminars for service dealers.
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Features

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1. SmartCursors ™ track trigger level, ground level or peak voltages.
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Put voltage. If it continues to increase beyond the normal level, you know that a bad regulator is causing the shutdown.

**How the regulator prevents startup**

The regulator also can be the cause of a startup problem if its output is too low to operate the output stage. To further complicate matters, some receivers use a shutdown circuit that kills the regulator, which makes it important to monitor the collector of the output stage from the very first moment power is applied.

A dc-coupled oscilloscope lets you test for dc during the first few seconds. Before applying power, set the scope's input coupling switch to dc and set the trace position near the bottom of the scope face. Set the vertical attenuator to the highest volts per division setting.

You know that dc was present if the trace moves up from its resting position when you apply power. If the trace then settles back to its original position, the regulator has gone into shutdown. If your scope can monitor the dc level digitally, use it to check the resulting voltage after the initial excitement dies down. Also, watch for flyback pulses. If they build and then collapse, the set started and was then shut down. (See Figure 3.)

Any dc you measure at the collector while the set is shut down can be misleading. The voltage usually will be too high because the output stage is not drawing current. Reducing the voltage and then increasing it slowly lets you confirm whether the regulator is working while the output stage is pulling power.

Now that you know how the regulator can cause shutdown or startup problems, let's look inside several typical regulator circuits to learn better ways to troubleshoot them.

**Nothing beats a zener**

Nearly all voltage regulators use a zener diode as a reference. The zener, however, needs some help to control the high power used by a TV output stage. Before we look at the helper circuits, let's review how a zener regulates. (See Figure 4.)

When reverse biased, a zener acts like an open circuit as long as the voltage across it stays below its breakdown level. If the voltage exceeds the zener's rating, it begins to draw more current in an attempt to hold the voltage across it to a fixed level. As the current increases, the diode dissipates the excessive power as heat. If too much current flows for too long, the heat destroys the diode.

The circuit that uses the zener needs to limit the maximum current to prevent the zener from burning out. Most circuits use a series resistor. The resistor and the zener then form a voltage divider, with the difference between the zener voltage and the raw supply voltage dropping across the series resistor.

Some small power supplies use a zener as the sole regulator. There are, however, two limits to the zener regulator. First, the zener runs out of regulation range if the power dissipated by the load is equal to or greater than the zener's power rating. This power limitation worsens if the power drawn by the load varies greatly. The zener/resistor regulator also does not work well if there are large variations in the applied voltage, because the series resistor always drops some voltage, even if the zener is not conducting.

A television has all these conditions. The television draws 100W or more, depending on many variables, including the brightness of the picture and the loudness of the audio. Moreover, ac line voltages may change from 90V to 130V.

**Figure 2.** Use an adjustable, isolated ac power supply to reduce the voltage to the receiver. This gives you manual control of the voltage regulator, which lets you find what is causing the circuit problem.

**Figure 3.** Set the scope's input coupling switch to "DC" to tell whether power is still present immediately after it is applied. If so, the line will move from the position set before applying power. If your scope has a digital readout, use it to confirm the correct dc level.

**Figure 4.** Zener diodes can be used as a regulator as long as the load has low power requirements and the input voltage does not vary over too wide of a range. (Schematic courtesy of Sencore.)
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Figure 5. The addition of a power pass transistor increases the zener's current capability. A single power transistor typically provides a 10-fold increase in current compared to the zener by itself—not enough to regulate most TV receivers. (Schematic courtesy of Sencore.)

as the power lines swing between brownouts and peak voltages. Therefore, the zener needs some help.

The pass transistor
A power transistor is often used to assist the zener diode. The zener is placed in the base, with the transistor acting as a follower. The result is a multiplication of the zener’s power rating. (See Figure 5.)

The transistor helps the zener diode regulate higher current levels. It is somewhat limited, because most power transistors have a beta gain of around 10. You would need an expensive 10W zener to regulate a 100W load.

The multiplication effects are enhanced if more than one transistor is used between the zener and the load; this allows a small zener to be responsible for controlling large power levels. However, cascading transistors create a new problem: As more and more transistors are used between the load and the reference, there is less responsiveness with changes in load current.

One solution is to use a feedback system. (See Figure 6.) The voltage at the regulator output is fed back through an amplifier and then compared to the zener. The results of this comparison are then fed to the power transistor for final control. Although this results in a very tight control of the output, it also complicates troubleshooting, because problems in the feedback amplifier, the pass transistor and its driver, or in the zener can all cause the regulator to put out the wrong voltage.

Increased efficiency
Regulation power transistors all have another problem. They are linear devices that regulate by changing the resistance to current passing between the collector and the emitter. They must waste excess power as heat. They must, therefore, be mounted on large heat sinks to allow the excessive heat to be conducted to the surrounding air. The wasted heat causes the receiver to use more power than really needed.

The best way to identify the cause of a shutdown is to monitor the collector of the horizontal output stage when you first apply power to the receiver.

To correct this, some manufacturers have replaced the regulator transistor with a silicon controlled rectifier (SCR). An SCR is not a linear device. It is an electronic switch that is either on or off. (See Figure 7.) Because there is no in-between state, it wastes less power. But there must be some way for this on/off device to compensate for many load and line variations.

The SCR compensates by varying the time it conducts; if it is switched on for longer periods, the load receives more power. This switching is done with an oscillator that is synchronized to the 15,734Hz horizontal output circuit. The oscillator fires the SCR at some point during the horizontal trace time. If the regulator needs to reduce the output power (such as when the television has a black picture or the line voltage is high), the SCR fires later in the trace time. If the regulator needs to increase the power, the oscillator fires the SCR earlier. The oscillator compares the reg-

Figure 6. More elaborate regulators such as this one need feedback amplifiers to sample the output voltage and control the power transistor. Notice that a zener diode, inside IC601, still serves as a standard for comparison. (Schematic courtesy of Sony.)
ulated output to a precision zener diode to determine this timing. (See Figure 8.)

Once the SCR is fired, it will stay on until the voltage between its anode and cathode drops to zero. An extra flyback winding, wired in series with the SCR, provides a pulse to turn off the SCR. The flyback pulse reverse-biases the SCR during each time the beam retraces. The SCR remains off until the oscillator turns it on, sometime during the trace time.

Startup and shutdown problems are tough to find because of the way the circuits operate. A shutdown happens so fast that it often looks like a startup problem. Three closed loops intertwine, which turns your troubleshooting into a wild goose chase. Voltage regulator problems can also cause either type of problem.

Two techniques solve these problems. First, watch the collector of the output transistor to monitor both ac and dc conditions during the first few seconds of operation. Second, reduce the ac line voltage so that you have manual control over the regulator circuits. Then, move slowly through the circuits until you’ve isolated the problem.
**Nu Data introduces three interface break-out testers.**

The models 9200, 9230 and 9240 meet the new RS-232 D specification and have dual pulse traps, positive and negative source voltages and 2-3/3-2 reversal for instant null modem configurations.

The model 9200 features a quad-state design with 100 LEDs to monitor signals from both sides of the interface. The models 9230 (interface powered) and 9240 (high-impedance) monitor the quad-state condition of the 11 major interface signals, with a spare LED pair for monitoring remaining signals.

The 9200 also tests IBM parallel interfaces and RS232 (or parallel) cables that use DB25 connectors. The 9230 and 9240 feature control lead activating switches for RTS, CTS, DSR and DTR.

Nu Data also has introduced the model 9500 25-pin cable tester that features auto scan, auto shut-off, manual step and a built-in audible continuity tester.

**ESD protection kits**

A series of static protection kits has been introduced by Atrix. The kits include one of four mat types, ground and wrist strap terminators, and color-coded alligator clip ground leads. Kits are customized according to the needs of the buyer.

Users may select from four mat types: conductive; 2-sided conductive/non-conductive; dissipative; and tri-layer (with a conductive layer in the center and dissipative layers top and bottom).

**Backup power systems**

Panamax has announced the PowerMAX line of backup power systems. When power failure occurs, the unit's proprietary fast-transfer circuitry switches to the internal battery, typically within 2ms. The units use an internal battery to maintain power to computers and other connected components, providing power for up to 80 minutes (depending on the power demands of the connected system). Three versions are available: a 450VA unit with a 300W capacity; an 800VA unit with a 600W capacity; and a 1,200VA unit with a 1,000W capacity.

**IC test clip**

The model A-TEK IC test clip from Davie Tech is designed to facilitate temporary connections to the dual, in-line packaged components in conjunction with a number of test instruments for power on/hands off circuit testing. The test clips are available in 16-, 20-, 24- and 40-pin versions. Features include standard DIP spacing, gold-plated contacts, low-contact resistance and less than 1μΩ at 1kHz.

**Wire analyzer**

SureTest, developed by Polytronics, is a multi-function wire analyzer that detects problems common to electrical circuits. The portable, hand-held device tests for current-carrying capacity with a built-in, 15A load. The analyzer applies the load and determines if the voltage drop is less than 5%. The unit also checks circuits for voltage level, wiring connections and operation of a ground fault circuit interrupter.

**Tack kit**

The Micro Bond superadhesive tack kit from Chemtronics is designed for PC board rework and repair. The kit allows for wire tacking and component bonding to printed circuit boards, resulting in a low PCB profile that prevents damage due to sagging wires or loose components. The kit includes a 5-ounce bottle of #200 cyanoacrylate adhesive, an applicator needle and an activator pen. Each kit contains enough adhesive for about 800 to 1,000 drops.

**Soldering iron/hot-air tool**

Weller has introduced a cordless, pocket-size, lightweight tool that works as a soldering iron, a brazing torch or a hot-air tool. Fueled by butane gas, the unit is 7 inches long and fits into a shirt pocket. Temperature controls range from 392°F to 842°F (200°C to 450°C) as a soldering iron; up to 806°F (430°C) as a hot air gun; and up to 2,372°F (1,300°C) as a torch.

**Soldering station**

The DPU30 electronic soldering station from Orxix is a 30W unit housed in a steel box designed for industrial production. It contains a connection for anti-static grounding and meets the requirements of DOD-STD-2000-1. Operating temperatures are adjustable between 465°F to 750°F, controllable to ±1%. The station features a digital readout, solid-state power supply unit; OV switching to ensure spike-free operation; and a proportional control circuit to eliminate temperature overshoot.
Welcome to our special report on computer servicing. Contrary to the fears of some of our readers, we do not plan to become another computer book. In response to a recent questionnaire in this magazine, more than 80% of those who responded said that they want to read articles about servicing televisions in ES&T. We have no plans to do anything other than continue heavy coverage of TV servicing for those readers, with at least one article on that subject in every issue.

On the other hand, the population of personal computers is growing, and a lot of you want to read about servicing them—nearly 50% of those who returned the questionnaire, in fact. That’s the reason for this special report. (For more on what our readers’ survey revealed, see the Editorial on page 4.)

Here’s what the EIA had to say about personal computers in the 1987 issue of its publication, Consumer Electronics Annual Review:

“. . . many manufacturers feel that by the year 2000, consumers will be spending more for home information processing and communications equipment than they will for purely entertainment products.

“Functions normally associated with a business office are performed in nearly every home. Income and expenses have to be kept track of, appointments to be made and messages to be taken and delivered. There’s correspondence to be handled and, where there are students in the house, reports to be researched and written. For many years businesses have turned to electronics for products that simplify and improve information handling. Now, similar, though much more affordable and often less complex products that bring office-like efficiencies to the home are being made and marketed by consumer electronics manufacturers.

“Almost 3.8 million personal computers were sold for home use last year and, with software and accessories, represented a $3.8 billion business. Today a personal computer housed in a type-writer-like console, with brain power equal to that of the room-sized multimillion dollar computers of the 1960s, can be purchased for less than $300. Prices, however, can run up to $2,000, depending on the functional capabilities, memory power and accessories included.

