The how-to magazine of electronics...

AN INTERTEC PUBLICATION

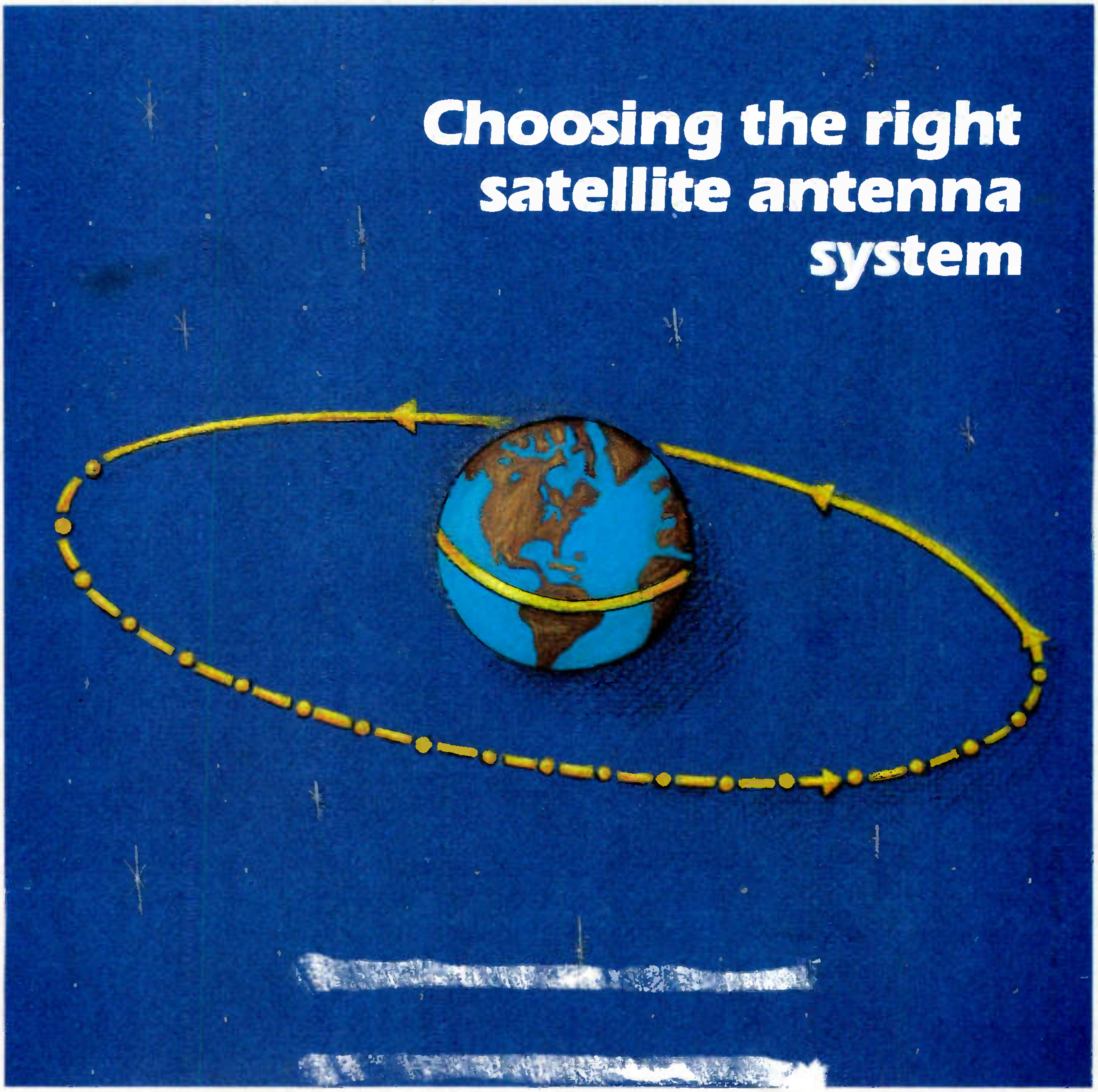
ELECTRONIC™

Servicing & Technology

AUGUST 1988/$2.50

Solving the TV shutdown puzzle • Unusual uses for varactor diodes

Continuing your electronics education



Easier Testing. By Comparison.

