The how-to magazine of electronics...

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ELECTRONIC Servicing & Technology

September 1987/$2.25

Don't let shutdown circuits shut you down

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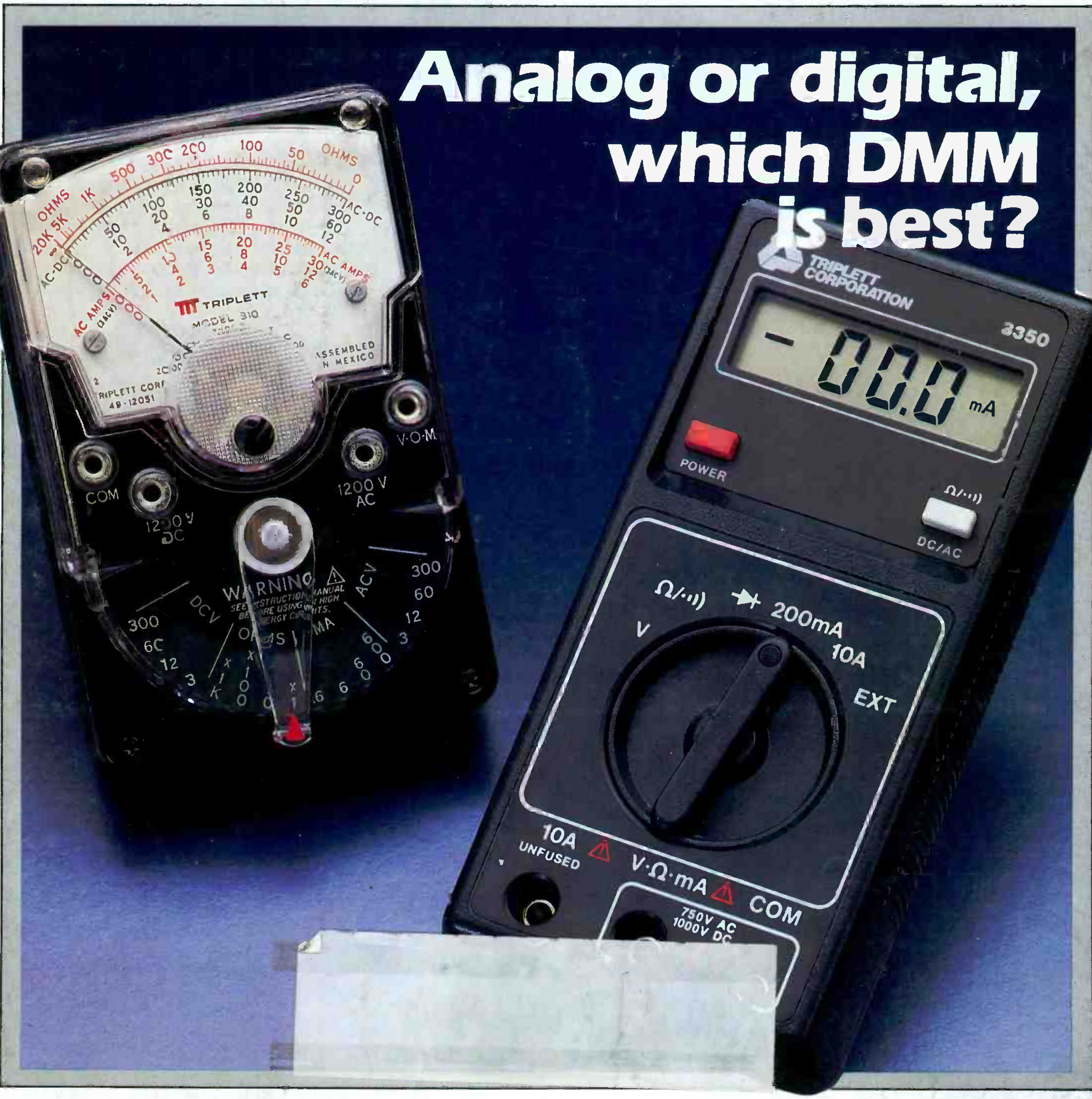
Analog or digital, which DMM is best?



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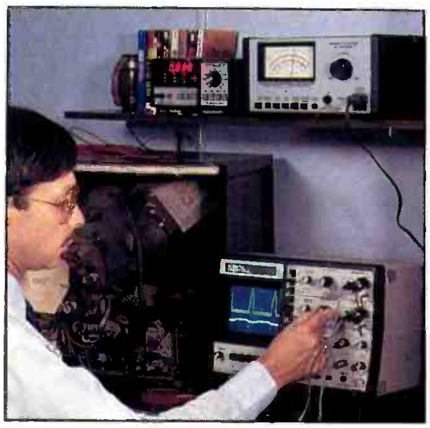
Circle (3) on Reply Card

The how-to magazine of electronics...

ELECTRONIC Servicing & Technology

Volume 7, No. 9 September 1987

page 10
The main advantage of the digital multimeter is its easy-to-read display.



page 18
Shutdown circuits can be complicated to troubleshoot, but once you know how they work, you can quickly zero in on the problem.

Departments:

Helping us help you

Consumer electronics technology continues to advance at a breakneck pace. Not only are manufacturers producing a stream of new products, such as digital audio CD players and, more recently, digital audiotape, but the technology of the old standbys, such as television and stereo, are constantly being updated.

Take, for instance, one of today's high-end TV sets. You'll find it full of integrated circuits that give it excellent picture quality and allow you to tune the set remotely or view a program from one channel inset with a picture from another channel. These modern sets have startup and shutdown circuitry that provide additional safety factors.

All of this new technology is of great benefit to consumers, but it frequently causes additional problems for servicing technicians. When a TV set fails, for example, is it a simple problem with one of the TV circuits, or did something trigger shutdown? Or did the startup circuitry fail to operate properly for some reason? What's inside one of the ICs, and how do you tell when one is malfunctioning? And how does that digital circuitry operate?

These questions and more have been asked by readers in letters, in phonecalls and in some of the questionnaires we have included in past issues of ***ES&T***. One of this issue's articles, "Don't Let Shutdown Circuits Shut You Down," is in direct response to an overwhelming number of reader requests that we publish articles on that subject. In the future we'll be running more articles on subjects that have been specifically requested by readers.

This issue presents an especially good opportunity for readers to tell us what kind of articles they want to see in ***ES&T***. We are, at this moment, planning the articles that will be published next year. To help us find out what articles *you* want, we're running a special questionnaire on one of the pages of heavier paper in this issue, page 45. The answers to that questionnaire will provide us with important information about you and your information needs. Won't you take just a moment to complete that questionnaire?

Another important source of information that helps us know more about our readers is the Reader Service card in every issue. It gives you a convenient way to request additional free information from advertisers or companies whose products or literature are mentioned in the issue, and it tells us more about you: the type of business you're in, your position, the type of work you do. This information is also vital to us in planning what types of articles to publish. If you do send in a Reader Service card, won't you fill out those spaces and tell us that valuable information?

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Below that is another space where you can tell us what kind of articles you'd like to see in future issues of ***ES&T***. In the past, comments in that space have led to specially commissioned articles about frequently requested information. Tell us what you want to see and we'll try to oblige.

Readers' Exchange

Readers' Exchange is a free service that we provide to ***ES&T*** readers. Judging by the number of items we publish each month, it's a popular service. It allows readers to contact each other in order to buy and sell equipment and share information.

If you wish to make use of this service, there are only two things we ask: 1) Please limit your For Sale or Wanted items to only three. Space in the magazine is limited and we can't possibly publish someone's long list of items. 2) Please type your Reader's Exchange items when possible, and if that isn't possible, please print carefully and legibly. Please spell out names of manufacturers and products, and if there's any possibility of miscommunication, please provide any clarifying remarks that might be necessary. If we can't read an item, we'll return it and ask that it be resubmitted, and that wastes your valuable time.

Nils Conrad Persson

News

DAT legislation on hold

In response to the controversy surrounding digital audiotape (DAT) recorders and the CBS anti-taping chip's audible distortion of music, the congressional committee studying the problem has asked the National Bureau of Standards (NBS) to test the chip. NBS is expected to conduct the test within the next few months. CBS has refused to release the exact specifications of its system unless assured that NBS will keep them confidential.

In a related development, the Home Recording Rights Coalition (HRRC) has been joined by several recording artists in the fight against legislation that would prohibit for three years the U.S. manufacture, sale, resale, lease or distribution of DATs that do not contain an anti-taping chip.

EIA publishes consumer electronics sales figures

Sales of color televisions expanded during the first half of 1987, according to the Electronics Industries Association (EIA), Washington, DC.

Color TV sales to U.S. dealers totaled nearly 8.8 million units during the January to June period, as compared with 8.1 million during the first half of 1986. June sales topped 1.7 million units, a 10% improvement over the same month last year. EIA predicts that at least 18.3 million color sets will be sold in 1987, which would make this the biggest sales year in the product's history.

In terms of percentage growth, however, the hottest video hardware product is the camcorder (camera/VCR combinations for family movie-making). For the first six months of this year, camcorder sales totaled more than 580,000 units – a 49% jump over the same period a year ago.

For the first half of the year, almost 5.7 million videocassette recorders (VCRs) were sold to dealers, off fractionally (0.5%) relative to the January to June 1986 period. EIA predicts that 13.7 million VCRs are likely to be sold during 1987, which by year's end will extend VCR penetration to 50% of the U.S. households.

Consumer electronics sales
June 1987 vs. June 1986

	Jan.-June 1987	Jan.-June 1986	Percent change
Color television	8,768,844	8,113,441	+ 8.1
B&W television	1,415,623	1,744,956	– 18.9
VCRs and camcorders	5,690,707	5,716,562	– 0.5
Camcorders only	583,229	390,929	+ 49.2

ES&T

The how-to magazine of electronics

ELECTRONIC Servicing & Technology

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ELECTRONIC SERVICING & TECHNOLOGY is the "how-to" magazine for technicians who service consumer electronics equipment. This includes service technicians, field service personnel and avid servicing enthusiasts, who repair and maintain audio, video, computer and other consumer electronics equipment.

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RT Check out these features & prices. WOW! FL

B&K-PRECISION'S new 2905 is a more-than-full-feature 3½ digit DMM, at a surprisingly low price. Features include 0.5% VDC accuracy; 100 µV, 0.1µA, 0.1Ω, resolution. Measures capacitance to 20mF with up to 1pF resolution. Audible continuity and diode junction tests are built in. For field survivability, it features a drop resistant case, reverse polarity and overload protection and high-energy fusing. Contact: B&K-PRECISION, 6460 W. Cortland Street, Chicago, IL 60635 (312) 889-9087.

FREQUENCY COUNTER AND DATA HOLD HIGHLIGHT NEW 4½ DIGIT DMM

For engineers in need of a high-accuracy 4½ digit DMM and a low range frequency counter the 2940 is made to order. DC voltage accuracy is 0.05%. Resolution is 10µV, 10nA, and 0.01Ω. Frequency measurements span from 20Hz to 200kHz with up to 1Hz resolution. The 2940 features a drop resistant case with full internal circuitry protection. $155.00 Contact: B&K-PRECISION, 6460 W. Cortland Street, Chicago, IL 60635 (312) 889-9087.

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The new 2906 3½ digit DMM from B&K-PRECISION is virtually a hand-held test bench, with a remarkable range of functions. °C and °F temperature measurements cover from −20C to 1000°C. The logic capability is ready for TTL and CMOS circuits. Other features include drop resistant case, reverse polarity and overload protection; plus high-energy fusing. DC accuracy, 0.25% VDC. $95.00 Contact: B&K-PRECISION, 6460 W. Cortland Street, Chicago, IL 60635 (312) 889-9087.

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3½ digit true RMS handheld DMM featuring 0.1% DC accuracy. Housed in an ergonomic, drop-resistant case, the 2907 offers many functions and a low price. Resolution is 100µV, 0.1µA and 0.1Ω. Capacitance to 20µF with 1pF resolution. Peak hold feature freezes transient readings. Fully protected. Also checks logic, continuity and diodes. $190. Contact: B&K-PRECISION, 6460 W. Cortland Street, Chicago, IL 60635 (312) 889-9087.

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The new 2945 is well suited for both the analog and digital worlds. DCV accuracy is 0.05%, with 10µV, 10nA, 0.01Ω resolution. Data hold freezes voltage and current readings. °C and °F temperature readings are from −20° to +1000°C; frequency from 20 Hz to 200kHz. AC voltage and current are read in true RMS. Also checks continuity and diodes. $250.00 Contact: B&K-PRECISION, 6460 W. Cortland Street, Chicago, IL 60635 (312) 889-9087.

Circle (42) on Reply Card

Analog or digital, which DMM is best?

It depends on what you'll use it for

By Mike Hahn

Analog VOMs long have been used in the repair and maintenance of consumer electronics products. However, developments in digital meters and in the equipment to be serviced have eroded the foundation of the analog meter. There are still applications, however, in which analog meters excel. Before examining these areas, I'd like to give an overview of the current state of digital and analog products.

Hahn is manager of test and evaluation at Triplett.

Although commercial-grade instruments were available to the industry in the early '60s, digital meters for use in servicing consumer electronics products were not abundantly available until the late '60s and early '70s. These meters initially resembled their analog counterparts in both form and function.

Several restrictions did apply, however. These early DVMs were tied to a 110Vac power cord. They had limited resolution (about 2½ digits), were not very reliable, and often behaved unpredictably. DVM portability was achieved by using power inverters to raise battery voltages up to the potentials required to operate nixie tubes. Considering these limitations, analog meters had the edge.

In these "medieval" times, meter circuitry was usually discrete, being overpopulated with resistors, capacitors and transistors. Some designs compressed the components into standing-room-only areas, which made the circuit boards look as if they were covered with miniature cordwood. Integrated circuits gradually reduced the component count by replacing sections of the analog front-end with op-amps and sections of the digital circuitry with RTL and DTL logic devices. Similarly, the 3½-digit voltmeter came into being.

Although modernized, today's 3½-digit meter is much the same in concept as its predecessors. The slope integration technique, then and now the typical method of measurement, was reduced to microchip and resulted in *voltmeter-on-a-chip* ICs. The large majority of 3½-digit meters manufactured prior to about 1980 were based on these chips. Consequently, most digital meters from that era bear very similar characteristics, the most notable being the familiar 200mV basic range with 2,000-count resolution. All higher ranges fit this form with a simple 10:1 resistive divider between the ranges. An instrument with readouts of 0.2V, 2V, 20V and 220V is common.

In search of new capabilities, several meter manufacturers moved into custom LSIs. True rms ac circuitry became possible when Analog Devices developed a chip that contained all the necessary circuitry. Coincident with these developments, offshore competition, mostly from Japan, was becoming a threat to American manufacturers. Many American digital meter manufacturers, unable to compete with the offshore products, simply began marketing the offshore products, with new labels bearing the American companies' logos.