“The term ‘computer literate’ has become more than a catch phrase to describe those in the know. It’s now a requirement for graduation from many high schools and colleges, and some colleges include the cost of a computer for each student in their tuition. ‘Keyboarding,’ or how to interact with a computer, is being taught at the elementary grade level.

“In the home, computers are used for financial and family function planning, record keeping, educational enrichment, training and word processing. Connected to the telephone lines through a built-in or add-on device known as a modem, computers provide access to outside data banks containing a vast variety of research information, along with business, professional and transportation directories, games and message centers that serve as electronic bulletin boards for computer owners with similar interests. Modems also let computers be used for home shopping, banking and travel reservation services that are now becoming available.”

This special report is intended to bring together several types of important information on computer servicing, in particular:

• a concise overview of the development of personal computers and approaches to servicing;
• some specific problems and cures for the Apple II+ personal computer;
• specific suggestions on servicing the Commodore disk drive;
• a comparison and contrast between active and passive breakout boxes, describing the advantages and drawbacks of each; and
• a discussion of how to use a logic probe in computer servicing.

The usefulness and ease of use of personal computers is increasing rapidly; at the same time, the cost is coming down precipitously. Their numbers will continue to grow, and many of those computers will need servicing at some time in their lives. We hope you benefit from this special report.
Troubleshooting microprocessor-based circuits

Part I: The world went digital

By Tom Allen

This is Part I of a 2-part article exploring the changes in electronics troubleshooting brought about by the growing popularity of microprocessor-based products. In this first segment, we'll discuss how analog, digital and microprocessor-based systems differ, why traditional troubleshooting equipment isn't sufficient for microprocessor-based products; and what new types of equipment have emerged to fill the gap. Next month, we'll explore the techniques needed to troubleshoot microprocessor-based systems effectively and show how these techniques, together with an inexpensive digital tester, can significantly simplify the process of troubleshooting microprocessor-based products.

The past 25 years have witnessed a technology explosion that has completely changed the nature of consumer electronics, causing the familiar analog circuitry of the past to be replaced first with digital and then with microprocessor-based circuits. Although the new microprocessor-based systems may have simplified the lives of consumers, they have made the job of the service technician a great deal more complicated than in the past.

Take the case of a simple wall thermostat, for example. Once thermostats consisted simply of a bimetal bar and a pair of contacts. Now they have liquid crystal displays and keypads. Today's automobiles make heavy use of microsystems for purposes ranging from emission control to mileage and gas calculation. Even the cash registers at the supermarket checkout line are heavily computerized.

Two key events played a key role in creating this technology explosion. The first, the development of the integrated circuit (IC), sparked the move from analog to digital circuitry. The second, the development of the microprocessor, opened the door for microprocessor-based electronics.

Analog to digital circuitry

The appearance of the first ICs in the early 1960s was a direct result of the efforts that were then being made to put a man on the moon. Computer technology was a necessity if the expedition was to succeed, but computers were far too large at that time to fit inside a space capsule. It was this need for smaller computers that led to the development of the first IC.

As the price of ICs decreased, they began to appear in other applications, including a variety of consumer electronics products. Digital circuitry began to replace analog circuitry in products ranging from clocks and watches to microwave ovens and TV tuning systems. Without ICs, this transition from analog to digital circuitry simply would not have been possible: The digital electronics would have taken up far too much space to be practical.

Digital to microprocessor-based circuits

In 1974, Intel Corporation developed the world's first microprocessor, the 4004. Use of the technology originally was limited to military and industrial applications, such as instrumentation, communications equipment and data processing equipment. As with ICs, however, continued development of the technology, together with significant price reductions, soon led to the increasing appearance of microprocessor-based circuitry in consumer electronics products. Figure 1 demonstrates this growing trend, showing how the number of microprocessor-based boards in production has increased from 1980 to 1985.

Microprocessors vs. microcontrollers

It should be noted that the term microprocessor may be used in both a generic and a specific sense. In a generic sense, a microprocessor is any chip-sized device capable of making decisions and sending out instructions based on values entered into it. In a more technical sense, however, the term microprocessor refers only to those chip-sized computing devices that do not contain their own built-in control program. Instead, the microprocessor's control program is built into a separate chip known...

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as read-only memory (ROM). Microprocessors also make use of another chip, known as random-access memory (RAM), as a temporary holding area for data. Personal computers are a good example of a system based on a true microprocessor.

Less sophisticated microsystems, in contrast, have a built-in control program and little, if any, RAM. Technically speaking, these microsystems are based on microcontrollers, not microprocessors. Microcontrollers are typically found in products such as microwave ovens, VCRs and CD players.

In this article, we will be focusing on microsystems based on true microprocessors, not microcontrollers, although the two share many of the same characteristics.

How the circuitry differs

There are certain elements that are common to all types of circuitry, such as the presence of some type of power supply (even if only a battery) and some type of human interface for control purposes, display purposes or both. Beyond these few elements of commonality, however, the three types of circuitry are characterized more by differences than by similarities. The key differences among the three types of circuits are outlined below.

Analog circuitry: The primary characteristic of analog circuitry is that it provides an infinite number of values between 0 and the specified ceiling level of a signal. Consequently, analog circuitry uses control and display devices such as volume knobs and clock dials, which move in continuous increments rather than in discrete steps. The continuous nature of these control and display devices, however, makes analog signals highly susceptible to distortion. That is, even slight distortions in reading or controlling a signal's amplitude can result in distorted information, because the exact amplitude of the signal is significant in interpreting its value. Similarly, the polarity of an analog signal conveys significant information.

Analog signals may be either static, as is the case with bias levels on an amplifier, or dynamic, as is the case with a local oscillator in a stereo system or a color-burst oscillator in a television. However, the dynamic signals always change in a repeatable manner, making them relatively easy to measure during troubleshooting. Figure 2 shows an example of a typical analog waveform.

Digital circuitry: Unlike the continuously variable values found in analog circuitry, digital circuitry is based on discrete values. These values are developed using a binary numerical system in which a signal can have only one or two values—on or off (represented as 1 and 0). Figure 3 shows a typical digital waveform.

In digital circuitry, a signal of +3.5Vdc or higher is typically considered to be on, and one of +0.7Vdc or lower is considered to be off. Because the voltage level indicates only whether the signal is on or off, as opposed to its exact value, small changes in voltage will not affect the accuracy of the information being conveyed by the signal. Similarly, the polarity of the signal is not significant in interpreting its meaning: It is simply there (on) or not there (off).

As with analog circuitry, digital signals may be static or dynamic and those that are dynamic are generally repeatable. For example, the signal generated by pressing a key on a thermostat or microwave is dynamic in that it is there only when you press the key. But it is repeatable in that the same logic level is generated each time you press the key. Therefore, digital and analog signals are both relatively easy to measure with traditional test equipment.

A final characteristic of digital circuitry is that it contains one or more digital logic devices. On the low end, these may be as simple as a few AND and OR gates, as shown in Figure 4. On the high end, the circuit may include programmable logic devices (PLDs) or other application-specific ICs (ASICs). Digital circuits may also include analog-to-digital converters to convert analog values, such as temperature, into digital representation.

Microprocessor-based circuitry: Microprocessor-based circuits are significantly more complex than either analog or digital circuits. Like digital circuits, they are based on a binary numerical system, in which a signal is either on or off. However, they go beyond digital circuits in that the microprocessor is more than just an IC: It is a tiny computer. Under the control of a program, it can accept user-entered data and then make decisions and take actions based on that data.

Because the operations performed by a microprocessor are determined by software instructions rather than being built into the circuitry, you can change the function of a circuit without rewiring it. All you need to do is switch to a different set of software instructions. These instructions may be stored in some form of programmable storage medium, such as a floppy or hard disk, or they may be built into the unit's ROM (in which case they are technically known as firmware). In the latter case, you would need to replace the existing ROM chip with a new one, but this is still much easier than designing and rewiring the entire circuit.

Like analog and digital systems, microprocessor-based systems contain a power supply of some sort and a human interface of some sort. In addition to these elements shared with all circuitry, however, microprocessor-based systems contain several components that are unique to this type of circuitry alone.
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Figure 5. A typical microprocessor-based system contains the functional blocks shown in this illustration. See the text for a brief description of each of the blocks.

These components include the microprocessor itself, ROM, RAM, an input/output (I/O) interface, buffers, buses (signal lines) of various sorts, address decoders and a clock. Some microprocessor-based systems also include a DMA (direct memory access) controller. Each of these components is illustrated in Figure 5 and described in the sidebar.

How troubleshooting equipment has evolved

As electronics products have evolved from analog to digital to microprocessor-based systems, the equipment required to troubleshoot these products has gone through a corresponding evolution. The traditional multimeters and oscilloscopes are still useful, but they are no longer sufficient to do the job: The complexity of microprocessor-based systems requires the use of newer, more sophisticated tools. For evidence of the difficulty of isolating faults on microprocessor-based boards using traditional test equipment, look at the repair statistics: Some 40% to 60% of the microprocessor-based boards sent back for repair are found to have no defects. Their operation simply couldn't be verified properly using traditional test equipment.

In this section we'll take a look at the evolution of test instrumentation, explaining the benefits and limitations of five types of instruments: multimeters, oscilloscopes, logic analyzers, signature analyzers and emulative testers.

Multimeters: Multimeters, capable of measuring voltage, current and resistance, traditionally have been one of the most useful tools for electronics troubleshooting. Although the original multimeters were analog devices, most service technicians today use digital multimeters, which are more rugged and more accurate than their analog counterparts.

Multimeters work best for measuring static signals—those signals that don't change over time. However, there are few such signals in microprocessor-based circuitry. Multimeters can be used for such purposes as determining whether the power supply is putting out the proper voltage or whether a particular bus is shorted to ground. But most
Microprocessor signals are dynamic, changing millions of times per second as data is moved on and off the bus. Because a multimeter has no way of measuring time, it can't be synchronized to the microprocessor clock. Therefore, it has limited usefulness in a microprocessor-based environment.

Oscilloscopes: The oscilloscope—the other traditional tool of the service technician—is better than the multimeter for measuring dynamic signals because its trigger mechanism allows the technician to select a particular time window for measuring a signal. However, it works best for those dynamic signals that are repeated in a predictable manner, and microprocessor signals tend to be non-repetitive. This characteristic, together with the high speed of microprocessor signals, makes them hard to capture on an oscilloscope. The result may be a jittery display, with multiple signals appearing superimposed on one another as in a double-exposed photograph. Using a high-frequency digital storage oscilloscope will alleviate this problem, but such instruments may be too expensive for a service operation to afford.

Another drawback: Oscilloscopes can display measurements for only one or two bus lines at a time. In microprocessor-based systems, the timing relationships between events on different lines is important, so the usefulness of oscilloscopes for microsystem troubleshooting is limited.

A third problem is that the oscilloscope's measurements may be difficult to interpret. To know what its findings mean, a technician needs a detailed knowledge of the circuitry of the unit under test. This fact alone makes the oscilloscope an impractical solution for shops that handle a variety of microprocessor-based boards.

Logic analyzers: Logic analyzers are more sophisticated than oscilloscopes because they can display data streams for several lines at a time, allowing the technician to examine all data lines—or even all data and address lines—simultaneously. However, there are several drawbacks to using logic analyzers for microsystem troubleshooting. First, their high price may put them outside the reach of many service operations. Second, they take a long time to set up, making them expensive to operate. Finally, like oscilloscopes, they provide no help in interpreting the results, so the technician must have a detailed knowledge of the circuitry of the unit under test to understand what the measurements mean. All of these characteristics make the logic analyzer more useful in a design environment than in a service operation.

Signature analyzers: Signature analyzers are used in conjunction with a special diagnostic program located in the board's ROM. The program stimulates the board, causing a data stream to appear at different points in the circuitry (nodes). The signature analyzer then interprets this data stream as output by particular ICs on the board, timing this interpretation to occur between a specified START and STOP signal. The interpretation step involves a special algorithm that translates the data stream into an abbreviated code, or signature.