Scopemate 2.™ With Your Scope Or Ours, Still The Best Price Solution For Good/Bad IC and Component Testing.

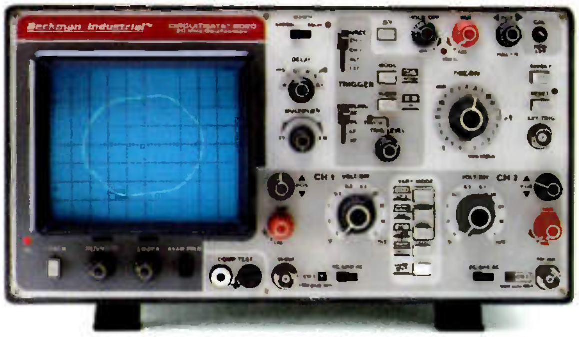
Now you can economically test all types of analog, digital and hybrid components—including resistors, capacitors, diodes and ICs with up to 40 pins—using a simple X-Y oscilloscope. In the field or on the bench, in-circuit or out-of-circuit. Without tedious pin-by-pin or contact-by-contact testing.

It's made possible by Scopemate 2™ from Beckman Industrial. All it does is plot voltage vs. current. Just a lot easier. A lot faster.

Scopemate 2 compares components known to be good with those to be tested, giving you a very accurate and fast way to identify bad devices. The voltage vs. current plot from a known good device is compared to the device under test. In fact, since there's no complex numerical test data to interpret, Scopemate 2 is ideal for less experienced personnel.

And, at $395 it doesn't take too long to figure that Scopemate 2 may pay for itself in saved testing time. Real soon. Scopemate 2 comes with a simple yet comprehensive operator's manual, a complete set of leads, interconnect cables and plug-in transformer.

Although Scopemate 2 will work with just about any X-Y oscilloscope,



9020 20MHz Delayed Sweep Oscilloscope $589.00

Vertical Accuracy:	±3%
Time-based accuracy:	±3%
Input Impedance:	1M ohm 35pF (2%)
Input Max. Voltage:	400V (DC+pos. peak AC)
Sweep Delay Ranges:	10,1,0.1ms; 10,1,0.1μs
Mode:	Normal, search, delay

Beckman Industrial Circuitmate™ Model 9020 offers capabilities seldom found on other scopes costing less than $600.

Proven capabilities such as **delayed sweep** for easy bandwidth analysis, zoom-in for short-duration events, a variable holdoff function for a stable display of non-periodic signals—even beam finding to locate and return trace to view regardless of control settings. And switchable X1/X10 probes give you more sensitivity for low frequency measurements, less circuit loading for high frequency measurements.

For real value, combine the 9020 and Scopemate 2 for performance and flexibility unmatched by systems costing $1,500 or more.

Both Scopemate 2 and our Circuitmate Model 9020 illustrate a simple commitment by Beckman Industrial—to provide service test instruments that meet your needs. Whether through advanced technology or value-oriented applications of proven technology, Beckman Industrial gives you the right features at the right price, with service test instruments built to rigorous standards of quality and reliability.

Visit your Beckman Industrial distributor today and find out how the ruggedly reliable Scopemate 2 and the 9020 Oscilloscope can meet your needs. And why they offer the best value around. By comparison.

Scopemate 2™ IC/Component Tester $395.00

Test Method:	Direct Visual Comparison (known good vs. device under test)
Test Sockets/Interface:	20 and 40-pin ZIF IC sockets; banana jacks
Power:	120 or 220VAC, 50/60Hz, 5VA max. (specify)
Circuit Test Voltage/Current:	14VAC RMS (voltage, approx.); 300μA AC RMS (current, approx.)
Pin Test selection:	Push-button switch per pin.

In Service Instruments, We're The One.