American vs. Japanese

The outcome of this situation is a schism in product offerings to service and repairmen. Today, digital meters, with few exceptions, are manufactured offshore. These products often use a chip set developed in Japan. As with the American voltmeters-on-a-chip, these Japanese chips also are recognizable by their behavior. They are 3½-digit voltmeters with autoranging and extremely high impedance on the dc basic range. Because these chips have some features that can be programmed during manufacturing, some variations exist, but in general the chip architecture limits the amount of customizing that can be done, and consequently most of the products incorporating these chips behave similarly.

So, on the one hand we have the digital meters based on Japanese chips, and on the other hand we have American meters based on American standard ICs or custom ICs. The two groups are outwardly recognizable by the features on the meters. Of course, this basic division of meter types does not include all of the myriad possibilities. There are some offshore meters using American chips and some American meters using what appear to be Japanese chips.

New features

Meters with 4½-digit resolution also are commonly available. Again, there are American chips and Japanese chips to accomplish this function. One interesting 4½-digit, hand-held meter provides autoranging in volts and ohms as well as true rms ac, a built-in frequency counter, a digital thermometer, a continuity beeper, a dBm range, RELative measurements, Data Hold and Peak Hold.

The A/D converter is also a 25,000-count unit, as opposed to a 20,000-count unit. This allows the

Digital multimeters

- A 3½-digit or 4½-digit meter usually is adequate. Choose one that has the greatest number of counts on each range, as this increases the accuracy and resolution.
- μP-controlled meters often offer additional features such as autoranging and a variety of measurement functions.
- Particularly useful when troubleshooting linear ICs, they are even more useful when used in conjunction with an oscilloscope.
- Unless they are adequately shielded, they usually are susceptible to interference from extraneous noise sources.
- DVMs offer 10MΩ or more of input impedance.
- Their price ranges from $30 to $700 for general-purpose troubleshooting.

Analog multimeters

- They are subject the destruction of meter movement because of excessive current flow through the circuitry. Choose one that offers a lot of input protection.
- Usually the least susceptible to interference from extraneous noise sources, they can malfunction around an RF transmitter.
- Because of their lower input impedance (50kΩ/V) and consequent ability to inhibit noise pickup, they are often the best choice for servicing appliances.
- Incorporating multiple scales, they make several related readings available simultaneously.
- Their built-in electromechanical integration smooths jittery readings.
- They vary in price from $10 to about $400.

meter to measure with 5½-digit resolution (when compared to a 200,000-count, 5½-digit meter) between 20,000 and 25,000 counts. For example, a 20k count voltmeter would measure 2.2 volts as 2.200V (1mV resolution). A 200k count voltmeter would measure 2.2 volts as 2.2000V (100μV resolution). A 25k count voltmeter would measure 2.2 volts as 2.2000V (100μV resolution), or with the equivalent resolution of a 5½-digit, 200k count meter.

A more sophisticated benchtop meter has these capabilities and more. Among its features is the user-definable *comparator*. This feature allows the user to select, via the keyboard of the meter, acceptable limits to an anticipated measurement. A simple example of such a function would be the sorting of resistors for a particular value. The meter could be set to accept only 10,000Ω ±0.1% resistors. When various resistors are connected to the meter, the meter's display indicates the resistor's value and informs the user, via annuciators in the LCD display, whether the resistor is high or low in value or is within the acceptable limits. If the resistor is acceptable, a beeper sounds. So, resistors easily can be graded as to their value. The high and low signals, as well as the *go* (acceptable) signal is available on the back panel of the meter so that external equipment, such as a sorting gate, can be controlled.

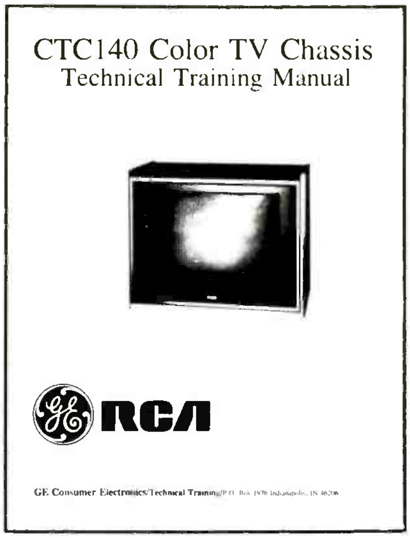
Similarities/differences

Several basic similarities exist among hand-held digital meters. The LCD has displaced all other technologies for readout display, primarily because of LCDs' low power consumption, which greatly extends the battery life of hand-held meters. The LCD also allows manufacturers to customize the aesthetics of their particular product by providing specialized displays for various measurement functions. Perhaps the most flamboyant display of this ability is found on a French meter that generates an analog-like meter scale on the LCD.

Another similarity exists in the method of powering hand-held meters. Most fall into one of two categories, either 3V power (from two AA or button cells) or 9V power (from a standard 9V transistor radio battery). The battery life is usually somewhere between 200 and 2,000 hours. Most meters are limited to a 1,000Vdc input or 750Vac input. In fact, examination of hand-held meter specifications will undoubtedly reveal more similarities than differences. Again, this results from the chips used to construct the meter.

Some differences are noted in available features. The ability to measure transistor gain and capacitance or to act as a logic probe is found on some meters. In general, these features, when included in a DMM, do not perform as well as a product dedicated to performing these tasks. They are included to broaden the appeal of the product to the user.

Some not-so-obvious differences in meters include the ability to withstand mechanical and electrical abuse. Beckman markets a line of meters advertised as being water- and drop-resistant. This is accomplished with seals and internal supports to improve mechanical stability. Fluke states that a large percentage of the circuitry in its hand-held meters is dedicated to input protection. Typical protection devices include varistors, zeners, current limiting resistors, PTCs, clamp transistors, clamp diodes, fuses, gas discharge tubes and spark gaps.



You are only one manual away from knowing how the new technology in RCA's CTC 140 color TV chassis operates and how to service it!

Some servicers were expecting tomorrow's high-tech color TV chassis to have a lot of technician-obsoleting, expensive black boxes . . . The CTC 140 is a high-tech color TV chassis, but it doesn't have any black boxes. It is a state-of-the-art unitized chassis with advanced technology that can be easily and economically serviced by professional consumer electronic technicians . . . As a professional technician you need to learn how the new technology in the CTC 140 operates and what strategies we recommend you use to proficiently service it. That's why you should buy and carefully read the CTC 140 Color TV Chassis Technical Training Manual. Its price of $19.95 is an excellent investment in professional upgrading . . . And to make the learning easier, we've included the companion Technical Training Workbook content at no extra charge. You get both the manual and the workbook information in one manual for only $19.95.

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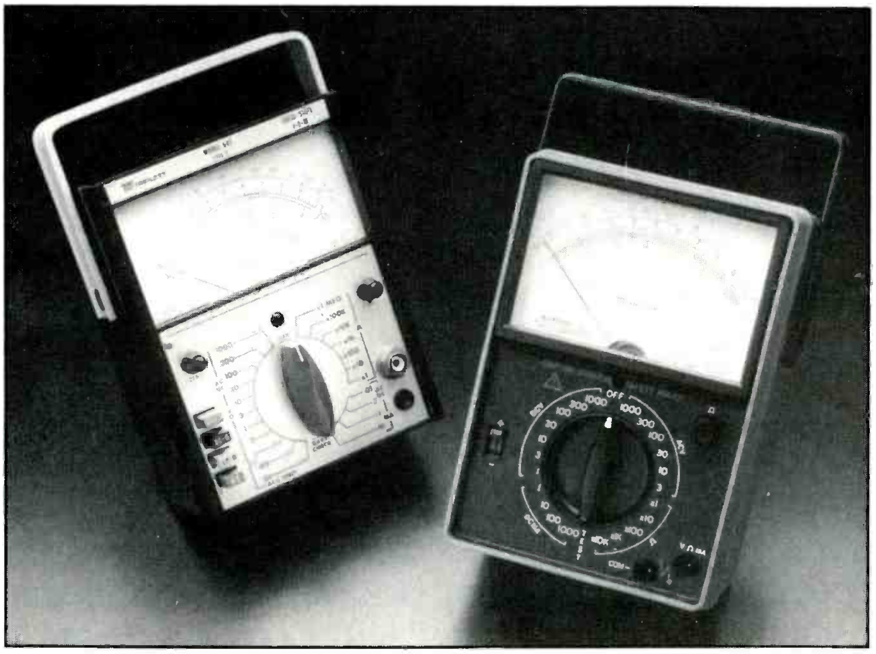

Another area of difference, seldom mentioned, is the product's ability to perform in environments permeated with RF, such as in close vicinity to TV or radio transmitters. Because the hand-held meter's case is plastic, RF susceptibility will be affected by internal shielding and RF noise filtering.

Benchtop service industry meters are quite similar to the hand-held meters in function and often differ mostly in physical form. The most obvious difference is in the type of readout used. Because 110Vac is available to power the instrument, LEDs, gas discharge, fluorescent and Numitron displays may be used in place of LCDs.

Benchtop meters are often, *although not necessarily,* more accurate. Specifications should be examined closely to determine the performance of any product considered for purchase. In 3½-digit meters, accuracy usually varies from 0.5% to 0.1% on dc ranges; 4½-digit meters are usually accurate to 0.05% on dc. Prices range from about $30 for an inexpensive 3½-digit pocket meter to about $700 for a 4½-digit benchtop meter with some additional measuring features.

New ideas in analog

Analog VOMs have remained unchanged in function for years. However, some imaginative ideas have surfaced in their packaging. This is exemplified by the fold-up meter introduced by Metrawatt and later offered by Radio Shack.

Early design goals of analog VOMs centered upon extending the measurement range of the instrument while reducing the loading of the circuit under measurement. This resulted in the *vacuum-tube voltmeter*. The concept, although viable, produced a meter with unusual power requirements (plate and filament voltages) and sometimes bias supplies.

Portable VTVMs used multiple batteries to supply these needs. Some used special batteries that contained all the necessary voltages in one *block* consisting of several types of batteries in a single cardboard container. The modern version of this meter is transistorized or uses ICs. It is sometimes known as a transistorized voltmeter (TVM) or FET VOM.

Another design goal was the development of drop-resistant VOMs. The Triplett Model 60 series is an example of this technology. During in-depth testing, these meters are subjected to several 5-foot, free-fall drops onto a concrete floor. They are expected to survive with only cosmetic damage.

Perhaps the most devastating failure that can befall an analog VOM is the destruction of the meter movement by way of excessive current flow through the circuitry. This happens most often when the user inadvertently applies 110Vac to the X1 or X10 ohmmeter range. The result is a bent meter pointer and some toasted resistors. In an attempt to prevent such failures, most better-grade VOMs incorporate fuses, clamp diodes, zeners, gas discharge tubes or relays to limit or prevent damage.

Analog vs. digital

The cost of digital and analog meters overlap each other, inasmuch as prices range from $30 to $700 for a digital and $10 to $400 for an analog model. This can complicate choosing which meter to purchase. Following are some guidelines.

First of all, as with all products, manufacturers try to convince users that newer is better. Although there is a certain amount of truth to this claim, one should be aware that not all innovations can be used effectively for all types of electronic servicing. A case in point is the analog vs digital controversy or old-against-new technology.

For years, servicing of household appliances relied on measurements taken with non-electric analog meters. Most of the voltages measured were 110Vac, 220Vac or 24Vac. About the only resistance measurements necessary were continuity and leakage resistance from the electrical components to the case of the appliance. Analog meters served this purpose well and they continue to satisfy the test requirements. On the other hand, digital meters or electronic VOMs actually can deceive the user. Because of their high input impedance, these meters will measure stray 60Hz noise in the air, producing readings of voltage when connected to de-energized open lines. This can be misleading to someone unfamiliar with this type of instrument.

Although appliances are using more and more electronics, most service technicians who work on this type of product consider the electronics as replaceable modules. It is therefore unnecessary to have a meter capable of troubleshooting electronic circuits. Given this criterion, a non-electronic analog meter is the best choice. It is easy for the user to understand, and it creates the fewest measurement eccentricities.

Consumer entertainment electronics, on the other hand, poses a different problem. Present designs rely on precision voltages, currents and resistances. Troubleshooting this type of equipment requires a meter with accuracy and resolution. Although a 3½-digit meter is adequate in most cases, 4½-digit meters offer a greater level of confidence in measurement accuracy. This is particularly true when measuring voltages around an IC or tuning voltages in a voltage-tuned RF stage. As with all electronic troubleshooting, it is not wise to rely upon one source of instrumentation. A good meter is the basis of a technician's required equipment, but an oscilloscope is just as useful, and in many cases, more useful. Try to troubleshoot a digital circuit without a scope!

Drawbacks with digital

Still, there are times when servicing consumer equipment that a digital meter is a hindrance rather than a help. A digital meter is useless for measuring quantities that change quickly over a large range of amplitudes. The user would see a constantly changing group of numbers on a digital meter. An audio voice or music signal is a good example of such a quantity. Analog meters, called VUs (volume units), were developed years ago to measure audio signals of this type. They have standardized sensitivity and ballistic characteristics that define how the meter must respond to constantly changing complex signals.

Digital meters are also a nuisance when trying to peak or null a circuit. This situation might arise when you attempt to align tape heads or an RF circuit. Although it is quite easy to understand how an analog meter shows a peak or null, these types of measurements on a

digital meter require the user to calculate mentally whether a reading is greater than or less than the previous reading.

This is relatively simple to do, but it does represent additional mental fatigue if the user is performing such measurements continually. Makers of digital meters have recognized this problem and have introduced models with analog bargraphs in the LCD display in addition to the typical digital readout. Fluke hand-helds are noted for this feature.

The multiple-scale feature of analog meters, although initially confusing to someone not familiar with multimeters, has several advantages. The pointer of the meter intersects all scales simultaneously. It is therefore possible to indicate quantities that change mutually on two different scales, one above the other. For example, when you measure sine waves, rms and peak-to-peak voltages can be shown on the meter dial and indicated simultaneously. Consequently, it is unnecessary to perform calculations to convert from rms to p-p or vice versa. On a meter that measures temperature, Fahrenheit and Celsius can be indicated simultaneously. Resistance and semiconductor material also can be indicated simultaneously.

Analog meters also have some advantages in terms of response time, depending upon the user's requirements. Because of the ballistics of the meter movement, a typical VOM will integrate the signal applied to it. In fact, this property is exploited in the ac circuit of the meter. After rectification of the input signal, there is no capacitive filtering. The meter movement itself, in effect, filters the signal, integrating the signal peaks into a smooth reading. Depending upon the update interval and amount of R/C time constants in the signal chain of a digital meter, the reading may change continuously, never stabilizing.