(Continued after sidebar.)
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**Components of microprocessor-based systems**

**Microprocessor:** The "brains" of a microprocessor-based circuit reside in the microprocessor itself. That is, everything that happens in the circuit is initiated by the microprocessor. Although the microprocessor is a tiny computer, it is really not that complicated a device. It can do only one thing at a time, and then only under the direction of the control program. And the operations it performs consist primarily of data reads, data writes and basic arithmetic operations. In other words, in response to instructions contained in the control program, the microprocessor orders data to be placed on the databus, reads it, performs arithmetic operations on it as required and writes (sends) the resulting data out to specific circuit elements over the same bus. Even the most complex program instructions can be reduced to these few simple operations.

**ROM:** The ROM contains built-in instructions for the microprocessor. These instructions are specific to a particular type of microprocessor and are known as its instruction set. Of course, many types of microprocessor-based systems, such as personal computers, obtain additional instructions through software programs. But all microprocessor-based systems need ROM instructions to get them started when the system is first powered up to tell them what to do and where to find the data they need. Without these ROM instructions, they would be unable to load and read other software instructions. In effect, the ROM instructions allow the system to pull itself up by its bootstraps, which is why the process of turning a computer on is known as booting.

**RAM:** RAM consists of one or more integrated circuit memories. It serves as a temporary storage area for data, holding it where it will be readily accessible when needed. There are two key differences between RAM and ROM:
- RAM can be written to and read from, whereas ROM can only be read;
- RAM serves only as a temporary data storage area, whereas ROM stores data permanently. This means that data can be moved in and out of RAM as needed. It also means that once the power is turned off, all the data in RAM is lost.

Effect, RAM serves as scratch pad for the microprocessor, keeping data handy while it is needed and replacing it with new data when a new operation is begun.

**Input/output interface:** The I/O interface allows the microprocessor “kernel” (consisting of the microprocessor itself, ROM, RAM, buses, address decoders and clock) to communicate with the system’s input/output devices (keyboard, video display and printer). These I/O devices are also known as *peripherals*, because they lie outside the microprocessor kernel. Unlike the components of the microprocessor kernel, I/O devices are not always governed by the microprocessor clock. This is why the peripheral portions of a microprocessor-based system are often said to be *asynchronous*—their timing is not synchronized to the microprocessor clock.

**Buffers:** Buses are communication paths: They conduct information from one place to another. A microprocessor-based system has three types of buses:
- **Databus:** The databus carries information to and from the microprocessor, connecting it with every part of the system that handles data: RAM, ROM, I/O devices and, if present, DMA controller and mass storage (floppy or hard disk). The number of databus lines in a system is equal to the number of bits its microprocessor can handle at a time, because each bit requires its own line. Thus, an 8-bit microprocessor needs eight databus lines; a 16-bit microprocessor needs 16.
- **Address bus:** The address bus carries information about where a particular piece of data is to be found or sent. Each device in the system (ROM, RAM, I/O, etc.) has a specific range of addresses unique to that device. The data and address buses work together to respond to the microprocessor’s read and write requests—one specifying the data origin (or destination), the other providing a path on which the data can travel.
- **Control and status bus:** The microproc-
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In a properly functioning microsystem, a given node will always produce the same signature in response to the same stimulus when measured within a particular time window. Therefore, by comparing the actual signature of a node with the correct signature for that node, the technician can determine whether the output at a particular node is good or bad. Once a node is found to have a faulty signature, the technician traces back through the circuitry from that point looking for a device that has bad output but good input (one where the signature of the preceding device was correct). This device is likely to be the source of the fault.

Signature analysis is well-suited to troubleshooting microprocessor-based systems: It is fast, it allows the measurement to be timed to particular events, and it simplifies interpretation of the results. The technician does not need detailed knowledge of a specific board's circuitry. Whether a node is good or faulty can be determined by simply comparing its signature to that of the same node on a known-good board.

However, signature analysis does have its limitations. First, it can be used only on boards that were designed specifically for this technique—boards for which the manufacturer has included a special diagnostics program in the unit's ROM and specified the required START and STOP signals. Also, the manufacturer must provide the correct signature for each node, or the technician must collect these signatures from a known-good board. Finally, because actual signature of a node is created by an algorithm specific to the signature analyzer, the technician's signature analyzer must be compatible with the one used by the manufacturer or the signature won't match.

Emulative testers: One of the most effective instruments for troubleshooting microprocessor-based systems is the emulative tester, because this type of instrument tests the board from the inside out. The tester copies, or emulates, the functions of one of the kernel devices that is capable of reading and writing data to other devices on the board. By sending out a known stimulus to each device and measuring its response, the emulative tester is able to verify that each device in the kernel is operating properly.

There are three types of emulative testers: microprocessor emulators, ROM emulators and the recently introduced DMA emulators. All three types are quick and easy to set up, because they connect to the board at a single point. All are well-suited to measuring the dynamic, nonrepetitive signals that characterize microprocessor-based circuitry, because they are capable of synchronizing their measurements to the cycle of the microprocessor clock. (Some also include a logic probe that can be synchronized to events other than the microprocessor clock, allowing them to be used to measure events that occur more intermittently.) Finally, all three are easy to use because they perform many of their tests automatically. Also, emulative testers provide the technician with an interpretation of the test results, making them ideal for those who do not have a detailed knowledge of a specific board's circuitry.

- Microprocessor emulators: Microprocessor emulators either clip over the microprocessor or plug into its socket. Like the microprocessor itself, microprocessor emulators can read and write data to any addressable device or memory location, allowing the technician to thoroughly exercise every node on the board. Because they replace the board's microprocessor with their own, they are effective even when one or more of the
kernel components is completely dead.

Because each type of microprocessor
has its own characteristics, a microproc-
essor emulator needs some way of being
tailored to the characteristics of the par-
ticular microprocessor it is emulating.
This is achieved through special hard-
ware modules, called pods, which con-
tain microprocessor-specific informa-
tion.

- ROM emulators: ROM emulators
  plug into the ROM socket, taking con-
  trol of the board by replacing the ROM
  control program with diagnostic soft-
  ware that exercises all parts of the board.
  They are more limited than microproc-
  essor emulators because they can only be
  used on boards that have a properly
  functioning microprocessor and ROM
  address decoder as well as no stuck or
  shorted bus lines. They are also limited to
  testing systems that have a removable
  control program—that is, systems where
  the control program is located in a
  separate and unsoldered ROM rather than
  in the processor itself. Because of
  this limitation, they can be used only to
  troubleshoot true microprocessor-based
  systems as opposed to systems that are
  based on microcontrollers.
  ROM emulators have the advantage of
  not requiring a specific hardware inter-
  face unit for each type of microproces-
  sor, because they use the board’s own
  microprocessor to perform the data
  reads and writes. They do, however, re-
  quire a software interface for each type
  of microprocessor to be able to commu-
  nicate with it during data reads and
  writes.

- DMA emulators: DMA emulators
  clip over the board’s microprocessor.
  Like the DMA controller they emulate,
  these test instruments steal cycles from
  the microprocessor and use them to read
  and write to memory directly.

DMA emulators are similar to micro-
processor emulators in that they do not
require the kernel to be fault-free in
order to conduct full sets of tests. They
are unlike both microprocessor and
ROM emulators, however, in that they
do not take complete control of the unit
under test. Instead, they take their meas-
urements while the board is operating
in its normal environment. This ap-
proach makes them useful for testing
boards that exhibit problems when run-
ning their own control software. These
emulators are also ideal for testing
boards with solder-in components be-
cause they do not require removal of
either the microprocessor or the ROM
chip.

As the preceding discussion has
shown, microprocessor-based systems
are much more complex than traditional
analog, or even digital, circuitry. There-
fore, attempting to troubleshoot such
systems using only the traditional tools
of the service technician, such as mul-
timeters and oscilloscopes, is time-con-
suming and difficult. This type of trou-
bleshooting also requires a detailed
knowledge of the circuitry of the unit
under test, because traditional instru-
ments provide no assistance with inter-
preting the results of the measurements
they take.

Part two of this series will take a
closer look at how this new type of
equipment works, explaining the general
approach for troubleshooting micro-
processor-based systems and walking
the reader through a specific trouble-
shooting example.

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Servicing the Apple II+

By Michael J. Zoiss, CET

The Apple II is a great tool for learning the basics of computer hardware and digital troubleshooting because it is a basic, single-board microcomputer. (See Figure 1.) Digital troubleshooting requires the same steps necessary to repair anything electronic: Understand how the equipment operates, then analyze the symptoms. This information will help you right to the problem. The following five case histories of servicing the Apple II computer demonstrate how to apply these principles.

**Figure 1.** The Apple II+ is a single-board microcomputer with connectors that accept interface cards for connection to peripherals such as tape drive, disk drive, printer or modem. It is called single-board because all of the computer components (microprocessor, RAM, ROM and input/output interfaces) are contained on a single PC board. Arrows point to the areas mentioned in this article.

**Symptom:** No response when the computer is turned on.

**Clue:** Different sound to the high-frequency power supply when turned off.

In this case, there was no video, the disk drive wouldn't boot, and the power light was off. One other symptom, which gave a clue to the problem, was that the high-frequency switching power supply sounded different when the computer was turned off.

In this case, the symptoms suggest that the first item to check is the power supply. But let's look at the evidence first. The power-on lamp is driven by a +5V supply. Because the lamp isn't lit, we know the +5V is gone. Also, because an unusual, high-pitched squeal was heard when the power supply was turned off, the power supply is probably good. The problem was most likely a power-supply overload on the +5V source. A resistance check of the +5V supply revealed a direct short to ground.

A direct short in any of the supplies is most likely a shorts 0.1µF decoupling capacitor. The question is, which capacitor out of approximately 45 is it? The only safe way to find the offending capacitor is to keep an ohmmeter connected across the +5V supply with the Apple power supply disconnected and desolder one leg of each capacitor until the meter reading indicates an open. Because this board is double-sided, I suggest the only way to desolder the component leads is to use a vacuum desoldering station. Any other method can damage the printed circuitry or the components.

As Murphy's Law would have it, every decoupling capacitor for the +5V supply was checked and the B+ short remained. However, the test wasn't entirely inconclusive. If the short wasn't caused by a decoupling capacitor, then there must have been another reason for the B+ short. Close examination of the expansion edge card connectors revealed a tiny piece of metal lodged between pins 25 and 26 (+5V and ground, respectively) of slot 5. Removing it restored proper operation.
Symptom: Computer locks up while executing a program.

Clue: Computer boots a system master disk but not a 48K slave disk.

Examination of this computer determined that it would boot a system master disk but not a 48K slave disk—an important clue, because there is a difference between these two disks.

Before we continue, let’s look at what is meant by booting and DOS, and examine what constitutes a disk. A floppy disk is a 5-inch, round piece of plastic film that is coated with a magnetic medium. The film is permanently sealed in a square jacket and allows rapid storage and retrieval of information. The program responsible for storing and retrieving information is called the disk operating system (DOS). Booting is the process of loading the DOS, which resides on the disk, into the computer. Once DOS is loaded, the information on the disk can be accessed.

A system master disk has self-relocating DOS that locates itself into the top of RAM, independent of the amount of RAM. RAM stands for random access memory or, more definitively, read/write memory. The Apple II contains 48Kbytes of R/W memory, which is divided into pages. Each page of memory has its own allocated function or functions. This is called a memory map. (See Figure 2.) The top 40 pages or top 10K of R/W memory is where DOS resides after it is booted from the system master disk.

A slave disk has DOS that is memory-size dependent. If a new disk is initialized on a 48K machine, it becomes a 48K slave disk. When it is booted, DOS will always be loaded into the top 10K of the 48K. It will not boot, for example, on a 32K machine. This characteristic provides a clue to the problem.

The symptoms point to some kind of R/W memory problem, so the first order of business is to boot a diagnostic disk and to execute a memory test. In this case, doing so revealed that all memory in the range from 32K to 48K (top 16K or RAM) was bad. Because all 16K couldn’t be bad, some study of the hardware was in order to determine a reason for this.