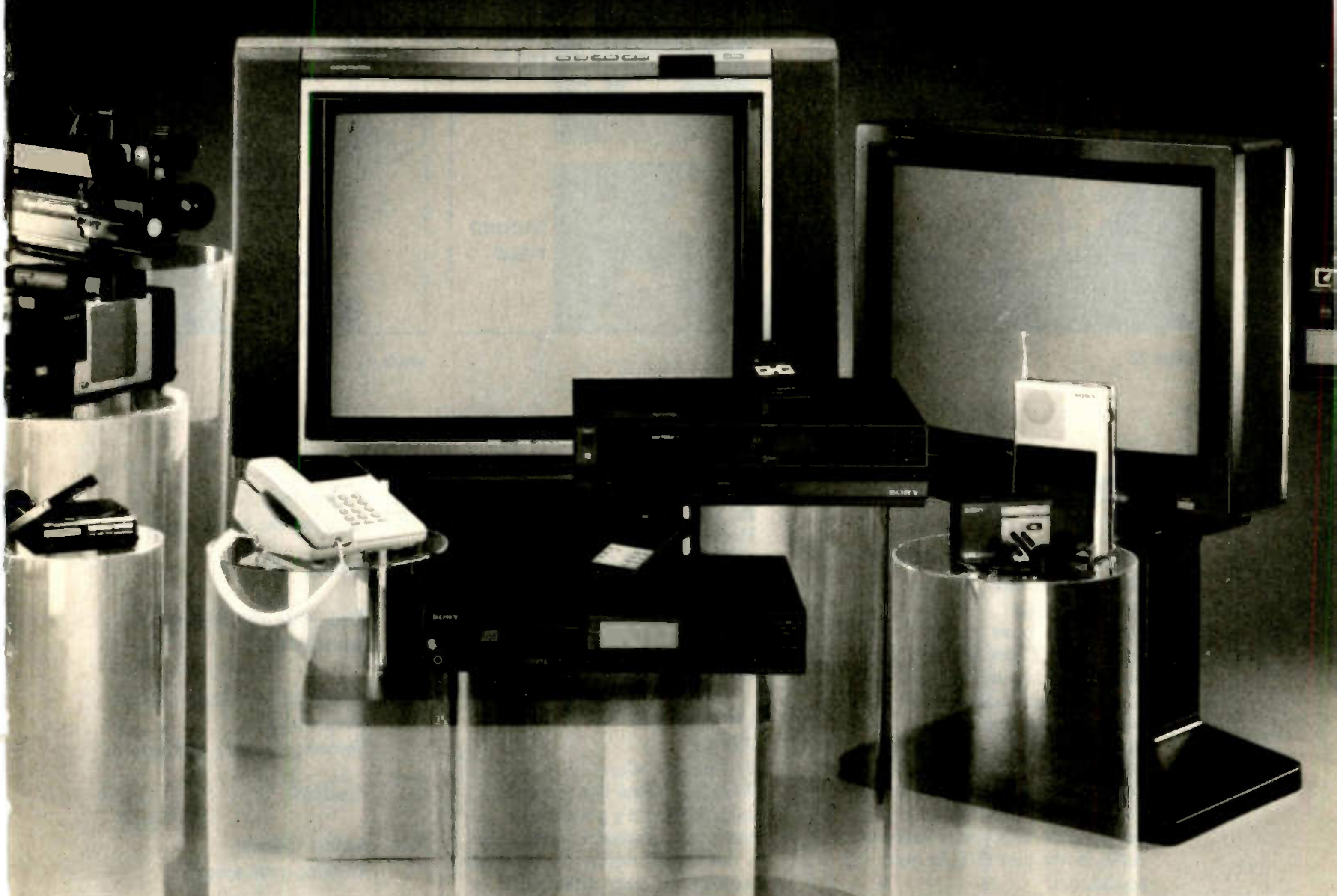
EMERSON

Beckman Industrial™

Beckman Industrial Corporation
Instrumentation Products Division
A Subsidiary of Emerson Electric Company
3883 Ruffin Road, San Diego, CA 92123-1898
(619) 495-3200 · FAX (619) 268-0172 · TLX 249031

Circle (1) on Reply Card

EVERY SONY PRODUCT COMES FULLY EQUIPPED WITH OUR DEDICATION TO QUALITY SERVICE.



Your customers may never need The Sony Service Company, but it's comforting to know we're only a phone call away.

Our nationwide network of Sony Service Centers, Training and Technical Departments and our National Parts Center represent our commitment to service. This means if you sell or service Sony products, Sony is there for you. Read on to find out more.