Personally, I use both analog and digital meters for troubleshooting consumer electronics products, selecting whichever meter best suits my intended use.

ES&T

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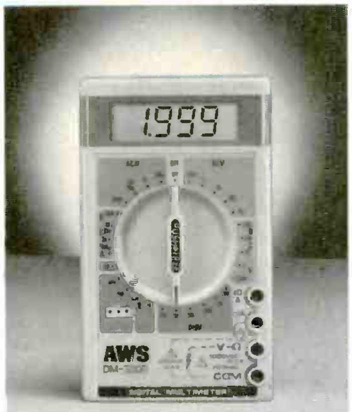

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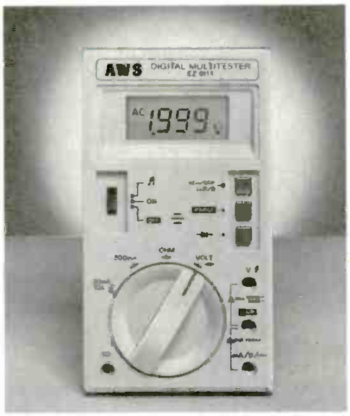

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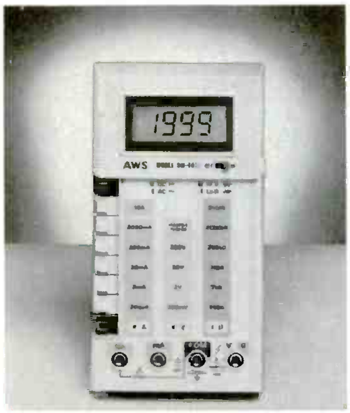

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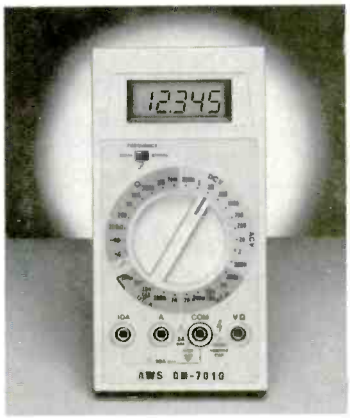

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Circle (10) on Reply Card

Don't let shutdown circuits shut you down

This is the first of three articles explaining how to isolate high-voltage problems related to startup, shutdown and regulator circuits. Troubleshooting these circuits is complicated because all three circuits cause nearly identical symptoms. And, when shutdown happens, it does so in the blink of an eye, leaving you with a dead set and few clues.

Part I covers the safety shutdown circuits. Part II will concentrate on startup circuits and Part III will look at the regulator circuits, which intermingle with the other two. These three articles will combine to give you a full understanding of modern television horizontal output circuits.

Learning how shutdown circuits work and how to diagnose them will allow you to get TV sets back in operation quickly.

By Gregory D. Carey, CET

Shutdown circuits protect the owner of the TV receiver in several ways. First, they prevent excessive x-ray emission if the high voltage goes over its normal limits. Second, they reduce the chance of fire caused by a major failure. Third, they prevent a defect in one circuit from causing damage to other components.

Safety shutdown circuits became popular when manufacturers eliminated the bulky and expensive power transformer. The iron-core transformer developed the many power supply voltages, but it was always a source of wasted energy. However, the transformer also acted like a big sponge to soften surges in the ac line. With the transformer gone, some other means of protection was needed.

The horizontal output stage has suddenly taken over all the responsibility of power distribution and surge protection. The power handled by the flyback and output transistor is increased, because every microampere of current needed to operate the set now comes through them via scan-derived supplies. Surges on the ac line, including those induced by nearby lightning strikes, must now be absorbed by the output stage and its voltage regulator. All these things make the output stage more subject to damage and harder to repair.

The basic operation of the safety shutdown circuit is really quite simple. A circuit senses an electrical parameter such as voltage or current. If the parameter exceeds a safe limit, the circuit interferes with the operation of the horizontal circuits. This sound simple, but there are many factors to complicate matters. The circuits are easier to understand if you look at the different kinds of sensors first, and then look at the different ways the circuits interrupt the horizontal stages.

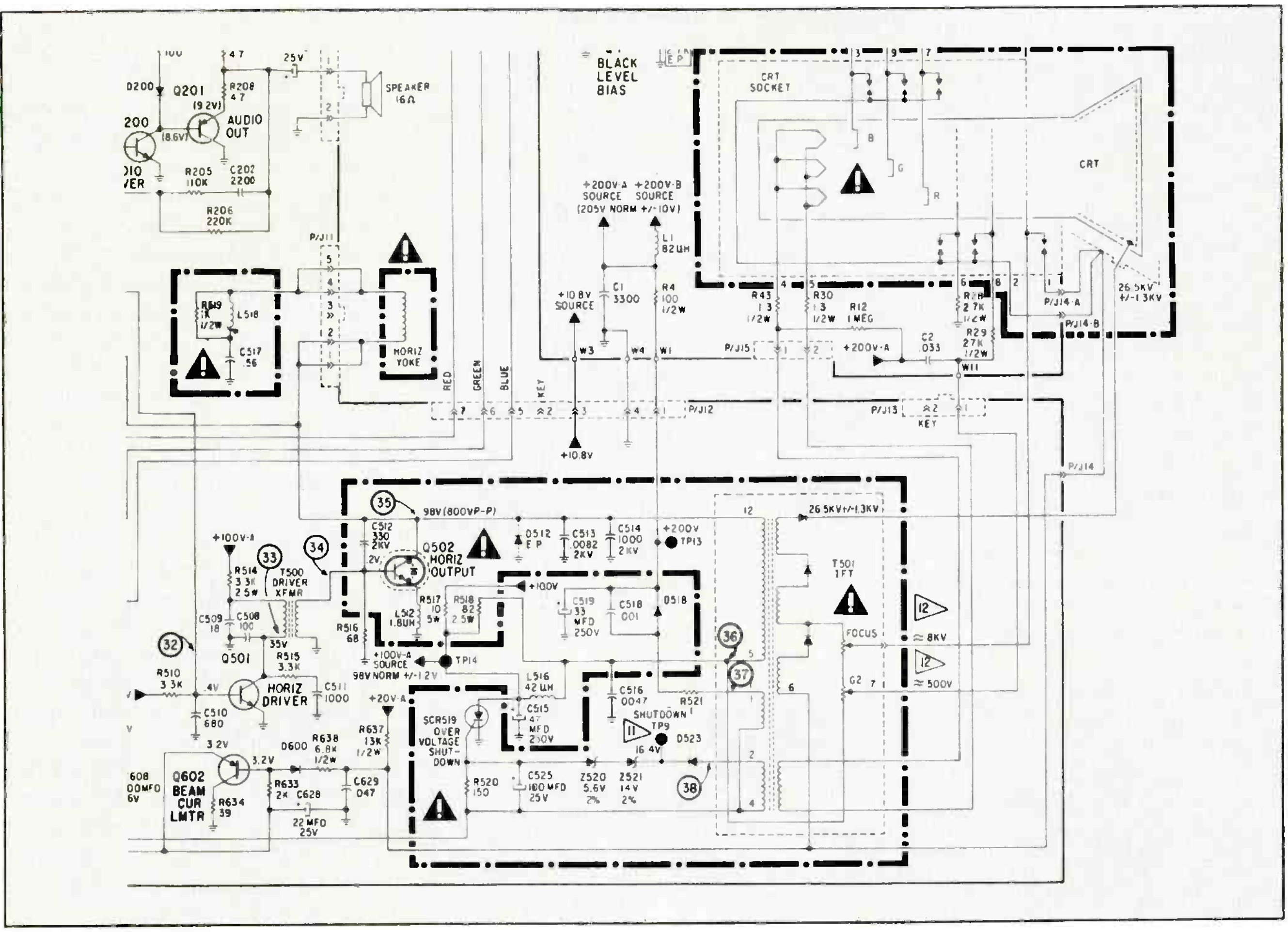


Figure 1. A simple but effective detector consists of a winding on the flyback that feeds to a level detector. This circuit shuts down the set if the flyback pulse is larger than the two zener voltages. *(Schematic diagram courtesy of NAP)*

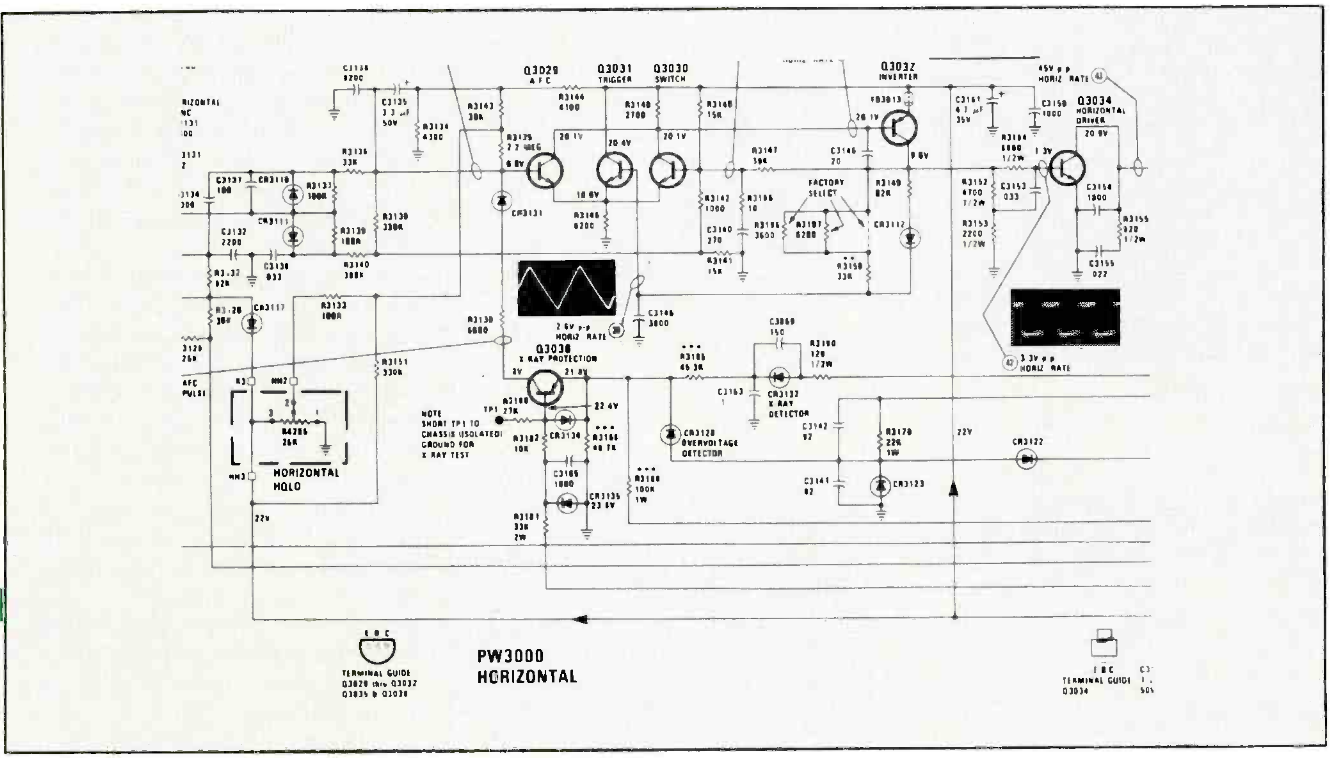


Figure 2. In some chassis, such as this RCA chassis, dc voltage from power supplies, CRT biases and high-voltage returns can be used to trigger shutdown. *(Schematic diagram courtesy of RCA)*

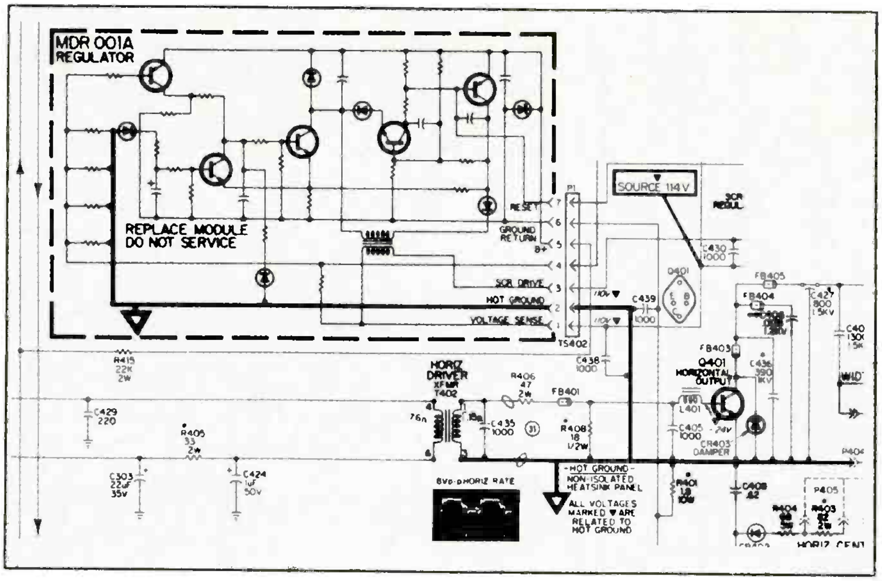


Figure 3. RCA models with a separate hot and cold ground also sense the current in the horizontal output stage by means of the 1.8Ω resistor used as a current shunt. *(Schematic diagram courtesy of RCA)*

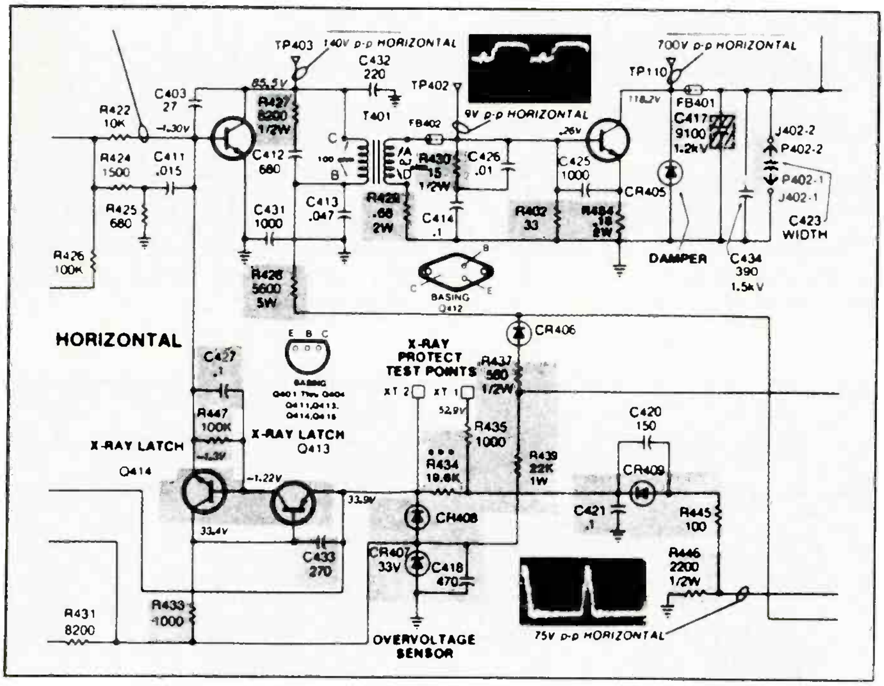
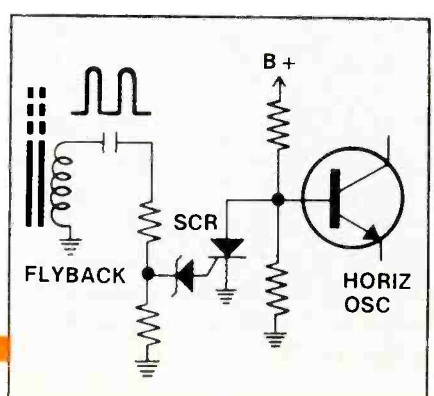


Figure 4. The most common method of shutting down the circuits is to block the drive to the horizontal output circuits. *(Schematic diagram courtesy of RCA)*

Figure 5. Some units use an SCR to short the drive signal to ground when a trigger signal has been applied to its gate.