It turns out that there are three rows of memory ICs, and each row contains 16Kbytes of memory (3x16K=48K). (See Figure 3.) Each row is connected to a CAS (column address strobe) line. A unique range of 16K is selected by addressing one of these three lines. The three CAS lines come from a 74LS139 2- to 4-line address decoder located at F2 on the mother board. This IC decodes the address bus and provides active low outputs to indicate the state of the address bus. That is, one CAS line will go low when one of the three 16Kbyte ranges is addressed. Replacing the 74LS139 address decoder solved the memory problem.

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<td>I/O ROM (2K)</td>
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<td>ROM (12K)</td>
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Figure 2. The Apple II contains 48Kbytes of read/write memory, divided into pages. Each page of memory has its own allocated function or functions. This is called a memory map.
Symptom: Computer hangs up (no cursor) when turned on; screen is full of garbage; disk drive won't boot; computer doesn't beep normally.

Clue: Computer operates when reset button is pushed.

This machine with a problem was an Apple II+ with an Autostart Monitor ROM (read only memory). The monitor ROM contains software that controls the computer, in the sense that it provides a cursor, accepts keyboard characters, displays characters on the screen, etc. Without a monitor ROM, the computer is worthless. “Autostart” means that it automatically boots a disk, provided a disk is in the drive, when the computer is turned on. Although the computer displayed the symptoms already lined out, the computer would operate fine once the reset button was pressed.

Because the computer worked once the reset key was pressed, there had to be a problem with the power-up reset circuit, which automatically initializes the µP at turn-on. Pin 40 is an active low reset pin on the 6502 microprocessor.

Figure 3 shows the reset circuitry that includes the reset key on the keyboard and the power-up reset circuit using a 555 timer. During the first 240ms or so after the Apple is turned on, the 555 timer causes pin 40 to be held low until all supply voltages and clock signals stabilize. Once the 555 times out, the reset line goes high and the computer will execute its start-up sequence. After the computer is on, it can be reset by pressing reset on the keyboard.

All the evidence indicated that the µP was being held in the reset condition. A voltage measurement at pin 40 of the µP read only 2.5V. This voltage is in the gray area of logic levels; it just might be low enough to constantly hold the µP in the reset state. Pin 3 of the 555 measured 0V (good) but the voltage at the base of the 2N3904, Q5, was 2V (bad). Leakage between the normally reverse-biased B-C junction of the 2N3904, the pull-up resistor and the base resistor formed a voltage divider. This resulted in 2.5V on the reset line instead of +5V. A new 2N3904 transistor solved the power-up reset problem.

Symptom: Computer hangs up when turned on; screen is full of garbage; disk drive won't boot; computer doesn't beep normally.

Clue: No activity on address bus.

When the computer was turned on, it displayed a screenful of garbage, and it wouldn't boot a disk, accept any keyboard commands or display a cursor. An important difference from the previous example was that pressing the reset key had no effect.

A quick voltage measurement eliminated the reset circuitry as the cause of the problem (reset line was +5V). All

Figure 3. The RAM locations from which information is retrieved are selected via an integrated circuit know as a 2- to 4-line address decoder. If this device malfunctions it may appear that an entire section of read/write memory is defective.

Figure 4 shows a simplified diagram of the power-up reset circuitry. Pin 3 of the 555 is normally at 0V, turning off the transistor and causing the signal at pin 40 of the 6502 to be high. During the first 240ms after the computer is turned on, the 555 timer causes pin 40 to be held low. After the 555 times out, the reset line goes high.
Symptom: Computer won’t accept characters from keyboard.

Clue: KBD line is always high.

This one was a real challenge (or dog, depending on how you look at it), because the problem wasn’t caused by an electronic device. The computer would not accept any characters from the keyboard, and pressing reset would cause the speaker to beep, which is normal. Then the computer would resort back to the “strange state”: It would display six lines of garbage, then it would display, one by one, five more meaningless characters and then start the whole sequence over again. While in this state, the speaker would intermittently emit some awful sounds. Here’s the kicker: Pressing reset would sometimes cause the computer to resort to its normal state and allow you to boot a disk and run a program. After a short time, however, the computer reverted back to the strange state.

Because the computer would sometimes act normal but then emit strange sounds and display garbage, it was apparent that the computer was not under program control of the F8 monitor ROM. If the computer isn’t under control of the monitor, there must be a problem with the address bus. But how do you find a problem on a 16-bit address bus that travels all over the motherboard? You can’t ohm out each bus line to every connection they make.

Another approach needs to be taken to tackle this dog. Remember when the computer wouldn’t accept any characters from the keyboard? This is a good place to start, but first let’s cover some operational basics of the Apple. (See Figure 5.) Keyboard data are multiplexed onto the databus when the KBD (keyboard) and RAMSEL (RAM select) lines go low. The KBD line is used to select between the keyboard data and the RAM data. The RAMSEL line enables the multiplexer and allows the selected data to be placed onto the databus. When a key is pressed on the keyboard, its 7-bit ASCII byte is placed at the input of the data multiplexer and waits to be placed on the databus.

Let’s continue with the keyboard approach. When the computer is operating correctly, there are pulses present on the KBD and RAMSEL lines. The pulses are selecting between RAM or keyboard data and multiplexing the selected data onto the databus. But during the
"Strange state;" the KBD line was always high. No wonder the computer didn't accept any keyboard characters—it was never looking at the keyboard!

The keyboard is memory mapped, which means the Apple gets a character from the keyboard by reading a memory location. To read the keyboard data, the keyboard address (C000 hex) is placed on the address bus and is then decoded to create the KBD signal.

We know the KBD line isn't going low, so what is causing it to stay high? (See Figure 6.) The KBD line comes from pin 15 of the 3- to 8-line I/O decoder (74LS138) located at F13. A little investigation showed that all the outputs of the decoder were stuck high. So far, so bad. All the input pins were found to be active except one—the active low enable at pin 5. It was always high. This signal comes from another 3- to 8-line decoder located at H12, pin 15. The same condition was found here. All outputs were high and all inputs were active except for the enable inputs at pins 4 and 5.

This line is connected to another 3- to 8-line decoder at F12, pin 15. Some of this IC's outputs were active and some weren't, including pin 15. The input lines were checked, and a problem was found at pin 2. The signal was active, but its logic level only had a low of 2V and a high of 3.5V.

We finally got it. Pin 2 is connected to address bus line 12 (AD12), which comes from the 8T97 address bus driver at H4, pin 3. There was a good active signal at the bus driver, which means only one thing—an open line between pin 3 of the bus driver and pin 2 of the decoder at F12. (See Figure 7.) AD12 travels from the bus driver to all the expansion slots, then down to the decoder IC at F12. The open was found between expansion slots four and five. A 2-inch piece of 30AWG wire between pins 16 (AD12) of these two slots solved this strange problem.

These case histories were presented to demonstrate the power of deductive reasoning. The key to troubleshooting any piece of electronic equipment is understanding how it operates, then analyzing the symptoms. Doing so will speed up repair time and give you a great feeling of accomplishment. Remember to always ask yourself—why?
Product safety should be considered when component replacement is made in any area of a receiver. The shaded areas of the schematic diagram designate the components in which safety is of special significance. It is recommended that only exact cataloged parts be used for replacement of these components.

Use of substitute parts that do not have the same safety characteristics as recommended in factory service information may create shock, fire, excessive x-radiation or other hazards.

This schematic is for the use of qualified technicians only. This instrument contains no user-serviceable parts.

The other portions of this schematic may be found on other Protex pages.

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A system schematic was combined with block diagrams and other elements to form the hybrid troubleshooting aid seen on this sheet. Included among its features are key voltages, the make-up of individual cables, all connections between modules and assemblies, major components and the main lines of interaction related to these components. It is a format for use in circuit overviews and circuit tracing.

The cable assemblies illustrated at and around each module show both connectors of the cable, one incard to the module itself, the other to the remote module.
HITACHI CT1358 BASIC
CIRCUIT DIAGRAM

Product safety should be considered when component replacement is made in any area
of a receiver. Components marked with a ! and shaded areas of the schematic diagram
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user-serviceable parts.

The other portions of this schematic may be found on other Profax pages.

- Because this is a basic circuit diagram, the value of the parts is subject to be altered for
  improvement.
- All dc voltage to be measured with a test-er (100kV).
- Voltage taken on a complex color bar signal including a standard color bar signal.

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Notes:
1. Capacitance shown in microfarads unless otherwise specified.
2. Resistors are ±5%/W, film, ±5% tolerance unless otherwise specified.
**HITACHI CT1358 BASIC CIRCUIT DIAGRAM**

- Because this is a basic circuit diagram, the value of the parts is subject to be altered for improvement.
- All dc voltage to be measured with a tester (100KΩ).
- Voltage taken on a complex color bar signal including a standard color bar signal.

Product safety should be considered when component replacement is made in any area of a receiver. Components marked with an ‘a’ and shaded areas of the schematic diagram designate sites where safety is of special significance. It is recommended that only exact cataloged parts be used for replacement of these components.

Use of substitute replacement parts that do not have the same safety characteristics as recommended in factory service information may create shock, fire, excessive x-radiation or other hazards.

This schematic is for the use of qualified technicians only. This instrument contains no user-serviceable parts.

The other portions of this schematic may be found on other Profax pages.
The Commodore 1541 disk drive is similar to most other personal computer disk drives in the way it stores data on the magnetic disk and retrieves that data. It is very different from most other PC disk drives in the way it is controlled.

Most other disk drives are controlled directly by the computer. The software that performs this control, the disk operating system (DOS), is read from a disk during the computer startup operation and stored in the computer’s read/write memory (RAM). In contrast, the control of the 1541 disk drive comes from a microcomputer in the drive itself. The microcomputer gets its instructions from a program that is permanently stored in a read-only memory chip in the disk drive.

This article generally describes the components and function of the Commodore 1541 disk drive, lists some of the more common malfunctions, and shows how to troubleshoot and correct these problems.

Two earlier articles might enhance your understanding of this subject: “Understanding the Floppy Disk” in the April 1985 issue and “Servicing the Commodore 64” in the March 1986 issue.

How disk drives work

The function of the disk drive is to magnetically store and retrieve computer data onto or from a floppy disk. The disk drive takes the advantages of a phonograph record and a tape recorder and combines them into one computer-controlled unit. The advantage of tape over the phonograph record is that you can record as well as play back a particular piece of music. The advantage of a phonograph record is that you can move the tone arm to a particular track.

The data on the disk also is stored much like on a phonograph record. (See Figure 1.) There are a number of concentric circles, each one bigger than the last, each independent from the other. These circles are called tracks. Track 1 is the outermost track, located at the edge of the disk. Track 35 is the innermost track, located near the hub or inner edge of the disk. The center track is 18, which is used for disk organization, sometimes called housekeeping.

The jacket of the disk has several cutouts in it. The head-access slot allows the disk drive head to touch the

Balogh is an instructor at the Electronic Servicing Institute in Cleveland, OH.

Figure 1. Personal-computer information is stored permanently on a floppy disk, which consists of a circular piece of plastic film with a layer of magnetic medium, much like magnetic tape. The disk is divided into blocks. Each block is the area where a pie-shaped sector and a circular track intersect.

Figure 2. The functional relationships of circuits in the 1541 disk drive are shown in this simplified block diagram.
magnetic coating. The write-protect notch protects a disk against accidental erasure or overwriting. If the write-protect is left uncovered, writing to the disk is permitted. If the write-protect notch is covered, writing is disabled. This type of protection is similar to that used in audio and video cassettes. (However, if the write-protect circuitry is defective, it is possible for disks to be damaged by erroneous information being written onto the disk, even though the notch is covered. For that reason, make sure you use "scratch" disks when servicing and have a couple of backup disks ready for test programs.)