1. Sony Service Centers. Repair work is performed at over 27 Sony Service Centers located throughout the country (even Hawaii). The Centers also sell Sony accessories and rent video equipment. For the nearest Sony Service Center call (201) 930-SONY (7669).

2. Regional Centers. Our Regional Centers are set up to assist you with any technical questions. Just call one of the following numbers. Mahwah, NJ (201) 529-1616; Philadelphia, PA (215) 632-7999; Irving, TX (214) 550-5269; Fort Lauderdale, FL (305) 920-5656; Honolulu, HA (808) 834-6622; Niles, IL (312) 647-2424; Detroit, MI (313) 477-4805; Costa Mesa, CA (714) 549-4836, San Jose, CA (408) 280-7675.

3. Training & Technical Departments. Because constant innovation is the rule in the field of consumer electronics, authorized servicers and Sony Service Center technicians need the latest information available. This information is provided through training sessions at our Regional Training facilities and publication of Service Bulletins by our Technical Department.

4. National Parts Centers. All Sony Service Centers, parts distributors and authorized servicers depend on the National Parts Center. The Center also provides up-to-date service manuals and training tapes. To receive the Comprehensive Service Literature brochure free of charge write: Sony Service Company, National Parts Center, 8281 NW 107th Terrace, Kansas City, MO 64153 Attention Publications Department or call (816) 891-7550.

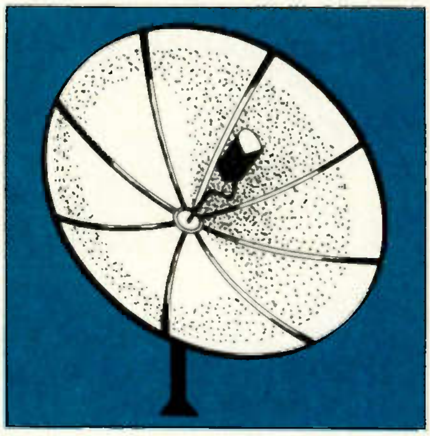
SONY®

Sony Service Company

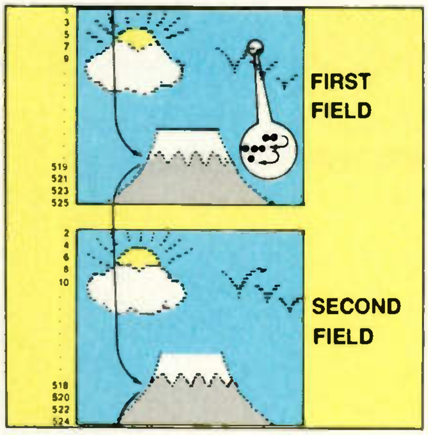
A Division of Sony Corporation of America