The sensors

Shutdown circuits need a method of sensing when something has gone wrong. Three methods are commonly used: sensing a flyback pulse, monitoring a dc voltage and sensing the horizontal output transistor current. All these sensors detect whether an ac or dc signal is larger than a particular level. Sometimes a single sensor has inputs from two or three sources, allowing several test points to be monitored simultaneously.

The most common sensor is a winding on the flyback transformer that feeds to a level detector. Excessive amplitude of the pulses from this winding means voltages at the other flyback outputs are too high. Shutdown occurs.

The winding usually connects to a transistor, diode or zener diode that has been biased just below the winding's normal pulse amplitude. If the pulse exceeds the normal level, it causes the diode or transistor to conduct, which in turn activates the circuits that interfere with the horizontal stage.

Figure 1 (page 19) shows a common version of this sensing technique used in the NAP 19C7 chassis. The zener diodes (CR520 and CR512) normally do not conduct because the pulses coming from pin 2 of the flyback are lower than the zener breakover voltage. If the pulses become larger than 19.6V (the two zener voltages), the zeners conduct, firing the shutdown SCR (SCR519), shutting down the output stage.

Safety sensors may also monitor dc voltages. Some RCA chassis, for example, sense a regulated dc power supply, the beam current coming back from the CRT, and the dc at the CRT screen grid. If any of these voltages climbs too high, the set shuts down.

Figure 2 (page 19) shows the method RCA used in the CTC97 chassis to combine a pulse detector and a dc level detector in a single transistor. The dc arrives through the emitter resistor (R3198), which comes from the low side of the high voltage flyback winding. This signal represents the total beam current drawn by the CRT. If the dc is too high, the x-ray protection transistor (Q3080) turns on. The same transistor also monitors two puls-

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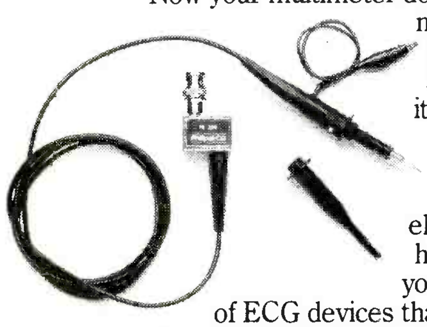

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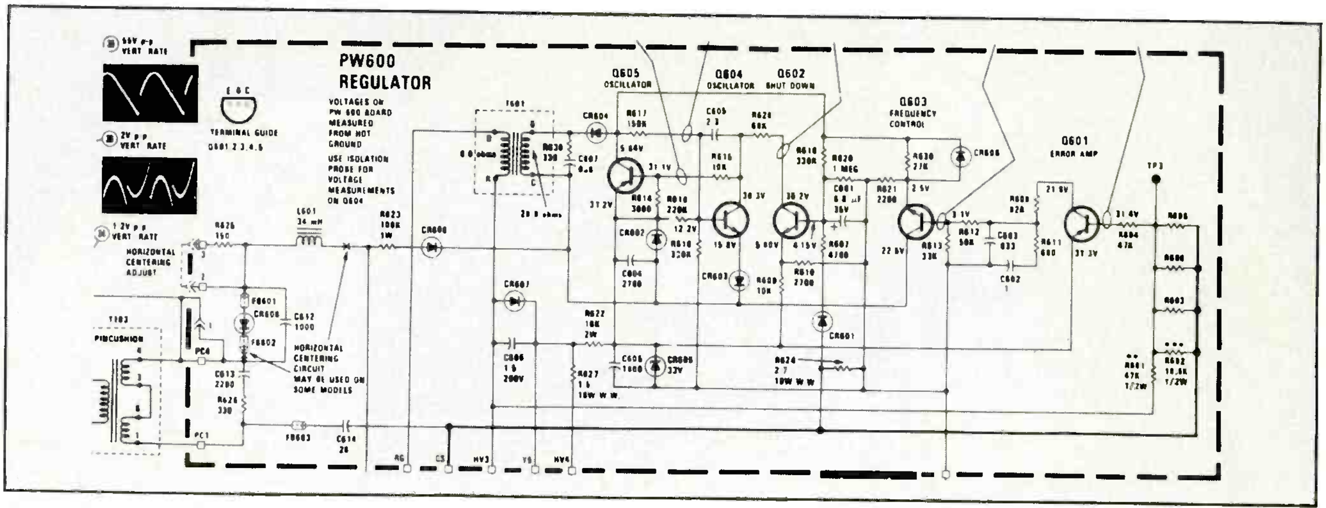


Figure 6. Many RCA chassis also include an extra safety circuit that shuts down the power supply oscillator during some overload conditions. *(Schematic diagram courtesy of RCA)*

es from the flyback, which enter through the x-ray detector diode (CR3132) and the overvoltage detector diode (CR3120). If either pulse is large enough to cause the transistor to conduct, the set goes into its protection mode.

A third kind of sensor monitors the current drawn by the horizontal output transistor. Figure 3 (page 20) shows how the RCA CTC89 chassis does this. The 1.8Ω resistor (R401) is between the emitter of the output transistor and the negative side of its power supply. The resistor acts as a current shunt. If the voltage across the resistor is too high, we know (from Ohm's Law) that the transistor is conducting too much current. There must be something wrong in the output stage, so the set shuts down to prevent damage to other components.

Some receivers use only one of these sensors. If so, it is generally the pulse sensor connected to the flyback winding. Some chassis, however, use two or three sensing methods. Because each sensor may monitor several test points, as many as six different circuits may trigger a shutdown. In any case, the horizontal stage is affected.

Affecting the horizontal

Sensing a problem is only half of the job. The sensor must, in turn, do something to the horizontal circuits to affect their operation. There are three methods used: blocking the drive, interrupting the power supply and throwing the horizontal oscillator out of sync.

The most common shutdown circuit blocks the drive to the horizontal output stage. Figure 4 (page 20) shows how the RCA CTC108 accomplishes this. If the safety transistor (Q414) is turned on, it drives the horizontal driver (Q411) into saturation, which blocks the output of the horizontal oscillator. Some chassis may use an SCR in a similar manner, where the SCR diverts the drive signal to ground, as Figure 5 (page 20) shows.

The second kind of shutdown circuit interrupts the power supply. RCA blocks the oscillator that operates the regulator oscillator, as Figure 6 shows. The NAP 19C7 chassis shown in Figure 2, by comparison, uses an SCR to divert the power around the output circuit in a crowbar fashion. If the SCR (SCR519) turns on, it grounds pin 5 of the flyback, which is the B+ source for the output stage.

The third method was used by RCA for many years (see Figure 7, page 24). Instead of shutting down the chassis, it only throws the horizontal circuits a long way off frequency. This may not seem effective, unless you remember that the amount of high voltage depends on the repetition rate of the flyback stage. Lowering the operating frequency prevents the voltage from getting too large. It also ensures that the set's owner will seek service, because adjusting the horizontal hold control has no effect on the picture.

Sets that use the out-of-sync scheme often include additional shutdown circuits as well. Some problems trigger the circuits that cause complete shutdown; other problems cause the horizontal to operate at the wrong frequency.

What causes shutdown?

A few circuit failures cause most shutdowns and would cause unsafe conditions if allowed to continue. Knowing these causes helps you find the shutdown problem faster.

Defective voltage regulators are common causes of shutdown. Regulators commonly short, applying raw dc to the output transistor instead of the reduced dc that should be there. If allowed to operate like this, the high voltage would rise dramatically. If, for example, the set normally uses 30kV, a shorted regulator may produce voltages of over 40,000V. X-ray emission may double, arcing may occur and the yoke or flyback may burn out.

High voltage may also rise if capacitance between the emitter and the collector of the horizontal output transistor becomes too small. Some sets use a single *safety capacitor*, while others use several capacitors in parallel. A single capacitor may change in value, or one of the multiple capacitors may open. (See Figure 8, page 50.)

Reduced capacitance causes the flyback pulse to become too narrow. Because the high voltage is based on the *rate of change* of the

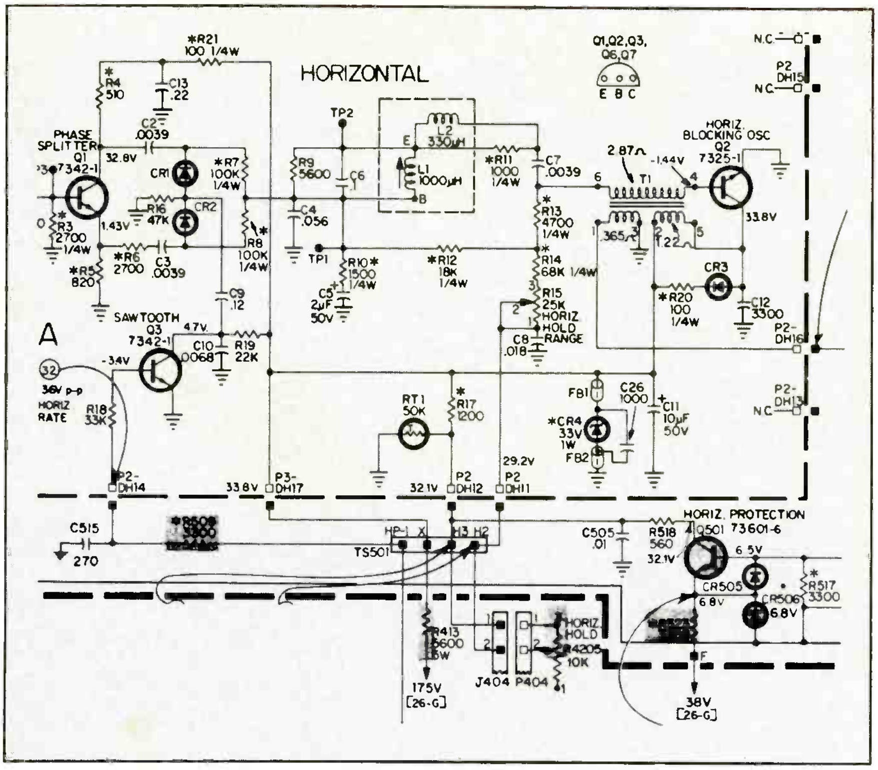


Figure 7. Many older RCA chassis had a third type of safety circuit that applied dc to the horizontal oscillator frequency control in order to shift its operating frequency. *(Schematic diagram courtesy of RCA)*

flyback current, a narrow pulse causes the voltages to rapidly increase.

If one of the flyback loads opens, the voltages at the other flyback outputs may increase. This is especially true if the open load normally carries heavy current, such as a power supply for the vertical output or the video output stage.

Sometimes the problem is in the shutdown circuits themselves, leading to nuisance shutdowns. A critical component, such as a transistor or SCR, may short, causing the chassis to shut down every time it is turned on. Or a zener diode may change in value just enough to cause random shutdowns. In such cases, the set may work for hours or even days at a time and then shut down for no apparent reason, or the chassis may work at reduced ac line voltage, but shut down when the voltage increases.

Continued on page 50

Literature

Test equipment catalog

Leader Instruments has published a test and measurement instrument catalog that details features, specifications and applications on more than 100 products, including 18 new products. Equipment available through the catalog includes oscilloscopes, signal and NTSC pattern generators, waveform monitors and power supplies.

The catalog also includes a section providing information on programmable RGB generators, designed to meet manufacturers needs for testing and aligning high-resolution RBG video and computer monitors.

Circle (125) on Reply Card

Relay guide

Philips ECG has released a pocket-sized relay selector guide that describes the company's electromechanical and solid-state relay devices. The 75-page guide provides all the information necessary to quickly and accurately identify the correct replacements for a wide variety of relays. Pictorial and tabular selector guides present different relay case styles and basic parameters in a quick-reference format. A 2-part cross-reference section contains industry part numbers sorted alphanumerically and by manufacturer. Individual numbers in both sections are crossed to the appropriate replacement relays.

Circle (126) on Reply Card

Data communications products and test equipment catalog

The 1987 Data Direct Sales Catalog from *International Data Sciences* is an 80-page catalog that covers the IDS line of hand-held test sets, modems, multiplexers, converters, data switches, soft switches, cables, data comm accessories and more. Descriptions, specifications, illustrations, photographs, schematics, pricing information and a glossary for reference is included.

Circle (127) on Reply Card

Test and measurement catalog

This 36-page, 15th annual direct mail catalog from *Extech Instruments* provides complete specifications and pricing for a wide selection of new, low cost measurement, calibration and testing instruments for the laboratory, field and plant. Major product headings include Thermometers, Humidity Meters, Panel Indicators, Multimeters, Tachometers, pH Meters, Conductivity Meters, Dataloggers, Timers and Pocket Computers. Most all products feature digital LCD or LED displays and are available in hand-held, bench or panel versions.