A disk drive basically consists of two main units. One is a mechanical unit composed of belts, motors and pulleys. The second is an electronic unit composed of solid-state circuits and a program called the disk operating system (DOS), which controls its operation. (Figure 2 shows the relationships between the circuitry.)

The mechanical unit
The mechanical part of the disk drive (shown in Figure 3), which includes the belts and motors mentioned before, includes the following parts:
- The read/write/erase head is basically a magnetic recording, playback and erase head similar to the head used in an audio recorder. This head must position itself over various tracks as directed by a program. The head is actually composed of two heads: the full erase head and the read-write head.
- The head-mount sidetraits allow the head to move freely across the diameter of the disk. A build-up of dirt on these rails can cause read errors.
- The track select band is a metal band that moves the head.
- The stepper motor drive wheel, track position pulley and spring all interact to move the head into the desired reading or writing positions.
- The stepper motor stop prevents the stepper motor from ever running the outermost track (track 1).
- The drive motor rotates the disk. It must do so at a precise speed: 300rpm. This allows the drive to locate a particular sector; it also allows the disk to be read by another drive.
- The drive hub is attached to the drive flywheel. Its purpose is to sandwich the disk between itself and the drive idler, called the pressure cone; this forces the disk to rotate.
- The write-protect detector is an optical switch. If the write-protect notch on the disk is open, the write-protect detector has no effect on the writing process. This is because the infrared light is unobstructed and is sensed by the phototransistor permitting the DOS to write. However, if the write-protect notch is covered with opaque tape, the write-protect detector will disable the DOS from writing.
- Underneath the mechanical unit (see Figure 4) is the track stepper motor, a special type of motor used to precisely position the read/write head. A stepper motor does not rotate like a regular dc motor, but instead turns in increments of a revolution. The more increments a stepper must make for one complete turn, the more accurately it can position the head.
- The drive belt connects the drive motor pulley to the flywheel. The flywheel smooths out the motion of the drive hub. A timing disk on the flywheel provides a reference for calibration of disk drive rotational speed.

There are two types of mechanical units used. First is the Alps unit, which has a spring-loaded latch on the door used to insert and remove the disk. (See Figure 3.) This type of assembly also uses an eject mechanism. Second is the Newtronic unit, in which a lever is used to lock a disk into position. An eject mechanism is not used and the disk must be manually removed.

The electronic unit
The electronic part of the drive consists of two boards. First is the motor drive board, which controls the speed of the drive motor. In older units it is located on the underside of the mechanical unit adjacent to the flywheel. In newer units it is located on the top side. The second board is the disk controller card (sometimes called the analog card). This disk controller card contains a dc power supply and seven computer-controlled circuits:
- the timing circuit, which simply produces the clock signals;
- the serial bus control, which organizes all the operations of the disk drive;
- the optical circuitry used in conjunction with the write-protect detector;
- the read circuitry, which controls the playback of digital information;
- the write circuitry, which controls the recording of digital information;
- the track-select circuitry, which controls the stepper motor; and
- the encoder-decoder circuitry, which detects the presence of data and performs a serial-to-parallel conversion within the drive's computer.

Commodore has revised its disk controller card no less than five times. Some of these revisions have their own particular problems not related to other boards. The first and second revisions, called the 1540 and the 1540 revised boards respectively, fill the entire top of the drive unit. The third and fourth
revisions are the 1541 and 1542 boards, which fill approximately 75% of the top unit and contain fewer components but larger-scale integrated circuits. (The 1541 board is shown in Figure 5.) Finally, the 1542C board is a half-board with more densely packed chips.

Accessing the drive

If the computer, drive and monitor are connected and there is a disk in the drive, typing LOAD "$", 8 (RETURN) will load the listing of file names into the computer from the disk. To display the listings, simply type LIST (RETURN).

The drive will go to and read track 18, which is set aside by the DOS for disk organization. Track 18 is automatically managed at all times by the DOS. The file names and disk name displayed is called the directory. The numbers displayed to the left of the file names is called the block availability map (BAM). The BAM tells you how many sectors are free (blocks free at bottom of directory). Track 18 should be the easiest track for the drive to read because it is in the middle of the disk.

Formatting a disk erases the entire disk, it also puts timing and block markers on the disk and creates the directory and BAM. The command for formatting is:

OPEN 15,8,15:"NO: FILENAME, ID"; CLOSE 15

The name entered as the file name becomes the name of the disk. The ID is any two characters, and they are placed not only on the directory, but on every block throughout the disk. That way, if you mistakenly replace the wrong disk while writing data, the drive will check the ID and know that something is wrong. This is important to remember when troubleshooting a “drive not ready” error with the disk inserted. This command is also useful in troubleshooting a writing problem.

Sometimes an error condition will stop the disk drive in the middle of an execution. This is indicated by a flashing red LED. To read the error message that caused the failure, enter the following basic program into the computer:

10 OPEN 15,8,15
20 INPUT #15,A$,B$,C$,D$
30 PRINT A$,B$, C$, D$
40 RUN

After RUN is entered, the error message should be displayed and the error light should stop flashing. The error message displayed may give you a clue as to why the drive failed.

At times, an error condition will exist that will prevent you from performing some disk operations. A command called the initialize command returns the disk drive to the same state as when you powered up. That command is:

OPEN 15,8,15; PRINT # 15; CLOSE 15

It also repositions the read-write head so it is in the track 18 position. (Please note: When typing in any of these programs, leave no spaces between characters.)

Editor's note:

This article should give you enough information to help you understand the general operation of the 1541 disk drive. Part II, which will appear in the February issue, will cover troubleshooting and repairing the mechanical section of the unit and will include an analysis of problems and solutions for the electronics section.
Break-out boxes: Active vs. passive

By Manfred R. Will and Cindi L. Kemper

For years, the active vs. passive debate surrounding break-out box design has been a familiar topic among many top technicians and service managers in the data communications troubleshooting and interfacing industry.

These differences translate into definite advantages and sometimes disadvantages, which experienced technicians should know and be able to use to their own advantage. The added advantage that comes with using the appropriately designed break-out box easily can equate to greater efficiency and information—information that means time savings.

Simply put, the base argument still centers on the method by which LEDs (light emitting diodes) on the break-out box are powered. There are two basic approaches to powering a break-out box: One way is to power the unit with a battery; the other is to take power from the system being tested.

An active box, by definition, is one that uses a buffer or amplifier of some form to drive the LEDs. The power needed to do this generally is provided by one or more internal batteries.

A passive box, on the other hand, is one that draws its power from the signal line itself. This design, in turn, serves to power LEDs without using any outside power. There is no dependence on a battery to help the break-out box function.

Unfortunately, that's where the definition stops and the debate begins, because there's really no right answer. Supporters argue both sides, and pros and cons exist for both designs. Anyone contemplating a break-out box purchase should take time to understand both the advantages and disadvantages of each.

Active design
One school of thought argues that test equipment should be transparent to the operation of the equipment being tested. False or ambiguous readings, which are caused by the testing unit loading down the system, are unacceptable, so for complex and intermittent problems, an active device should be used.

Classical engineering philosophy would support the concept that any device designed to measure the status of another device should not in any way affect the device being measured. This theory has its followers and would tend to support an actively designed box. (The technical explanation of this theory is expanded later in this article.)

On the other hand, a passively designed break-out box also has its supporters. Because a passive box is capable of reporting the relative signal strengths of each line in use, a great deal of added information suddenly is available at the technician's fingertips. Many technicians feel this additional information, along with its independence from an internal power source, far outweighs any question of impedance level. Besides this, new designs in break-out box construction are drawing as little as 2mA or less off the line.

To really understand the basis of this debate, a quick overview of the RS-232 protocol from a more technical point of view may be helpful. RS-232 is probably the most common protocol for serial data communications between computers and peripherals.

This standard calls for both positive and negative voltage transmission, typically +12V or -12V. A positive signal is +3V to +12V, a negative signal is -3V to -12V, and anything between +3V and -3V is a disallowed state. Integrated circuit manufacturers have responded to these standards with a pair of ICs (a transmitter and receiver) to handle the electrical characteristics of RS-232C.

An RS-232 transmitter (i.e., quad line driver No. 1488) is designed to convert up to four TTL signals into +12V or -12V levels with the output current limited to 10mA. The receiver (i.e., quad line receiver No. 1489) converts up to four RS-232 signals back into TTL levels and typically exhibits an input impedance level between 3kΩ and 7kΩ.

These specifications describe the foundation that supports the classical engineering philosophy. The ra-

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Will is vice president of engineering and Kemper is vice president of international sales and marketing for Datatran, Denver, a manufacturer of break-out boxes.

How they work

The connections between a computer and its peripherals or between a computer and data communications equipment are complex. When problems occur at these interfaces, it often is necessary to use some kind of test device to monitor the signals and determine the cause of the problem. When this interface is a serial interface to which the EIA recommended standard RS-232 applies, a commonly used testing device for this purpose is the break-out box.

In operation, the break-out box is connected to both sides of the interface. For example, if the problem is with a printer interface, one side would be connected to the computer and the other side to the printer. Connected in this manner, all communications lines would flow through the break-out box. Red and green LEDs on the box then show whether positive or negative signal voltage is present on each pin, on each side. (For a more detailed description of this interface, see "Testing Serial Communication With a Break-out Box" and Computer Corner in the February 1987 issue.)
tional here implies that an input buffer with a relatively high input impedance level, say several 100kΩ, would not affect or load down the signal under test. These buffers are typically of a digital rather than linear (analog) design and are therefore set to turn on at a predefined threshold point (usually +3V for positive signals and −3V for negative signals).

These buffers are capable of outputting 10mA to 30mA, so standard LEDs, which require 20mA for rated intensity and are more cost-effective from a manufacturing point of view, may be used. Because of the digital function of the buffer within an active-designed break-out box, all signals above the threshold voltage of the buffer will produce a bright, visible indication on its respective LED.

Some technicians prefer an actively designed box because they require brightly lit LEDs. But today, a number of passive boxes use new high-efficiency LEDs, which nearly equal the intensity of those in a buffered design even though no outside power source is being used.

**Passive design**

A passively designed box has its advantages as well. Returning for a moment to classical engineering philosophy, a device designed to test the performance of another device probably would affect or interact with the device under test. The rationale here is that a passive design (an LED combined with a series, current-limiting resistor that is placed across the circuit under test) derives its power from the circuit and should provide a reasonable load to the circuit.

Where the RS-232 protocol is concerned, a reasonable load would be equivalent to the input impedance of a 1489 receiver. The desired response in this case would be a reasonably bright LED indication. Because 1488 drivers are current-limited to 10mA and standard LEDs require about 20mA for rated intensity, an obvious problem exists.

Advances in LED technology throughout the last several years have led to the development of special high-efficiency LEDs. With only 2mA, these LEDs will demonstrate an equivalent brightness to conventional LEDs using 20mA. What all this means is that you can place a typical RS-232 receiver load on an RS-232 driver and see the result.

The advantage to this type of design is its ability to point out potential hardware problems or flaws. For example, a defective driver, which cannot supply rated current, can be quickly and easily detected. Another benefit inherent to a passive design is that the relationship between signal voltage and LED intensity is a linear one. As the signal voltage decreases, so does the LED's intensity, which provides a quick visual indication of relative signal strength. A 4V signal on an active box may be easier to see, but you would never know that a potential problem exists. The ability to measure while testing can be a real benefit in some cases.

Perhaps one of the most important benefits is a passively designed box's independence from batteries. Untold numbers of technicians have found themselves in the field only to discover they are unable to use their break-out box because of worn out or low batteries. A passively designed box always is dependent solely on the power from the interface and thus eliminates any dependance on outside sources.