Circle (128) on Reply Card

Circle (16) on Reply Card

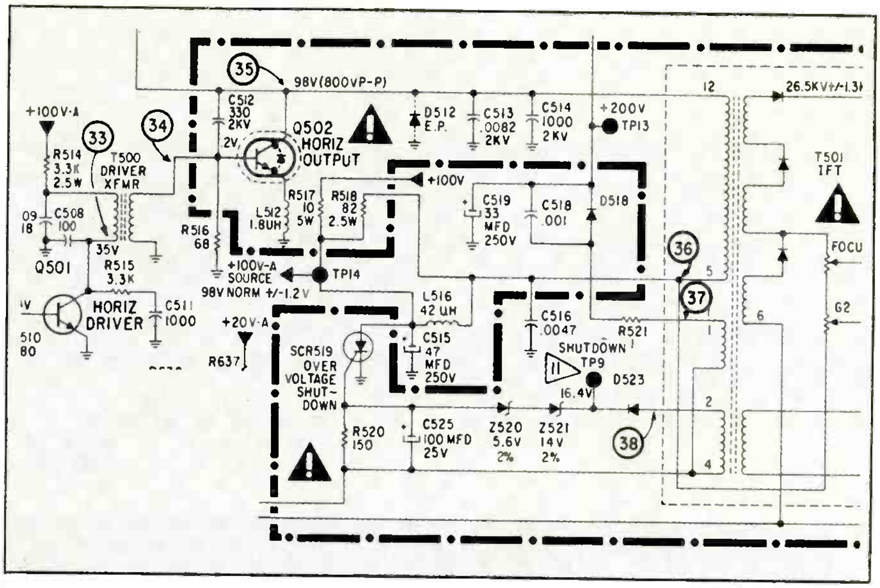


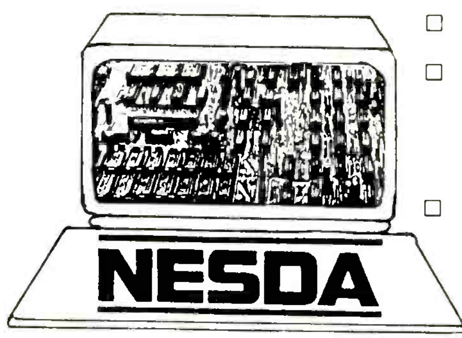
Figure 8. The high voltage tries to increase if the amount of capacitance between the collector of the output transistor and ground is reduced. *(Schematic diagram courtesy of NAP)*

Continued from page 24

The biggest trouble with shutdowns is that they happen so fast you can't tell one problem from another. You need a way to put the circuits into "slow motion" to give you time to isolate one probable cause from another. The best way to do this is to take manual control of the main voltage regulator, so that you can observe what happens when you slowly change the voltage. This may sound complicated, but it's really not if you use the right equipment.

You need a source of adjustable voltage from an isolated ac power supply. The isolation is essential, because almost all chassis that use shutdown circuits are also hot chassis using full-wave bridge rectifiers. You cannot connect a grounded piece of test equipment (such as an oscilloscope) to full-wave circuits without shorting out one of the TV's power diodes, along with other components. Isolation prevents this damage.

First, plug the TV into the ac supply and connect the dc voltmeter to the collector of the horizontal output transistor. Be certain that your meter has enough protection, because voltage spikes of more than 1200V are normal at



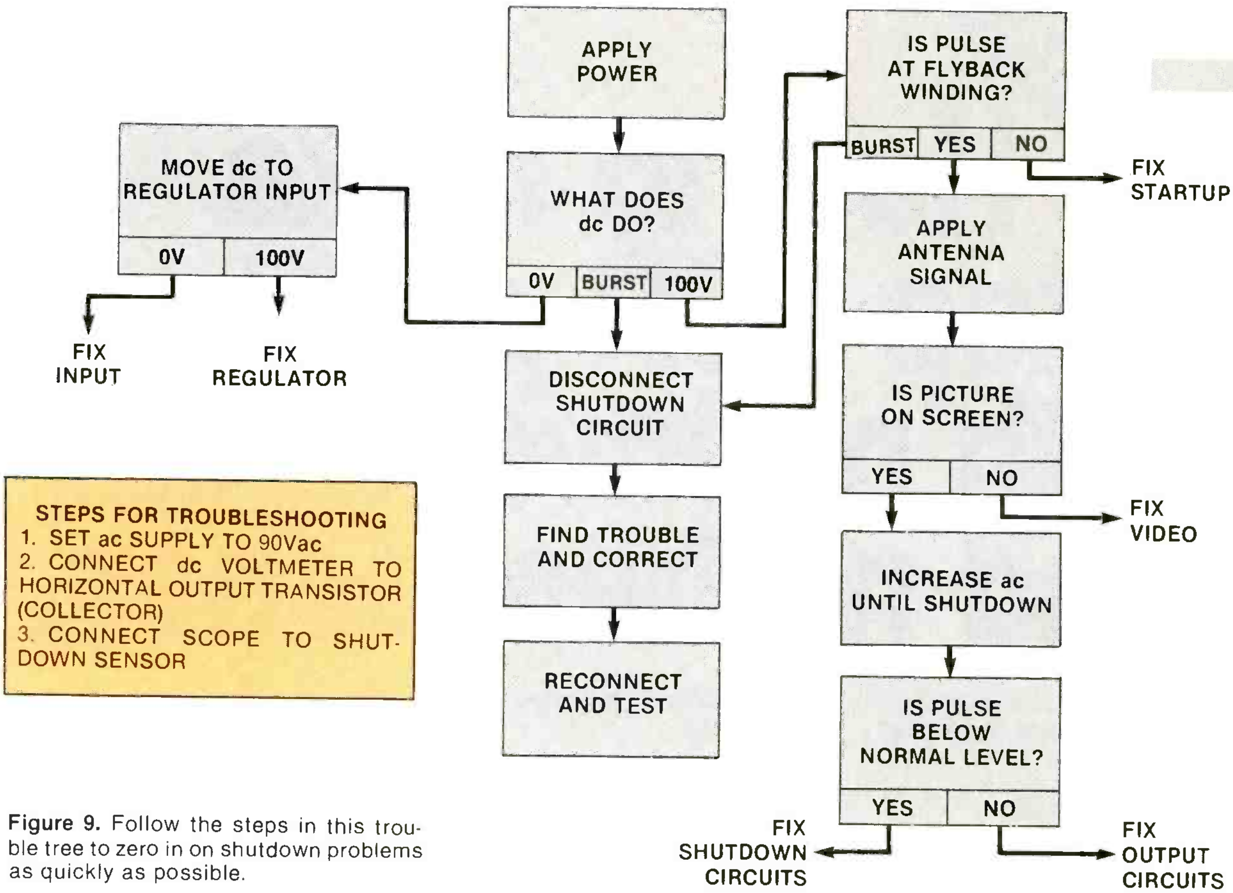


Figure 9. Follow the steps in this trouble tree to zero in on shutdown problems as quickly as possible.

this test point. With the TV turned off, set your ac power supply for an output of about 90V. This voltage is high enough to let the circuits operate, but below the point where the regulator is working.

Second, connect an oscilloscope to the winding on the flyback transformer that feeds to the safety circuits. If your scope has adequate protection (at least 1200Vpp) you can connect the second probe to the output transistor, along with the voltmeter.

Watch the dc voltmeter at the output transistor carefully as you turn on the set. One of three things will happen: the voltage will remain at zero, there will be a momentary burst of voltage that will then disappear, or the voltage will be at a level below the normal dc supply voltage. Your next step depends on which of these three things took place. (See Figure 9 for a troubleshooting flowchart.)

No dc

Absence of dc at the output transistor means you don't actually have a shutdown problem. Move your dc probe from the output transistor to the regulator input (the main power supply filter). If the meter shows about 100V, you know that the main power supply is good, so the trouble is in the regulator. (Details on regulators will be covered in a later article.) If there is no dc voltage here either, you have confirmed a defective power supply. Check the rectifiers, fuse and ac line choke.

Momentary dc

This indicates a shutdown has taken place that involves the power supply. Remember that some receivers use power supply interruption as a shutdown method. The high-voltage circuits should not be producing excessive output when operating at a 90Vac input. Shutdown could indicate a defective shutdown circuit. The exception is when a sensor monitors the emitter current from the output transistor. In this case, the shutdown could be caused by a short in the output circuits.

Constant dc

A voltage of about 100V confirms that the power supply and regulator are both working. At this point, you need to determine if the horizontal stage is running.

Check the scope connected to the flyback's safety winding. If you see pulses, you know the horizontal circuits are operating. You should apply a test signal to the antenna to check that the video, color and sound circuits are all working. In many cases, you will learn that you don't really have a startup or a shutdown problem at all. A dead video amplifier or similar trouble may cause a blank screen, even if the horizontal circuits are working fine. A problem in one of the low-voltage power supplies may also cause whole sections of circuitry to be inoperative.

If the output is dead, you need to know what happens when you first apply power. If you are lucky enough to be using a combination scope/digital readout, you can watch the scope CRT when you first apply power. If you are working with a separate scope and voltmeter, you may have to turn off the power, let the filters discharge (as indicated by the dc voltmeter dropping to near zero) and then watch the scope as you apply power a second time.

If the horizontal circuits produce no ac output at all, you have a problem in the horizontal stage or in the startup circuits. (These problems will be covered in the second installment of this series.) If, on the other hand, you see the pulses build for a short time and then disappear, you have confirmed that the circuits started and were then shut down.

Isolating the problem

If the set operates with a reduced ac input, or if it starts momentarily and then shuts down, you know for certain that your problem is shutdown related. Let's first discuss what to do if the set is shutting down with a 90V input.

In theory, the set should not be shutting down with the input voltage reduced because the output stages are not running with full power. The first thing to suspect is a problem in the shutdown circuits themselves. There may be as many as three sets of shutdown circuits, so your first step is to figure out which one is shutting the set down. The easiest way is to disconnect them one at a time to find which is responsible for the shutdown.

> **WARNING**
> *Do not operate the receiver at voltages above 90Vac with a safety circuit disconnected. Every safety circuit must be reconnected and tested before you return the set.*

After finding which safety circuit is causing the shutdown, confirm whether it's activated because its sensor has too much signal or whether the sensor is too sensitive. Correct the problem, reconnect the safety circuit and confirm that the chassis works correctly at full line voltage. Check the safety circuits using the procedures in the service literature.

Many sets will work normally at reduced voltage because the power of all the safety-monitored circuits is below normal. Next, you will slowly increase the ac voltage while watching the scope channel connected to the safety circuits. Pay close attention to the peak-to-peak level of the signal. You want to know the amplitude at the moment of shutdown.

If the pulse at shutdown is smaller than the normal level, the safety circuits are too sensitive; this confirms a nuisance shutdown. Suspect that a zener diode has changed value, that a resistor is shorted or off value, or that a diode or transistor has become leaky. If the pulse at shutdown is above its normal level, the safety circuits are doing their job and stopping some unsafe condition. The next step is determining which circuit is defective.

Test the regulator first. Return the voltage to 90V, turn off the set and wait for the voltage to bleed off. Reapply power and begin increasing the ac voltage while you monitor the dc voltage at the collector of the output transistor. You should see the voltage gradually increase from the 90Vac input level (about 100Vdc to 110Vdc) and then stop increasing when it reaches the normal operating voltage.

For example, if the output transistor normally operates at 118V, the dc level should increase from 110V to 118V but should then stay near 118V, no matter how much higher you adjust the ac power supply. If the voltage continues to increase as you turn up the ac voltage, the regulator is not working correctly. If the set shuts down before reaching the normal voltage (118V in this example), you know the problem is somewhere other than the regulator.

If the regulator is not the problem, you should confirm that the output stage is working correctly. The best way to do this is to check the waveform at the collector of the horizontal output transistor. Perform the following tests with the set operating at an ac line voltage low enough to prevent shutdown.

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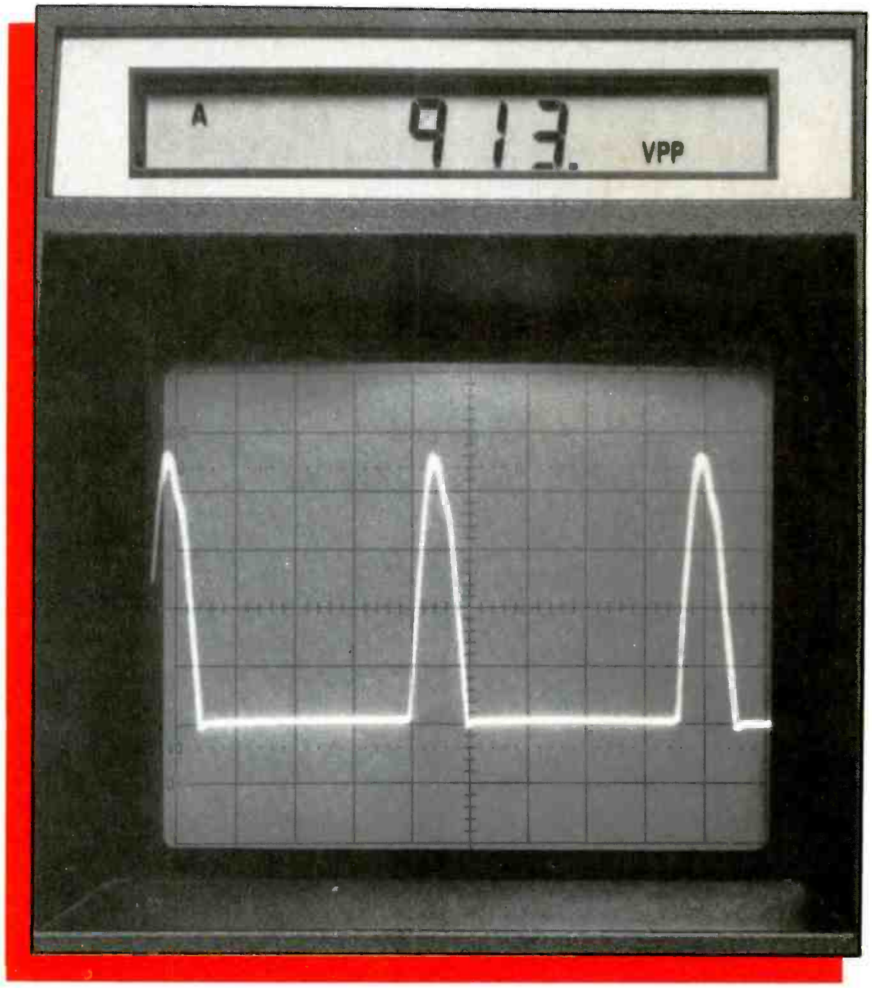


Figure 10. Many troubles can be isolated by observing the pulse at the collector of the horizontal output transistor if your scope has enough measuring range.

WARNING

Do not connect to the output transistor's collector unless your oscilloscope has adequate protection. Voltages as high as 1500V (dc plus peak ac) are possible when the output stages are not working correctly.

The width and shape of the transistor's collector pulse tells a great deal about the operation of the output circuit. (See Figure 10.) First, confirm that there is no saddle or dip in the center of the pulse. If there is, the flyback is either shorted or has a shorted load. Second, look for ringing along the baseline. Ringing is a symptom of a cracked core. Third, measure the width of the pulse (remember that pulse time is defined as the time from the 10% point to the 90% point, not from the base to the base of the pulse). The time should be near 12μs. If the pulse is too narrow, check the safety capacitors between the emitter and collector of the output transistor.

If the output pulse looks normal, suspect that one of the other flyback loads is open or shorted. Check the output of each scan-derived power supply for proper dc level. If you are operating with a 90Vac input, each voltage may be about 10% low, but none should be far above or below that variance.

It takes much less time to perform these tests than to read about them because you use each test to make a decision as to which way to go next. In actual troubleshooting, you should only use three or four of the steps covered. Remember that you are simply dividing your troubleshooting into an organized sequence of steps to identify which circuits work and which do not.

ES&T

Books

The Complete Compact Disc Player, by Martin Clifford; Prentice-Hall, 315 pages, $29.95, hardbound.

Although it is hard to say that any book about CD players is *complete*, this book, which covers both basic and advanced aspects of CD technology, covers the subject. The book starts with a lesson on binary arithmetic, which is important for understanding how the compact disc and its player work. Analog and digital recording are discussed, along with the pulse code modulator (the PCM, which converts analog to digital input) and the signal processing the PCM performs. The book examines CD player circuitry on basic and advanced levels, and provides a step-by-step operational analysis.

Published by Prentice-Hall, Englewood Cliffs, NJ 07632; 800-223-2336.

Electronic Industry Telephone Directory (8th edition); Harris Publishing, 704 pages, $44.50.

This desk-top directory and purchasing guide to electronics companies and products provides current verified address/telephone/zip code information on 22,752 electronics companies (488 of them are new), including manufacturers, distributors and manufacturers' representatives. The Yellow Pages provide more than 4,000 individual product classifications of components, instruments, accessories and systems, including computers and peripherals.

Published by Harris Publishing Company, 2057 Aurora Road, Twinsburg, OH 44087; 800-321-9136 (in Ohio, 216-425-9000). Contact Joyce DeRemer.

CD-I and Interactive Videodisc Technology, By Steve Lambert and Jane Sallis; Howard W. Sams, 224 pages, $24.95.

This source book for programmers and producers of interactive media provides a technical overview of the techniques and methods for using interactive videodisc (IVD) and compact disc-interactive (CD-I) technology. The book also covers types of laser videodiscs, videodisc formats and levels of interaction.

Published by Howard W. Sams & Company, 4300 W. 62nd St., Indianapolis, IN 46268; 317-298-5400.

IC Functional Equivalence Guide (8th edition); D.A.T.A., $95.

This guide provides alternate source and replacement information for more than 56,000 ICs from 164 manufacturers. Functionally equivalent devices (which are pin-for-pin compatible based on technical data and physical lab testing) are listed for each IC in the book. This edition contains more than 5,500 new device types, with updated information on another 16,000. The user can start with either the device part number or the function.

Published by D.A.T.A., 9889 Willow Creek Road, P.O. Box 26875, San Diego, CA 92126; 800-854-7030 (in California, 800-421-0159).

Test your electronics knowledge

By Sam Wilson, CET

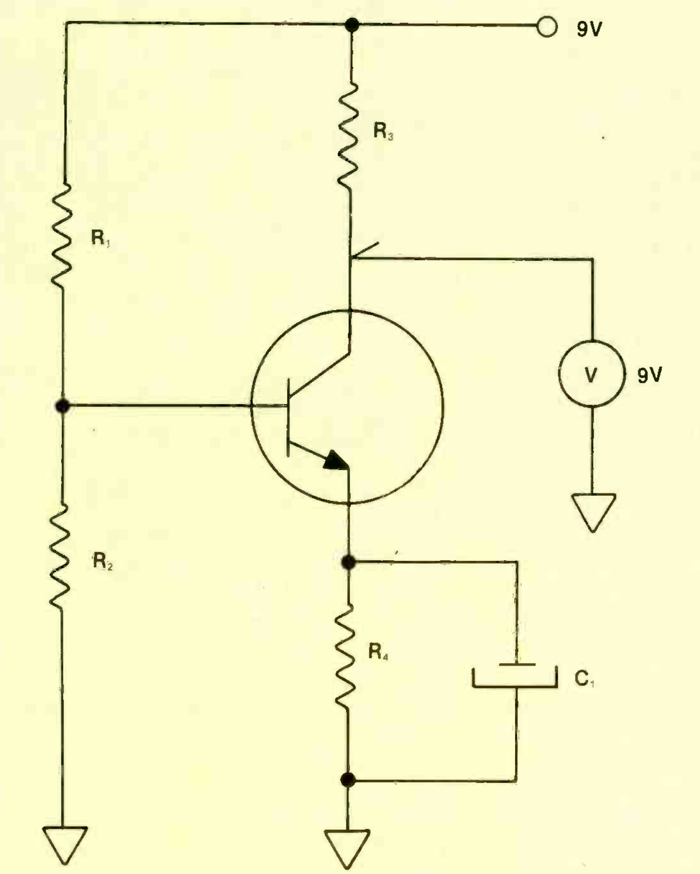


Figure 1.

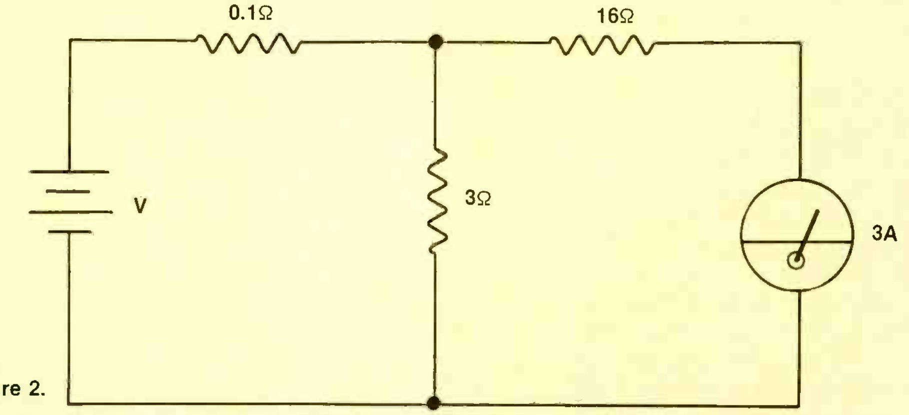


Figure 2.

In many ways, the second class FCC exam was a very good test. Here's a chance for you to see if you can answer some typical second class FCC license test questions. If you passed that test, this will be a good review. Expect to get a good grade. Some of these questions are also typical of those used in CET tests. However, FCC and CET test questions are multiple choice; in that sense these questions are not similar.

1. In a certain power tranformer the primary-to-secondary turns ratio (Np:Ns) is 3 to 1. If 5A of current flows in the primary circuit, how much current is available in the secondary? __________ amps

2. You cannot increase the capacity of a capacitor by
A.) increasing the area of the plates facing each other.
B.) increasing the distance between the capacitor plates.
C.) using a dielectric with a higher dielectric constant.
D.) None of these is correct.

3. A kilowatt-hour is a unit of electric
A.) real power.
B.) apparent power.
C.) reactive volt-amperes.
D.) None of these is correct.

4. Which of the following is likely to be used in a relaxation oscillator circuit?
A.) UJT
B.) PUT
C.) Both choices are correct.

5. What is the ripple frequency of a bridge rectifier operating from a line frequency of 400Hz? ______Hz

6. For the circuit of Figure A, which of the following is true?
A.) R_1 is probably open.
B.) R_2 is probably open.
C.) R_3 is probably open.
D.) C_1 is connected upside down.
E.) Nothing is wrong.

7. What is the battery voltage in the circuit of Figure B? ________V

8. The vertical broadcast antennas at AM radio stations are
A.) Zepp antennas.
B.) Rhombic antennas.
C.) Hertz antennas.
D.) Marconi antennas.

9. What is the conductance of a component that draws 332mA when it is connected across a 3V battery? ____________

10. Is the following statement correct? When you double the capacity, the capacitive reactance is halved.
A.) The statement is correct.
B.) The statement is not correct.

Answers are on page 65.

What do you know about electronics?

Do-it-yourself test equipment

By Sam Wilson, CET

The general procedure for troubleshooting – assuming that obvious faults have been eliminated – is:

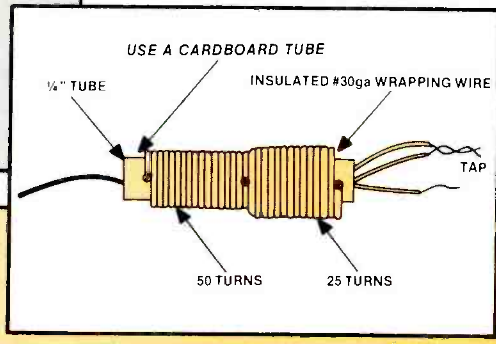
Step 1: Make a measurement.

Step 2: Compare the measured value with the value you should get.

Step 3: If the values compare favorably, you are not at the location of the trouble. Go to the next point.

If the values do *not* compare favorably, you should investigate further to find the source of the trouble.

I realize this is really an oversimplification. It takes years of experience and training to be able to go through those steps at a reasonably fast pace. It looks simple on paper, but, after watching students struggle through the steps when they are learning to troubleshoot, it is obvious that a considerable amount of skill is involved.



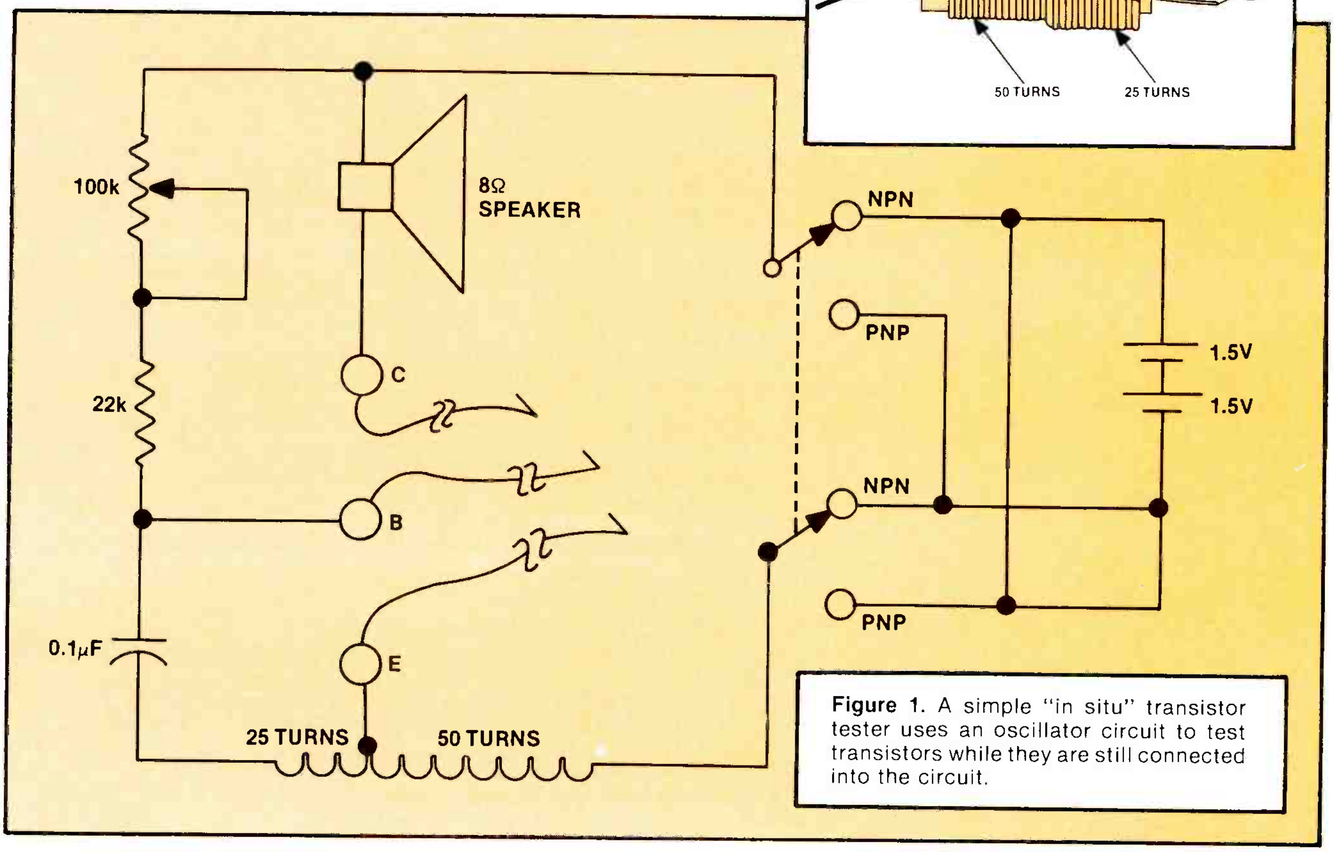


Figure 1. A simple "in situ" transistor tester uses an oscillator circuit to test transistors while they are still connected into the circuit.

The point I want to make is that an important part of troubleshooting is making measurements, and you need good test equipment for that step. There are many manufacturers with their versions of test instruments, but there is also some test equipment that you should consider making for yourself, because some valuable test equipment is not being manufactured.

One reason this equipment isn't being sold is that it is so inexpensive – there is simply no money to be made. When you consider the cost of manufacturing and distributing these testing devices, there is simply no room for a reasonable profit. However, you can make them on your bench in your spare time. It is an interesting and useful experience. *If you have a favorite example, please send it to us.* I'll pass it along.

Figure 1 shows a simple "in situ" transistor tester, submitted by Mike Olszewski of Palm Beach, FL. There have been many versions of this tester printed throughout the years.

The basic idea is that it tests transistors, while they are still connected into the circuit, by using the transistor in a simple oscillator circuit. The Hartly oscillator coil is wound as shown in Figure 1. A tone is produced if the transistor is OK. Defective transistors give no tone.

Olszewski used very small probes that clip onto the transistor leads; you don't have much room on most circuit boards. Two 1.5V cells are used for power.

I tried this device with both PNP and NPN transistors. Also, I tried it with both voltage and power amplifiers. It worked very well in all cases.

Quick transistor checks

The tester just described is one of many ways to check a transistor while it is in the circuit. The tester is used when the transistor circuit is not energized. You can use a voltmeter to evaluate a transistor in an energized circuit. Two ways of doing this are reviewed here:

- For a Class A resistor-coupled amplifier, the collector voltage should be about half the power-supply voltage when there is no signal applied.