The active vs. passive debate continues to recruit new support on both sides. Perhaps now you have a better understanding of the advantages of each. Five years ago, when most passive break-out boxes were inefficient and active break-out boxes were just being introduced, technicians probably would have opted for an active design. But today, because the method of break-out box construction has changed, components are more efficient and technicians are open to new ideas. The debate continues.
The logic probe:
Troubleshooting to the component level

By Conrad Persson

Servicing personal computers has typically been a matter of locating the problem at the PC-board level and then replacing that board. Taken on a case-by-case basis, this approach seems quick and efficient. The inefficiency in this approach, which is not readily apparent, is the investment in keeping a stock of spare boards on hand. Another problem is that a board that appeared to be faulty turns out to be perfect. The solution to this problem is to troubleshoot down to the component level and replace faulty components instead of board swapping. In some cases, this approach can require some sophisticated and expensive test equipment. In other cases, however, some very simple test equipment will do the job, or you might be able to find the faulty component without any test equipment at all (as mentioned in the Apple computer servicing article, page 24).

Persson is editor of ES&T.

The logic probe, shown at left, indicates whether the logic state of the point being tested is at a logic high or low. A sophisticated probe will have indicators to show whether the test point is high or low or is exhibiting pulses. Some will even have a memory or pulse stretcher that will show the presence of a 1-shot pulse that is of so short a duration that it is insufficient even to light the indicator, or it lights the indicator too briefly to be recorded by the human eye.

The indicators used to show the logic state of the pin being tested are usually LEDs. In some cases, a single LED is used to indicate any of the conditions (high, low or pulsing); in other cases, individual LEDs are used for each indication.

Let's say you're troubleshooting using a sophisticated logic probe that is capable of testing a number of different kinds of logic circuits: TTL, DTL, CMOS. You would connect the probe's power input to the power supply from...
which the circuitry being tested derives its power. Connecting the probe in this manner will indicate the approximate value of signal voltage that constitutes a logic low or high.

For example, the power-supply voltage for a CMOS logic circuit is 18V. A logic low in this circuit would be about 30% of that value or 5.4V. A logic high in this circuit would be about 70% of 18V or approximately 12.6V.

If you suspect a specific IC, it would make sense to go directly to that IC once you have the logic probe connected into the circuit's power supply. Otherwise, use the time-tested method of starting approximately in the middle of the circuit, and let the results at the point guide you upstream or downstream a half-circuit at a time.

**Guided fault isolation**

The logic probe all by itself is a valuable diagnostic tool. With a little help, it can be even more useful. One of the logic circuit testers that can help a technician use a logic probe to locate a faulty component is a guided fault-isolation unit. This unit connects to the PC system board input/output connectors and, armed with the proper software, goes through a step-by-step test routine that exercises the computer circuits. When it encounters a condition that casts suspicion on that circuit segment, it outputs a message that tells the operator to check the condition of a specific pin of a specific IC.

**Your choice**

Just as with the servicing of television, audio and other consumer electronic equipment, servicing of PCs can be done on just about any level. You can swap boards (where the product is modular) or troubleshoot to the component level. If you choose to troubleshoot to the component level, you can use simple, inexpensive test equipment or more sophisticated, expensive test equipment. Whichever you choose, the most important thing to bring to the test bench is good, solid information about the equipment you're servicing and sharply honed troubleshooting skills.

---

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By Sam Wilson

In the last few months, I've received many interesting and informative letters. Because they are informative, I'm going to include some of the more professional letters in this issue.

The shorted in-situ tester

I wish I could print all of the funny letters I got about the dead short across the battery in the in-situ tester schematic. The schematic, as it originally appeared in the September issue, is shown in Figure 1.

Here is what happened. I just finished the article when I decided to make the drawing by Olszewski a little more clear. I got so busy straightening up the lines, I didn't pay enough attention to the circuit. Olszewski's original drawing, showing the circuit as it should look, is in Figure 2.

Here is a letter from David A. Jenkins of Bennettsville, SC:

Sam:

Reading the September issue, got a good laugh when I hit page 60. Nice little circuit. Think I'll build one for myself. Will come in handy on my job (industrial electronics technician/electrician/hyp.). I'll probably leave out the DEAD SHORT across the batteries, though.

Mr. Jenkins also asked for a title or source for a good book on SCR dc drive circuits, such as the ones on electric tow-motors, trolling motor drives, etc. Anyone have a suggestion?

David R. Nomi of Saratoga Springs, NY, sent this message:

Sir:

Refer to September '87 edition, page 60, Figure 1. It would seem that the ideal way to keep the battery manufacturers in business is to build in a permanent short circuit.

Here is one more letter on that subject from Ernest Buonpane of Queens, Long Island, NY:

Dear Sir:

On page 60 of the September issue,
you show a piece of do-it-yourself test equipment. I am very interested in building this in-situ transistor tester, but I don’t understand why there is a jumper across the battery circuits, which I believe is short circuiting the batteries completely. I am anxious to build this circuit. Please let me know if I should make any changes in this circuit in order to correct it. Thank you.

I received the following letter from Keith A. Duke, a computer consultant and part-time instructor in West Palm Beach, FL. It shows how to use a calculator for decimal-to-hex conversion.

Decimal to hex conversion
When converting a decimal number into its binary equivalent, it is usually more convenient to convert it first into hexadecimal notation. To convert a number into hex, keep dividing the number by 16 and note the remainder at each stage. The first remainder is the least significant digit. The remainder after the final division is the most significant digit. (Disregard the remainders in between.) For example, convert 745 (decimal) into hex using this traditional method:

\[
\begin{align*}
745/16 &= 46, \text{ remainder } 9 \\
46/16 &= 2, \text{ remainder } 14 \\
2/16 &= 0, \text{ remainder } 2
\end{align*}
\]

The hex digits for 745 (decimal) are 2, 14, 9, or 2E9 as they are normally written.

When I tried to teach this method to my students, they complained that their calculators did not generate remainders, so we devised a method that could be used on a calculator.

The calculator method
Begin by generating the most significant hex digit: Repeatedly divide the

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January 1988 Electronic Servicing & Technology 57
original number by 16 until the result is less than 16. The integer part of that result represents the first hex digit. Write that digit down, then subtract it from the displayed number to give a value whose integer part is zero. Multiply that value by 16; the integer part of the result represents the next hex digit. Repeat this procedure until you have multiplied by 16 as many times as you originally divided. At that point, the fraction part of the displayed number should be zero.

For example, using the calculator method to convert 745 to hex, you would get the following results:

1st divide:
\[
745/16 = 46.5625
\]

2nd divide:
\[
/16 = 2.9101563
\]

(1st hex digit is 2)
\[
-2 = 0.9101563
\]

1st multiply:
\[
x16 = 14.5624
\]

(2nd hex digit is E14)
\[
-14 = 0.5625
\]

2nd multiply:
\[
x16 = 9
\]

(3rd hex digit is 9)

The resultant hex number is 2E9, and its binary equivalent is:
\[
0010, 1110, 1001.
\]

This technique works for quite large numbers, although repeated division by 16 can generate round-off errors. I found round-off errors at six digits. The final digit may appear as 2.996, in which case read it as 3. It is essential to keep count of the number of divisions and make sure you have the same number of multiplications.

One meter equals what?

Michael B. Danish of Aberdeen Proving Ground, MD, caught a typo in the October issue.

Dear Sam:

You will probably get 100 or 1,000 letters on this one, but in the October issue, page 58, you say, "Note: 1m = 1,000cm." Of course, it should have read 1m = 100cm.

Your attempt at simplification is good, but this error (typo no doubt) will likely confuse the readers no end!

Michael Moran of Horicon, WI, likes the idea of home-brew equipment. He

---

**Figure 3.** You can make your own logic pulser like the one shown in this schematic. See text for details.
sends a circuit to keep it going.

Dear Sam:

Your article in the September ES&T concerning home-brew test equipment sounds like a great idea for a continuing feature with reader contributions. Here’s one of mine. (See Figure 3.)

UIA and B form a one-shot, which is triggered by pressing S1. UID forms an oscillator with a frequency of approximately 3Hz. This oscillator is gated on by UIB when S1 is depressed. S1 selects either the one-shot pulse from UIB or the pulse train from UID for application to the output circuit.

The pulses appear at the junction of R4 and R5. Positive going edges are coupled through R5 to the C1-R1 differentiating network, which causes Q2 to turn on and deliver a current-sink pulse of approximately 10µs. The following negative going transition at R4 causes Q1 to operate in the same manner, giving a 10µs current-source pulse. D1 and D2 protect each transistor from possible base-emitter reverse overvoltage. When the circuit is not active (S1 open), both Q1 and Q2 are off and the output is in a high-impedance state similar to a “TriState” logic gate.

Because the driving capability of a CMOS output is limited, Q1 and Q2 are Darlontons. I have been able to generate valid logic levels driving impedances as low as 10Ω between the pulser output and either supply rail, and I have pulsed both CMOS and TTL gates continuously for an hour without harming the driven chip.

Q1 and the LED give a visual indication of pulse activity. One note is in order concerning the MC4093B: The component values shown for the oscillator and one-shot may have to be adjusted if a manufacturer other than Motorola is used. This is because the hysteresis range on the Schmidt is different due to each chip maker’s process, and may even vary among chips in different production lots from the same manufacturer. In particular, the RCA version (CD4093BE) will run much slower as an oscillator.

The probe can be built into any convenient case. Mine is in a Global Specialties CTPI case pirated from an old Radio Shack logic probe, with two switches wired in parallel for S1, one on either edge of the case for convenient operation with either hand.

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Test your electronics knowledge

By Sam Wilson, CET

In this issue, I have taken some questions from practice CET tests that I wrote for ISCET a few years ago. These practice tests are no longer being sold, but the questions still demonstrate important facets of technology.

1. The rise time of the waveform in Figure 1
   A. is 3ms.
   B. is 4ms.
   C. is 5ms.
   D. cannot be determined from the information given.

2. If bandwidth is defined as the range of frequencies between the 1/2-power points, what is the bandwidth of an amplifier having the response curve shown in Figure 2?
   A. 20MHz
   B. 17.5MHz
   C. 10MHz
   D. 2.5MHz

3. Refer to Figure 3. What is the voltage at point A with respect to the voltage at point B?
   A. 5.0V
   B. 4.1V

Wilson is the electronics theory consultant for ES&T.
4. Which of the following components is sometimes used as a parasitic suppressor?
A. Thermistor
B. Bead ledge
C. Ferrite bead
D. 4-layer diode

5. It is a common practice to locate thermistors and other measuring sensors in one leg of a Wheatstone bridge. The reason for doing this is that it
A. increases the sensitivity of the measurement.
B. makes the measurement nearly independent of power-supply voltage variations.
C. permits a maximum power transfer condition.
D. increases the circuit resistance, as seen by the sensor, to a greater degree.

6. A logic probe is not normally used for measuring a
A. pulse condition.
B. logic 1 condition.
C. logic 0 condition.
D. delay condition.

7. The oscilloscope display of Figure 4 is obtained by delivering signals to the vertical input and the
A. z-axis.
B. horizontal input.
C. external sync input.
D. external calibrate input.

8. Figure 5 shows an amplifier that uses an N-channel JFET (Q0). The power supply should be
A. positive with respect to common.
B. negative with respect to common.

9. In the circuit of Figure 5, gate bias is obtained with
A. a source resistor.
B. a power-supply voltage divider.
C. a resistor between the gate and drain.
D. (None of the above.)

10. Is the following statement true? In a purely inductive circuit, no power is dissipated.
A. False.
B. True.

Answers are on page 73

1. Quickly locate defective circuits by injecting signals without disconnecting components.

2. Replace video heads with confidence; a simple good/bad head test removes all doubt.

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January 1988  Electronic Servicing & Technology 61
# Index of 1987 Articles

Compiled by Darren Sextro

## ARTICLES

### AUTOMOBILE ELECTRONICS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>New 4-wheel Steering Is Electronically Assisted</td>
<td></td>
<td>Jul</td>
<td>26</td>
</tr>
</tbody>
</table>

### CIRCUITS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit Analysis and Troubleshooting Quiz!</td>
<td>Bert Huneault</td>
<td>Jun</td>
<td>39</td>
</tr>
<tr>
<td>What Do You Know About Electronics?—Circuits</td>
<td>Sam Wilson</td>
<td>Feb</td>
<td>52</td>
</tr>
<tr>
<td>Don't Let Shutdown Circuits Shut You Down</td>
<td>Gregory D. Carey</td>
<td>Sep</td>
<td>18</td>
</tr>
<tr>
<td>What Do You Know About Electronics?—The Open Emitter Resistor</td>
<td>Sam Wilson</td>
<td>Aug</td>
<td>48</td>
</tr>
<tr>
<td>Troubleshooting Startup Circuits</td>
<td>Gregory D. Carey</td>
<td>Nov</td>
<td>42</td>
</tr>
<tr>
<td>Troubleshooting the Chopper Circuit</td>
<td>Homer L. Davidson</td>
<td>Dec</td>
<td>20</td>
</tr>
<tr>
<td>Unusual Waveform/Function Generator Circuits</td>
<td>Joseph J. Carr</td>
<td>Oct</td>
<td>45</td>
</tr>
</tbody>
</table>

### COMPONENTS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid-state Rectifiers: Using, Abusing and Selecting</td>
<td>Joseph J. Carr</td>
<td>Jul</td>
<td>18</td>
</tr>
</tbody>
</table>

### EQUIPMENT

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog or Digital: Which DMM Is Best?</td>
<td>Mike Hahn</td>
<td>Sep</td>
<td>10</td>
</tr>
<tr>
<td>Choosing a Low-cost Oscilloscope</td>
<td>Dave Herrington</td>
<td>Jan</td>
<td>18</td>
</tr>
<tr>
<td>What Do You Know About Electronics?—Do-it-yourself Test Equipment</td>
<td>Sam Wilson</td>
<td>Sep</td>
<td>60</td>
</tr>
<tr>
<td>Locating Replacement Parts</td>
<td>Conrad Persson</td>
<td>Dec</td>
<td>12</td>
</tr>
<tr>
<td>Oscilloscope: The Eyes of the Technician</td>
<td>Conrad Persson</td>
<td>Apr</td>
<td>10</td>
</tr>
<tr>
<td>Report From the Test Lab: Model AR-460-D</td>
<td></td>
<td>Apr</td>
<td>16</td>
</tr>
<tr>
<td>Report From the Test Lab: The Dissipation Factor, an Explanation</td>
<td></td>
<td>Oct</td>
<td>10</td>
</tr>
<tr>
<td>Report From the Test Lab: The Semianalyzer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transistor/junction Tester</td>
<td></td>
<td>Nov</td>
<td>12</td>
</tr>
<tr>
<td>Setting up a Test Bench</td>
<td>Conrad Persson</td>
<td>Mar</td>
<td>59</td>
</tr>
<tr>
<td>Test Equipment for Personal Computers</td>
<td></td>
<td>Jul</td>
<td>12</td>
</tr>
<tr>
<td>You Have to Buy Test Equipment OR DO YOU?</td>
<td>Jack Cunningham</td>
<td>Jan</td>
<td>25</td>
</tr>
</tbody>
</table>

### MANUFACTURERS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buyer's Guide 87, by the ES&amp;T staff</td>
<td></td>
<td>Mar</td>
<td>13</td>
</tr>
</tbody>
</table>

### POWER CONDITIONING

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Conditioning</td>
<td>Conrad Persson</td>
<td>Nov</td>
<td>26</td>
</tr>
</tbody>
</table>

### REMOTE CONTROLS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>What Do You Know About Electronics?—Infrared Remote Controls</td>
<td>Sam Wilson</td>
<td>Apr</td>
<td>50</td>
</tr>
<tr>
<td>What Do You Know About Electronics?—More on the Basics of Infrared Remote Controls</td>
<td>Sam Wilson</td>
<td>May</td>
<td>46</td>
</tr>
<tr>
<td>Tracking Down Remote Control Problems</td>
<td>Conrad Persson</td>
<td>Dec</td>
<td>46</td>
</tr>
</tbody>
</table>

### SERVICING METHODS

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Month</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desoldering Components, Using Continuous Vacuum Solder Extraction</td>
<td>James K. Bausell</td>
<td>May</td>
<td>12</td>
</tr>
<tr>
<td>Disk Drive/Printer Servicing</td>
<td>Conrad Persson</td>
<td>Feb</td>
<td>12</td>
</tr>
<tr>
<td>Knob-repair Nightmare</td>
<td>Larry Critchlow</td>
<td>May</td>
<td>52</td>
</tr>
<tr>
<td>Learning From a TOUGH DOG TV Repair</td>
<td>Max Goodstein</td>
<td>Apr</td>
<td>24</td>
</tr>
<tr>
<td>What Do You Know About Electronics?—Living With Models</td>
<td>Sam Wilson</td>
<td>Jun</td>
<td>52</td>
</tr>
<tr>
<td>Locating and Replacing the Defective Flyback</td>
<td>Homer L. Davidson</td>
<td>Jun</td>
<td>21</td>
</tr>
<tr>
<td>Servicing Microwave Oven Panels</td>
<td>Homer L. Davidson</td>
<td>Nov</td>
<td>18</td>
</tr>
<tr>
<td>Troubleshooting Horizontal ICs, Part 2</td>
<td>Homer L. Davidson</td>
<td>Feb</td>
<td>17</td>
</tr>
</tbody>
</table>

62 Electronic Servicing & Technology January 1988
VCRs
Technical Training and Testing
The Meter Said...What?, IC Tester, Testing Methods
Ruling Out Static, STATIC
MTS: TV Sound, MTh: TV
Digital Audiotape
We
Using the Scope
Electronic Principles: Integrated
Electronic Industry Telephone Directory
Communications Electronics: CD
BOOK REVIEWS
DEPARTMENTS

BOOK REVIEWS
ABCs of Electronics, 4th edition, by Farl Jacob Waters
Books for electronic communication available from Microwave Filter Company
CD-I and Interactive Videodisc Technology, by Steve Lambert and Jane Sallis
Communications Electronics: Systems, Circuits and Devices, by Forest Barker
Complete Compact Disc Player, by Martin Clifford
Computer Electrical Power Requirements, by Mark Weller
Digital Logic Circuits: Tests and Analysis, by Robert G. Middleton
Electric Circuit Analysis, by S.A. Boctor
Electronic Connections, Home and Car Entertainment Systems, by Martin Clifford
Electronic Industry Telephone Directory (8th edition)
Electronic Principles: Integrated and Discrete, by James F. Cox and S. Roger Everett
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VCR SERVICING

All you need to know about servicing VCRs is in this exclusive report coming next month in:

ELECTRONIC Servicing & Technology

66 Electronic Servicing & Technology January 1988
Tool/test instrument catalog
HMC is offering a fully illustrated catalog of electronic tools, test equipment and supplies for the manufacture and repair of computer, telecommunication and electronic applications. The 98-page catalog covers test equipment, tool kits, soldering/desoldering tools, lamps and magnifiers, anti-static products, work stations, wire prep equipment and hand tools.

Circle (125) on Reply Card

Replacement components catalog
Ampex Electronic Corporation, an affiliate of Philips ECG, has published the newly updated and expanded "ECG Semiconductors Master Replacement Guide." The guide lists almost 4,000 solid-state devices used as replacements for domestic and foreign types in entertainment, commercial and industrial equipment. The catalog includes 230 new types added to the ECG line.

The guide includes transistors; high-voltage rectifiers and triplers; small signal switching, zener and microwave diodes; rectifiers from 1A to 2,200A; SCRs and TRIACS; thyristors, over-voltage transient suppressors; bridges; optoelectronic devices; linear and digital ICs, both commercial and industrial; peripherals and accessories.

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Electronics catalog
B&B Electronics has announced its Catalog #10. The catalog features stock products as well as custom-designed electronic devices. Included are newly designed and manufactured 4-channel RS-232 to RS-422 converters, 8-channel RS-232 to RS-422 converters, a receive-only RS-422 to RS-232 converter, 10-mile short-haul modems, a serial-to-parallel converter, a 2-position scanning switch and a 2-position serial scanning switch.

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Tool and accessory catalog
Fordham's new 164-page catalog includes approximately 2,000 illustrated items, with specifications and application data for each. Products shown include test instruments and accessories; CATV, CCTV and MATV equipment and accessories; tool uses, tools and assembly aids; replacement components; TV replacement parts and antennas; and an assortment of consumer electronic and entertainment products.

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Cleaner/burnisher catalog
The Eraser Company is offering an 8-page catalog describing its industrial cleaning and burnishing brushes. The catalog includes technical and application data. Included in the catalog are hand-held cleaning brushes, power-operated tools and a range of industrial brush kits for specific applications, such as cleaning gold finger-edge connectors and plastic mold cleaning.

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Test equipment reference guide
A 350-page catalog from Tucker Electronics contains technical specifications and prices for more than 4,000 reconditioned test instruments and factory new instruments, power supplies, coaxial components, waveguides and waveguide components, and a line of technical books. Some items are current production models; others are hard-to-find, older models.

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January 1988
Electronic Servicing & Technology
67
More on audio servos

By Kirk Vistain

Let’s continue with the subject of servos motors in audio equipment. Where were we? Oh, yes, you’ll remember that the servo system used a sawtooth generated by a dc voltage source. It can only be as precise as the voltage source, capacitors and semiconductor circuitry used to produce it.

Practically speaking, performance is quite good, but if you clip a few more hundredths of a percent off the flutter, you might bring the drift (speed variation over a long time period) down to 0.003%. (Remember when we were oblivious to 3%?) For those of you who may have forgotten, in the old days audio specifications functioned as sales tools, and improvements of a few thousandths of a percent also brightened the profit picture for a company.

Enter a circuit that since has become popular throughout audio and video—the phase-locked loop (PLL). Figure 1 represents a simplified version. Notice it has all the necessary elements of a servo: motor, feedback, reference, comparator and drive amp. This time, however, the reference source is an ac signal precisely generated by a stable crystal oscillator. The FG servo discussed last month sampled a ramp voltage with a square wave developed by motor feedback. This circuit directly compares two frequencies or, more precisely, their phase. The result is greater speed accuracy, both short (W&F) and long (drift) term. (By the way, the common advertising jargon for this setup is quartz lock, referring to the composition of the reference crystal.)

Troubleshooting

Fixing these circuits is not much tougher than the FG servo. It just seems that way because the manufacturers often load up their top-of-the-line, quartz-locked units with a host of other features and, of course, a microcontroller or two.

Let’s say the reference source fails. There may be any of several symptoms associated with this, because failure modes are handled differently from unit to unit. It might not start, or it might run off-speed or backward. At any rate, you can check for an oscillation at a convenient low-impedance point, such as pin 3 of the IC in Figure 1, for example. You should see a healthy sine wave, with a peak-to-peak (p-p) amplitude close to $V_c$. Make sure you’re not loading the oscillator to death. Use the x10 setting on your scope probe.

If the signal is missing, you may have a bad crystal, capacitor, IC or something else that doesn’t show on the schematic. You can use a little trick to isolate the bad part, however. There’s usually an RF choke in the $V_c$ line for the PLL chip to keep the clock signal out of the power supply. Most times you can sub it for the crystal and get the oscillator to run, assuming only the crystal is bad. Of course, you must remember to put a jumper in the $V_c$ line to keep power supplied to the IC.

PLL circuits in audio servos tend to be highly reliable. Most problems are mechanical, as in any electromechanical device. I have even heard of a defective platter bearing causing intermittent loss of phase lock. Oddly, the bearing was not noisy.

Some units have what looks like a tape head that senses the flux of magnets built into the inside rim of the platter. This is necessary to produce an adequate FG signal with the slowly revolving rotor. The gap between the head and platter is sometimes quite critical. Too great, and intermittent speed lock occurs; too small, and runout causes mechanical interference, which may damage both head and platter.