- To check a Class A amplifier for distortion, measure the dc collector voltage with no signal applied. With the voltmeter still connected to the collector, apply a pure sine wave to the base. There should be no difference in the dc collector voltage with and without the signal applied.

Another often-used voltmeter test is to measure the dc base voltage and dc emitter voltage. The difference between those voltages should be about 0.7V for silicon transistors. You may run across a germanium transistor now and then, especially in the power amplifier circuit. In that case, the difference should be about 0.3V.

Gallium arsenide (GaAs) transistors are now being pressed into service. They are especially good for high-frequency, low-noise work. The emitter-base voltage for those transistors should be about 1.5V.

Don't get married to those emitter-base voltage values. They are just rough guidelines. The most important use of emitter-base voltage measurements may be determining that the transistor is operating. The actual voltage for a silicon transistor can be as high as 1.2V!

Remember to keep your fingers out of unfamiliar systems until you have measured the power supply voltage. It is easy to get careless when working in solid-state systems because low operating voltages are common. But, there are 90V *bipolar* transistors and 400V *enhancement MOSFET* circuits in operation. If you stick your finger into one of those you'll think you're getting an idea!

If you teach electronics

I recently had the privilege of coordinating an Electronic Industries Association (EIA) digital and microprocessor course, taught at the New England Institute (in West Palm Beach, FL) by Dr. Elmer Poe. It was specifically aimed at people who teach electronics. More than 150 teachers in Florida, Georgia and Alabama were invited to attend this *free* course, and were told that, in addition to the course, they would be given $100 in materials to take home.

The most frequent reaction was that anyone teaching digital and microprocessor courses doesn't need a course in those subjects. To be honest, I thought they could be right. During the week-long course I was able to sit in on most of the lectures and labs.

Let me tell you this. No matter how many years you've been teaching these subjects, you shouldn't miss the opportunity to take this course. Get in touch with EIA in Washington, DC, and find out if you, as a teacher, can get into a nearby course next year. Believe me, you won't regret it. It is *not* just a rehash of old material. You'll get new ideas for teaching these subjects.

A letter from Art Hansen

Dear Sam:

In your article in the May issue of **ES&T**, you quote this unusual (strange) theory: "A battery cannot produce voltage at any time unless current is being drawn from the battery."

I think the question is not technical but metaphysical, like this one: "If a tree falls in the forest, and no one hears it, is there sound?"

My field is engineering, not metaphysics, so I can't handle that kind of question. However, we could turn it into an engineering question by changing it to this: "How can a battery's voltage be measured while drawing zero (not merely 'very little') current?"

Answer: With a potentiometric method. Consider the circuit enclosed (see Figure 2), which shows a black box containing a battery of unknown voltage, a voltmeter, a potentiometer and a second voltage source. To find the voltage inside the black box, do this:

1. Connect the voltmeter between the unknown and the wiper of the potentiometer.
2. Adjust the potentiometer until the voltmeter reads zero. At this time, the meter, whatever its impedance, draws zero current.
3. Connect the voltmeter between the wiper of the potentiometer and common. The indicated voltage equals the battery voltage.

This method measures the voltage of the unknown battery without drawing current from it.

You may remember the Leeds and Northrup potentiometers for measuring thermocouple and other millivolt range voltages. This wonderful instrument had not one but *two* potentiometric measuring systems in it. The first was the millivolt measuring system itself. The system was mechanized using a servo and a motor-driven potentiometer. The servo ran on the difference between the input voltage and the voltage from the potentiometer, and ran the motor so as to reduce this voltage to zero. The motor shaft was coupled to the meter pointer, and the potentiometer was incredibly linear. As a result, when the error got to zero, the motor stopped and the pointer position indicated the voltage.

The second potentiometric system was in the calibration of the motor-driven indicating potentiometer. For the pointer position to accurately indicate the measured voltage, the excitation of the

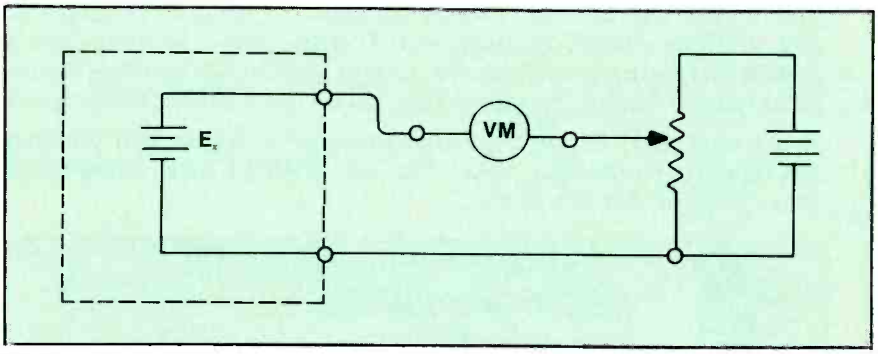


Figure 2. To measure a battery's voltage without drawing current from it, use a potentiometric method, using a voltmeter, a potentiometer and a second voltage source.

potentiometer itself had to be extremely accurate. The only suitable source was a standard cell, which was only accurate when no current was drawn from it.

To get the few milliamperes needed to excite the potentiometer, the company used a disposable flashlight battery with a manually operated potentiometer across it. The voltage at the wiper of this second, manual potentiometer was the excitation of the main, measuring potentiometer. This wiper of this second pot was connected through a resistor, a momentary pushbutton and a sensitive galvanometer to the output of the standard cell.

To set up the unit, you just pushed the pushbutton and watched the galvanometer. You then adjusted the manual potentiometer until the galvanometer was in the center, zero position. At this point, you knew that the voltage exciting the measuring potentiometer was exactly equal to that of the standard cell. You then released the pushbutton and could operate accurately for many hours without recalibration.

I enjoy your articles. Let's have some more stuff from that "box of unusual letters."

Is it a bram or a rambo?

As as general rule, read-only memory (ROM) is non-volatile. In other words, when the power supply goes off, the information in the memory is not lost. In a random-access memory (RAM), the information is lost when the power supply goes off, which is why RAM is called *volatile*.

However, there is a 40-pin RAM now being manufactured that has a built-in battery. The instant the applied power drops below a predetermined value, the battery takes over and saves the information in the memory. *The battery is guaranteed to hold the information in the memory for 99 years!*

No official name has been attached to this device. Here are two possibilities: BRAM (for battery-operated RAM), and RAMBO (for RAM-battery operated.)

Before I actually endorse this device, I'm going to get one and see if it actually *does* retain the information for 99 years.

Tuning VCRs with PLL and AFT circuits

One method used to tune VCRs is the method used in the GE 1VCR 4016X, a frequency synthesis system that incorporates a phase-locked loop (PLL) and an automatic fine-tuning (AFT) circuit (see Figure 1).

The PLL circuit includes the phase comparator, programmable divider I, low-pass filter, local oscillator, pre-scaler, reference oscillator and programmable divider II.

The AFT circuit includes the video IF (VIF), AFT comparator, frequency control logic, frequency control, up/down counter, programmable divider II, phase comparator, LPF, local oscillator and mixer.

How the PLL circuit works

The PLL circuit uses a 7.162109MHz oscillator as a frequency reference. The oscillator circuit is inside the IC, connected to pins 61 and 62, to which the frequency determining crystal and trimmer capacitors are connected. The output of the reference oscillator feeds programmable divider II, which in turn feeds one input of the phase comparator.

The local oscillator in the tuner produces a CW signal that is fed to the pre-scaler, which is also in the tuner. The pre-scaler output is fed to programmable divider I, which is programmed by the user according to the channel selected. The output of programmable divider I is fed to the second input of the phase comparator.

The phase comparator produces an error voltage proportional to the difference between the two inputs. If the input from programmable divider I is high, the phase comparator produces an output that will cause the local oscillator to tune to a lower frequency. The LPF integrates and amplifies the output and feeds it to the tuning (BT) terminal of the tuner.

How the AFT circuit works

If all transmitting stations used standard frequencies, the division ratios built into programmable divider I would allow the PLL circuit to accurately tune them. However, because some stations transmit on frequencies that are offset from the standard, a circuit that detects what the transmitting frequency is and adjusts the tuning system is necessary. The AFT circuit supplies this need.

The AFT detection circuit is part of the video IF. This circuit works just like the AFT circuit in a TV set: It produces the familiar "S" curve, centered at 45.75MHz. At this frequency the voltage is 6.5V. The voltage rises at lower frequencies and becomes lower at higher frequencies. The AFT voltage is fed to the comparators in IC7603 to provide AFT direction and AFT window signals for IC7601. These are used to change the division in programmable divider II to *fine tune* the reference frequency sent to the phase detector.

Adapted from GE VCR Service Bulletin No. 4016-1.

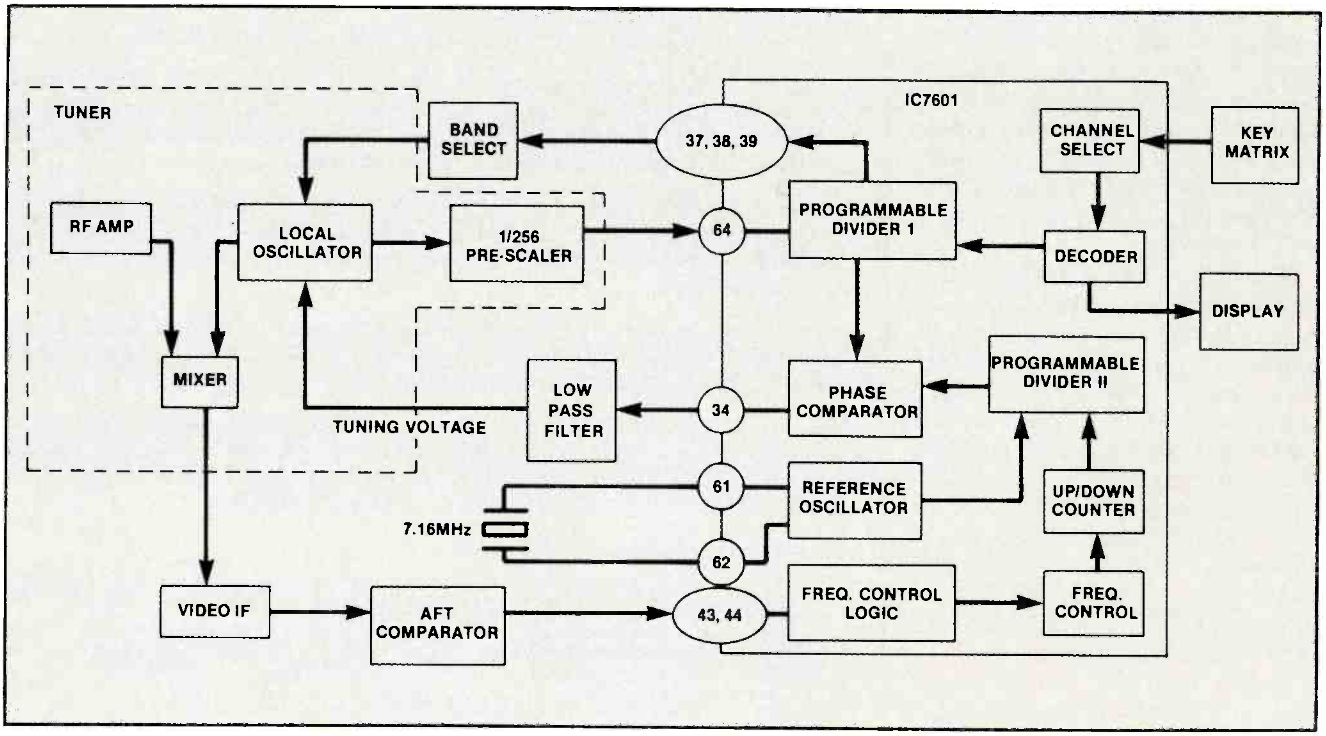


Figure 1. This block diagram shows one method of fine-tuning a VCR. The PLL circuit uses an oscillator as a frequency reference. The AFT circuit detects the transmitting station's frequency and adjusts the tuning system.

ANSWERS

Questions are on page 58.

1. 15A. Assuming a perfect transformer and a secondary circuit that will draw the maximum current, the secondary current will be 15A. The basic transformer equation is Np:Ns = Is:Ip.
2. B.) Increasing the distance between the plates will *reduce* the capacity of a capacitor.
3. D.) A kilowatt hour is a unit of electric *energy*.
4. C.) The unijunction transistor (UJT) and the programmable UJT are both breakover devices used in relaxation oscillators.
5. 800Hz. The bridge rectifier is an example of a full-wave rectifier, so the output ripple frequency is twice the input frequency.
6. A.) If R_3 was open, the voltmeter would not display 9V. If R_2 was open, the base voltage would be higher and the collector voltage would be lower. Capacitor C_1 is an electrolytic type and is properly shown. An open R_1 would remove base current, cut off the transistor and reduce the current through R_3 to zero. With no drop across R_3, the collector voltage equals the supply voltage.
7. 49.9V. The voltage across the 16Ω resistor is 48V. That voltage is also across the 3Ω resistor, so the current through that resistor is 16A. That makes a total of 19A through the 0.1Ω resistor and a voltage across it of 0.1x19 = 1.9V. That voltage added to the drop across the 16Ω resistor (48V) makes a total voltage of 49.9V. (There are other ways to work the same problem.)
8. D.) They are ¼-wave vertical antennas. In other words, they are Marconi antennas.
9. 0.1107MHOS. The conductance is equal to the current (0.332A) divided by the voltage (3V).
10. A.) In the June '87 issue you were warned (in the table of contents) to "look out for the trick question." This must have been it, because the wrong answer was given. Write the equation for X_c as:

$$X_c = \left(\frac{0.159}{f}\right) \times \frac{1}{C}$$

If $\left(\frac{0.159}{f}\right)$ is constant, then doubling C will halve X_c. ES&T

Audio Corner

By Kirk Vistain

PLL tuned FM receivers

This month, we'll take a look at how phase-locked loop (PLL) FM receivers work and try to give some troubleshooting tips.

Figure 1 shows a generalized version of the PLL high-fidelity FM receiver. Of course, like almost everything else nowadays, it's a loop. A sample of the local oscillator (LO) is divided by an integer value chosen via the microcontroller. This frequency is then phase-compared to a stable crystal reference to produce a correction voltage that biases the varactor diodes to the proper capacitance for the LO frequency desired. Notice that the PLL both samples and alters the LO. That's what makes it a loop.