Direct-drive brushless motors

For better or worse, most quartz-locked phonographs also incorporate direct-drive motors—that is, the phono platter is the motor rotor. Compared to using a separate motor and belt drive, this scheme has several advantages: There’s no belt to wear out; high-frequency rumble is eliminated; the mechanism has fewer moving parts; and speed control is more immediate. With belt drive, there is usually a slight lag between motor-speed correction and platter speed, thanks to the elasticity of the belt.

Unfortunately, there are a couple of disadvantages that are significant to the serious listener, but don’t show up in the

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Vistain is ES&T’s audio consultant.

Figure 1. This simplified version of a PLL has all the necessary elements of a servo, but the reference source is an ac signal precisely generated by a stable crystal oscillator.
specifications. First of all, isolation suffers, resulting in more susceptibility to acoustic feedback. Second, direct drive tends to produce subsonic noise. Although it is inaudible to most of us, it interferes with some signal-processing circuits, such as the companders in hi-fi VCRs. Thanks to direct coupling and the excellent low-frequency response of modern audio amps, these subsonic signals often make it to the woofers, where they mix with the program material to produce undesirable artifacts.

Theory
In order to directly drive a turntable platter, you have to get rid of the mechanically commutated motor that is common in belt-drive units and cassette decks. It can’t be operated at speeds as low as 33rpm without a pulse-width modulation scheme that would certain-

ly lead to a high-flutter figure unless the platter were unreasonably heavy.

What we need is an electronic analog of the commutator. Key to its operation are the two small blocks labeled H1 and H2. These are Hall effect devices. Each has four electrodes—two for biasing, two for output.

Imagine a uniform rectangular slab of semiconductor material, with current flow induced by a potential applied to the biasing electrodes. Another pair of contacts mounts to either end of the semiconductor, perpendicular to the electron flow. Because the slab is uniform, voltage is the same at both points. There is no output.

Now add a magnetic field at an angle to the movement of the charge carriers. The carriers no longer travel uniformly across the slab, but veer to one side. The resulting output voltage is proportional to biasing current and magnetic flux.

A ring magnet containing several poles (about eight), affixed to the bottom of the platter, rotates above the Hall devices. The varying outputs of the poles control the coil drive amps according to rotor position, causing it to rotate in the proper direction. (Figure 2 outlines the concept.)

Once you know that the power supply is OK, don’t automatically condemn the motor. It’s important to check whether some external control voltage from elsewhere in the circuitry is disabling the drive. You may be able to check the drive coils for continuity, but testing the Hall devices without damaging them is tricky.
**Accessing read-only memories**

By Bert Huneault

This is the last part of a 4-part series on non-volatile memories. Part one covered the basic read-only memory (ROM). Part two discussed programmable memory (PROM) and erasable PROMs. Part three covered read-mostly memory (RMM), which is electrically erasable and programmable.

Although the four types of ROMs differ in how they are programmed and whether they can be reprogrammed, they all share some basic similarities when it comes to reading and writing, or accessing, the memory. In the examples shown here, each has 10 or 11 address lines and eight data pins. The number of power-supply inputs and enable pins determines the size and type of memory.

### Reading from ROMs

Because ordinary ROMs can be read from but not written to, accessing this type of memory is very simple. Figure 1 is a diagram of a 1K x 8 ROM. This chip can store 1,024 data words because it features 10 address lines, A9 through A0 ($2^{10} = 1,024$). The data words are eight bits wide (byte size) because of the IC's eight data pins (D7 through D0).

CE (chip enable) is an active-low control input, as indicated by the overbar as well as by the bubble at the chip's CE input. Therefore, the CE line must go low to enable the chip, causing a read operation. Some manufacturers refer to CE as CS (chip select) or OE (output enable).

To read the information contained at a particular location in the ROM, the address (10-bit pattern) must be placed on the address bus; the CE input is then forced low (grounded) for a moment. This causes the data stored at the specified address to be output via the IC's output pins (D7 through D0). The data then travels along the databus to a microprocessor, peripheral device or whatever. Typical access time for such a read operation is on the order of a few dozen nanoseconds in bipolar ROMs.

When CE returns to the high state, the chip's outputs are disabled—the eight output lines return to the high-impedance state, effectively disconnecting the ROM from the databus.

### Readin' and writin'

Accessing EPROMs is a little different, because you can write to and read from an EPROM. Figure 2 is a diagram of a commercially available EPROM, type number 2816. With 11 address lines and eight data lines, it has a capacity of 2,048 8-bit words ($2^{11} = 2,048$); in other words, it can store 2kbytes.

**Figure 1.** With only one enable pin (CE, chip enable), the ordinary ROM can be read from but not written to. Ten address lines gives it a 1Kbyte memory.

**Figure 2.** The EPROM has two enable pins (CE and OE, or output enable) and two power-supply inputs, which allows data to be written to memory.

**Figure 3.** Three control lines (CE, OE and WE, or write enable) make several combinations of control logic, including single-byte erasure, possible for the EEPROM.
Note that the EPROM has two power-supply inputs, \( V_{cc} \) and \( V_{pp} \), and two control inputs, OE and CE (both active-low). OE controls the output buffers and determines whether EPROM data appears on the data lines.

To read data stored in the EPROM, the following conditions must be met:
- \( V_{cc} \) and \( V_{pp} \) terminals must both be connected to +5V.
- The address must be input via the address pins.
- CE must go low.
- OE must go low to enable the output buffers in the chip, allowing the stored data byte to be output on the data pins.

For a programming operation (to write new data into any one of the memory’s 2,048 address locations), the EPROM must have been erased with UV light to render it clean. Then:
- \( V_{cc} \) must be connected to +5V.
- \( V_{pp} \) must be connected to +25V.
- The address must be applied to the address pins.
- The 8-bit data word must be applied to the data pins.
- OE must be high (+5V) to convert the data pins into inputs rather than outputs.
- A 50ms positive pulse (+5V) must be applied to the CE control pin. By the time this pulse ends and CE returns to the low state, the selected address location will be storing the applied data byte.

Erasing one byte at a time
Accessing an EEPROM is quite similar to reading from or writing to an EPROM; of course, the EEPROM is electrically erasable rather than UV erasable. Figure 3 shows a type 2816 EEPROM, which is compatible with the 2716 EPROM.

Note that the EEPROM has an extra control pin: WE (active-low write enable). With three control lines, several combinations of control logic are possible, each one resulting in a different mode of operation. For example, for a read operation, CE and OE must be low, and WE must be high. To write a byte into a specified address, CE and WE must be low, and OE must be high. To place the chip’s data lines in the high-impedance state, CE must be low, and both OE and WE must be high. Other combinations of control-bus logic are used for byte-erase and chip-erase operations. The chip-erase mode has the same effect on the EEPROM as ultraviolet erasure has on an EPROM.

Although we’ve come a long way since the days of magnetic core memories—today’s solid-state memories are nothing short of phenomenal in terms of capacity and speed—the future undoubtedly has much more in store.

Huneault is an electronics instructor and head of the REE department at St. Clair College of Applied Arts & Technology.
The Newvicon pickup tube

By Conrad Persson

Home video has become so popular and affordable that more and more households are equipped with not only VCRs, but with video cameras as well. In order to understand the theory of operation for a video camera, it is essential to understand the operation of the pickup tube. One of the frequently used pickup tubes in consumer video cameras is the Newvicon tube. The theory of operation of this device, adapted from the 1984 GE Technical Training Manual for VCRs and Video Cameras, follows. (See Figure 1 for a cutaway drawing.)

Conventional electromagnetic focus/deflection pickup tube systems use external focus coils that form electronic lenses in the pickup tube, allowing the dc current to flow in the coils so that the beams are focused on the target. However, the new electrostatic focus system uses internal electrodes to focus the beams on the target, thus reducing power consumption. (Figure 2.)

The electronic beam is accelerated by grids G2, then passes through the beam-limiting aperture in order to generate fine-diameter beams. These beams are then focused by the electrostatic lens, composed of G3, G4 and G5. Grids G5 and G6 form a collimating lens, through which the beams are deflected so that they always hit the target at the proper 90° angle. This improves the resolution around the edges of the pickup tube.

The lens, located in front of the pickup tube, gathers the light from the scene and focuses it onto the face of the pickup tube. There, a photoconductive layer creates a large number of individual target elements. These elements are made up of electrostatic capacitance paralleled by light-dependent resistance, forming an RC time constant. (See Figure 3.)

The electrostatic capacitance is basically formed between the glass faceplate and the back surface, where the photoconductive layer acts as a dielectric. The target elements are all connected on one end to the signal electrode. The other end is unterminated and ready to receive the beam.

When there is no light striking the faceplate of the pickup tube, the light-dependent resistors create a high resistance. Whenever light hits the face of the target area, the resistance drops; the level depends on the amount or intensity of the light.

When a positive voltage is applied to the target, all the RC networks or elements charge as the beam first scans the target area.

When the beam is not in contact with the target element, the capacitance will slowly discharge through the light-dependent resistor connected across it. Keep in mind that each element's resistance will vary depending on the light level. On subsequent scans of the beam, the capacitors will recharge back to the target potential. It is this charging current that is sensed to produce the video signal. When the beam scans the target, electrons are deposited on the positively charged areas, which will return them to the negative potential of the cathode. This produces current, which flows through the external signal-developing resistor RL (Figure 4).
Quiz answers

Questions are on page 60

1. B. 4ms. Rise time is measured from the point where the curve is 10% of maximum to the point where the curve is 90% of maximum. Note that maximum is 0.5V, so the 10% point is one-half of the first vertical division.

2. C. 10MHz. Note that the vertical axis is marked in volts rather than power, so the 1/2-power points have nothing to do with this problem. Bandwidth is also taken between points that are 0.707 times the maximum voltage.

3. C. 3.3V. There is a series-parallel circuit between the +5V terminal and common. It can be redrawn as in Figure 6. The voltage can be found using the voltage divider calculations as follows:

\[ V = \frac{5 \times (470)}{705} = 3.33V \]

4. C. Parasitic oscillations can damage circuit components. The ferrite bead acts as an inductor that offers a high impedance to parasitic oscillation frequencies.

5. B. The Wheatstone bridge circuit is composed of resistors, and they do not have the capability to improve the sensitivity of the measurement.

6. D. A delay condition. The logic probe does measure the other three conditions.

7. A. The z-axis intensity modulates the beam. In other words, it turns the beam off and on, which explains why only parts of the waveform appear.

8. A. Positive. Note that the top view of Q_1 is shown on the board. The drain (at the top) gets its positive voltage through R_3.

9. A. The source resistor is R_1. Note that it is connected directly between the source and circuit common. Because the input signal is across this resistor and the gate is common (because of the presence of C_1), it follows that Q_1 is a common gate amplifier.

10. B. True. There is no power dissipated in purely inductive and purely capacitive circuits. Of course, they exist only in theoretical problems. In the real world, both have resistance.

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One of the easiest, fastest, and surest ways for you to preserve the pedigree of the Zenith products you service and maintain is with genuine Zenith replacement parts.

And at no time is this more critical than when you replace the more sophisticated components like modules, tuners, channel selectors and sub-assemblies.

Your participating Zenith parts distributor will supply you with a replacement remanufactured, reconditioned and serviced for reliability by Zenith people as dedicated and knowledgeable as those who made the original.

Equally important, the replacement module or sub-assembly you receive in exchange from your Zenith parts distributor will most likely incorporate Zenith factory modifications, if any, in effect at the time of remanufacture.

And nowhere else but in a participating Zenith parts distributor's Exchange Program can you get assurance that a replacement incorporates a Zenith factory up-date if one exists!

That's why you should start taking advantage of your Zenith parts distributor's R&R Exchange Program now.

We'll help you locate the Zenith R&R Exchange Counters in your area if you'll write on your company letterhead with your complete address element and Zip Code.

Chances are there's an Exchange Counter for Zenith factory-fresh replacement modules and sub-assemblies closer than you realize.

Write, if you don't know, and we'll tell you where it is! There's no sense risking an exchange for a Zenith replacement anywhere else!