Contrary to what you'd expect, most newer receivers do not read the LO to display the tuned frequency. This was true of older devices, such as the Sansui G4700, which had a digital display but conventional mechanical tuning. However, today's units are more trusting. On command from the operator, they send out a digital code in serial form to the PLL IC and display the selected fequency. Then they assume that any right-thinking PLL will obey and tune to the correct station. If the quadrature detector is misaligned, it might look like the receiver is tuning to an "even" number, such as 98.2MHz, which, of course, isn't supposed to be allocated in the United States.

Without a computer and knowledge of the correct digital codes, there's not any practical way to be sure the micro is outputting the correct data to the PLL chip. In general, however, if the clock, data and latch lines have clean signals (square wave pulse trains) on them, we can assume the data is correct. Just remember later on that you made this assumption if nothing else seems to be bad in the circuit.

By the way, the latch or strobe pulse occurs after a complete data word has been transmitted, signalling the PLL controller to latch the data into storage and tune the front end. Therefore, the pulse repetition rate of this signal will be significantly lower than that of the clock or data lines.

In order to tune the front end, the PLL IC needs three input signals: the LO sample, the reference oscillator and data from the micro. If any of these are missing, the usual symptom is no audio from the FM section, because the FM is generally muted between stations. A very simple way to determine whether you have tuning problems or a defective RF/IF section is to read the tuning voltage input to the tuner. It should change as you select different stations. To double-check, substitute a regulated, variable dc voltage (check the manual, but it's usually in the range of 2Vdc to 20Vdc) at the front end's tuning input. Slowly vary the voltage. If the RF/IF section is OK, you should be able to pick up stations, just as if you'd tuned in the conventional way.

If you've focused on the PLL controller as the culprit, first check the phase detector output. It's often some sort of cross between dc and pulse-width modulation (PWM), and is occasionally difficult to interpret, but it should change as different frequencies are selected. If not, test the reference oscillator. Use a scope and a low-capacitance probe to avoid loading. You should see a healthy sine wave at the correct frequency. If it's all right and you have a 100MHz scope at hand, see if there's an LO sample at the controller input. Don't assume that just because you can tune the FM with an external voltage, the LO sample must be present. There often are a buffer transistor and coupling capacitors in the front end to unload the local oscillator, and they can fail without upsetting the LO itself.

If all necessary inputs are present but the PLL phase detector has no output or change of output, the chip is probably bad.

If you feel that the phase detector output is normal, then the integrator stage may be bad. It should take the PWM and turn it into clean dc.

The latest receivers incorporate the PLL controller in the same chip as the microcontroller and display driver. The output to the tuner is pure digital, so there's no chance of troubleshooting by injecting an external control voltage. About all you can do is verify the presence of clock, data and latch pulses. If they're present, the tuner is probably defective.

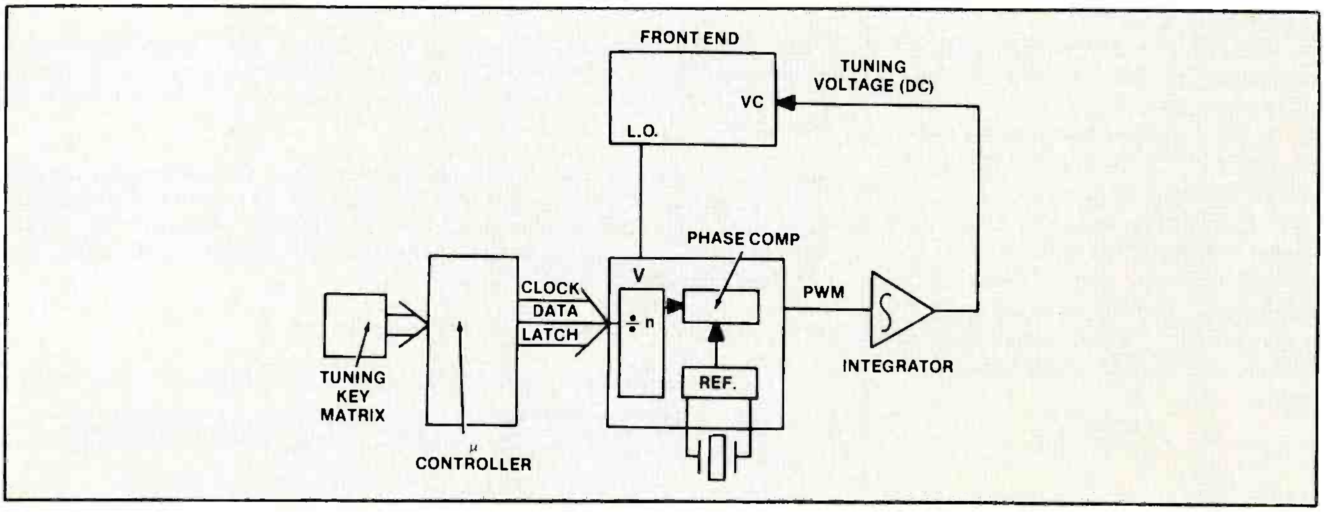


Figure 1. The PLL high-fidelity FM receiver employs a loop to both sample and alter the local oscillator, which is phase-compared to a stable crystal reference.

ES&T

Products

Digital-storage oscilloscope

The HM205-2 scope from *Hameg Instruments* offers analog operating modes and digitized waveform processing for signals and events. A 5 million sample per second digitizing rate, dual-channel acquisition, an 8-bit vertical resolution and 1K record length per channel are included. A linear interpolator helps improve waveform recognition. The scope also offers an active TV sync separator, jitterless triggering up to 40MHz, hold-off control, X-Y mode, Y-output and a built-in component tester. A GPIB interface with DSO software for IBM-ATs or compatibles is optional.

Circle (75) on Reply Card

Digital multimeter

The DM71 digital multimeter from *Beckman Industrial* is a hand-held, pen-type meter that features 3½-digit display with 0.7% accuracy (dc 2mV range) auto-ranging. The meter has a rotary dial and a data hold function that enables the user to manually freeze the display. Continuity and diode test functions are included. The unit has full auto-ranging capability on fifteen measurement ranges and measures voltages up to 450V and resistance up to 20mΩ.

Circle (76) on Reply Card

Autoranging DMM

The DM-76 digital multimeter from *Philips ECG* is an autoranging model with a 20mΩ scale that is extendable to 30MΩ. It features a range indicator, 24 ranges and 10 functions, and it is equipped with a data hold that holds a displayed reading in any range. The DMM has a diode test (VF) to measure actual forward voltage drop, plus a transistor hFE test. The RF-shielded meter also has an audible continuity test, overload protection, an over-range indicator and a metal tilt stand.

Circle (77) on Reply Card

Digital voltage calibrator

The DVC-350A from *Datel* is a microprocessor-based, hand-held digital voltage calibrator with true ±0.015% accuracy. The calibrator has a decimal entry mode with ±1.2V or ±12V output ranges, plus a hexadecimal entry mode that spans ±1.0V or ±10V. The fully bipolar output can source or sink up to 20mA at any voltage and is current-limited to 22mA. The calibrator has an operating range of 0°C to 50°C and a maximum calibration drift of ±10ppm/°C over 15°C to 35°C.

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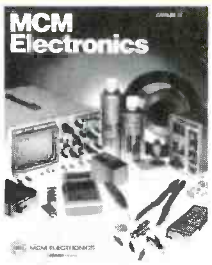

Computer Corner

By Conrad Persson

Knowing the parts of a personal computer

Before you can troubleshoot any kind of malfunctioning equipment, you have to understand the subsystems so that you can know what failure symptoms point to. For example, sound but no picture in a TV set might point to the horizontal deflection circuits, the luminance circuits or other circuits that affect the picture.

The same idea holds true with computers. Before you go jumping in and probing here and there in a malfunctioning computer, you have to understand the subsystems so that you can start at the most likely source of the problems, then work your way down to the least likely cause of the problem.

Figure 1 is a block diagram of the major subsystems in a typical microcomputer. When you encounter a problem with a computer, the first step in solving the problem is to examine the symptoms and ask yourself, "Given this symptom (or set of symptoms), what circuit is the most likely to be the cause?"

Looking at the subsystems

The concept of a *power supply* in a computer system should present no problems to someone who has had experience with TV's and other consumer electronics. Its purpose is to provide a dc voltage or voltages for the computer's electronic components; for example, the voltage might bias the transistors of ICs to their proper operating conditions.

The *clock* is a circuit that provides a continuous train of regular pulses (and frequently provides more than one such output) that is used to control the timing of events within the microprocessor. The clock circuitry in modern microcomputers is generally contained on the microprocessor chip. The clock input may be driven by a crystal, an LC circuit or an external clock source.

An example of the application of the clock circuit is in the operation of a shift register (see Figure 2), used to convert serial data to parallel data. (For more detail on shift registers see "What Do You Know About Electronics?" in the May 1987 issue of **ES&T**). The data (in the form of ones and zeros) to be stored in the shift register are presented to the shift register inputs a bit at a time. Nothing happens until a clock pulse appears at the clock input to the shift register. Each time a clock pulse is applied, a successive bit is entered into the shift register's first flip-flop, and previously entered bits are shifted one bit to the right.

In the next installment of computer corner we'll continue breaking down the personal computer into its elements in order to better understand what's going on inside.

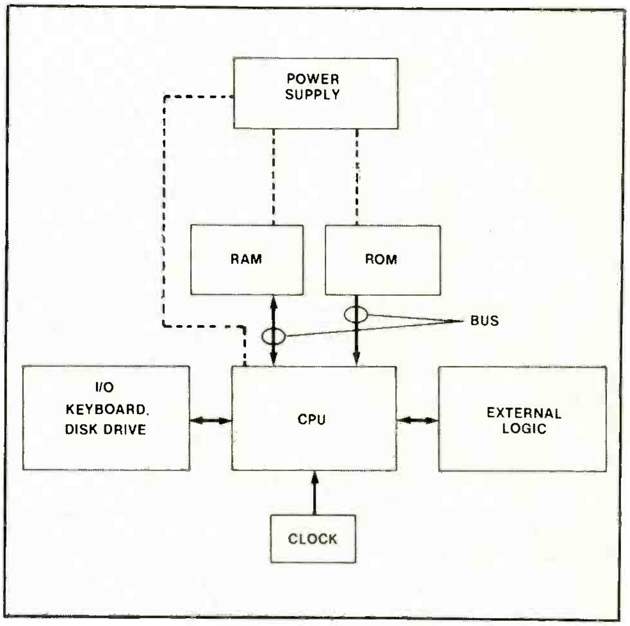

Figure 1. This block diagram of the major subsystems in a typical microcomputer gives you an idea of which circuits are most likely to be the problem behind a particular symptom.

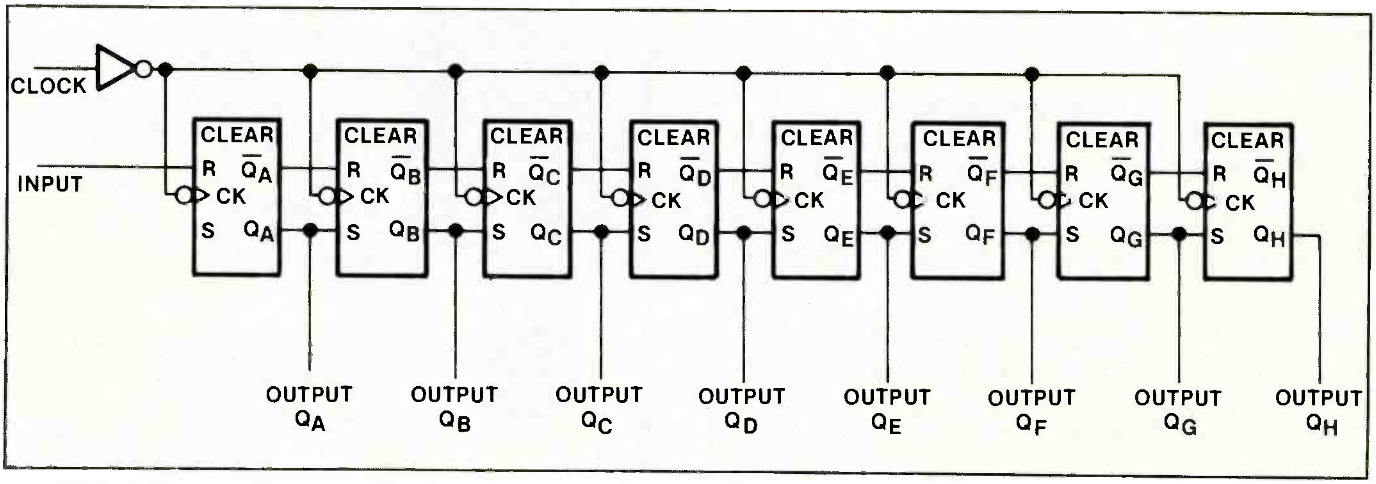

Figure 2. The operation of a shift register shows an application of the clock circuit, which provides a continuous train of regular pulses to control the timing of events within the microprocessor.

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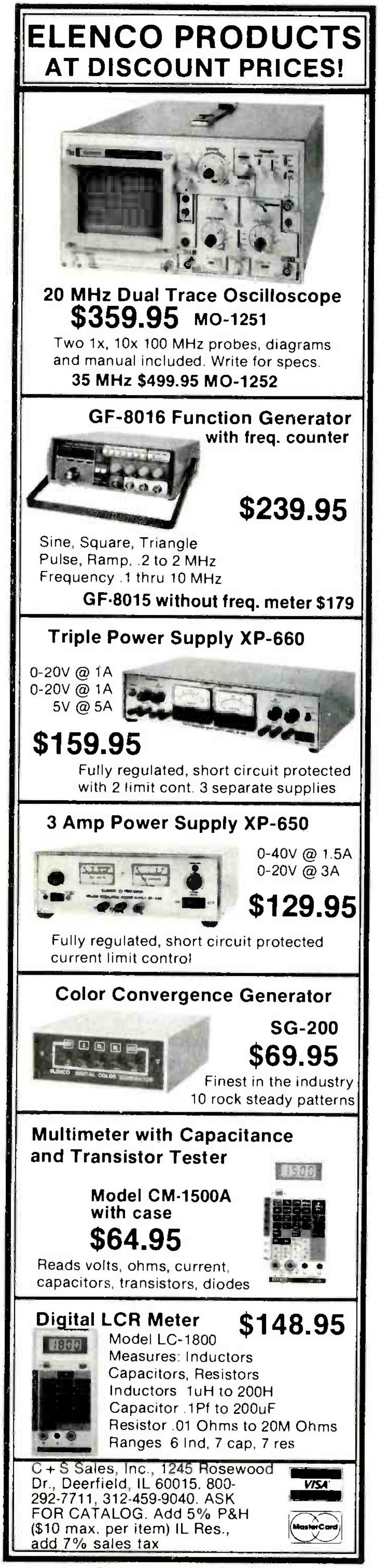

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