Contents

Volume 8, No. 8 August 1988



page 10



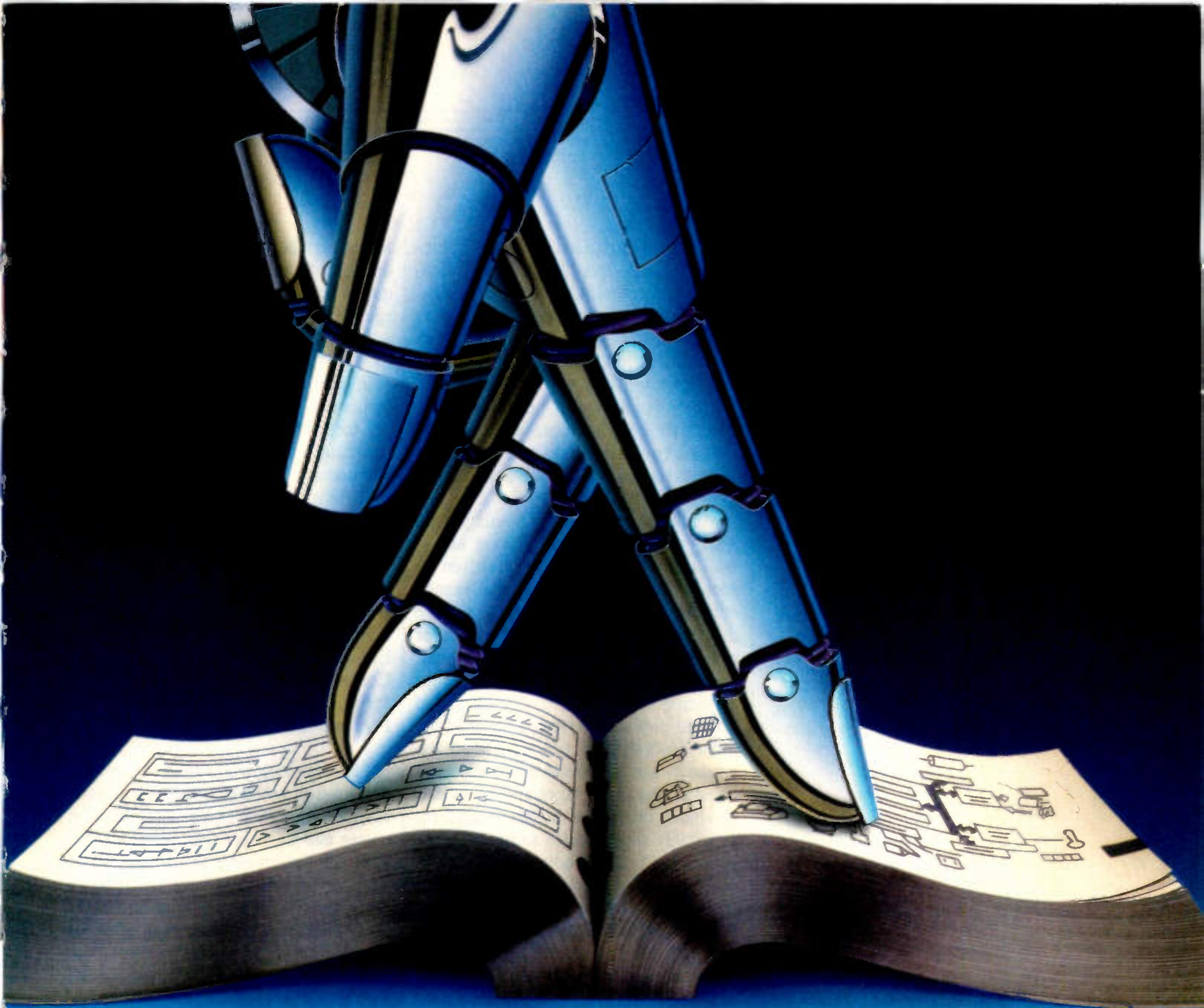
page 28

page 42

ON THE COVER

The earth is ringed with television satellites located in an orbit directly above the earth's equator between 69° west longitude and 143° west longitude. Catching the clearest signals from these satellites is a matter of knowing where the antenna will be located and calculating the proper G/T spec for that area.

The how-to magazine of electronics...
ELECTRONIC Servicing & Technology



Editorial

Keeping an open mind

The great musicians are said to practice for hours every day. This dedication is also common with great athletes. For example, Larry Bird, the Boston Celtics great, is said to spend hour upon hour during the off season shooting baskets, first with one hand, then with the other. Not only do they practice, but the best of the best in all professions study constantly. How would you like to be operated on by a surgeon whose education stopped 30 years ago?

Managers and professionals of all kinds attend seminars. Writers attend workshops. Teachers are required to spend part of their time taking advanced education. Many professions require that their members earn some number of continuing education units every year.

How about you? Today's electronics servicing technicians are being called upon to provide service on some of the most sophisticated products—and the products are becoming more sophisticated all the time. More and more new products, featuring different and increasingly sophisticated technology, are constantly being produced.

Any consumer electronics servicer who doesn't want to be left in the dust needs to spend whatever time is available polishing up old skills and knowledge and learning new ones.

Think about what's going on in consumer electronics:

• Greater numbers of TVs, VCRs, CD players and tape recorders are being designed around sophisticated integrated circuits.

• More and more consumer electronic devices are featuring microprocessor control.

• The array of electronic devices likely to be found in the home continues to grow: TV, VCR, CD, telephone, computer and peripherals, telephone answering device, copier, facsimile machine.

• Smaller and smaller devices such as surface-mount components require soldering skills that rival the surgical skills of a heart surgeon.

• Increasing numbers of components are susceptible to electrostatic discharge damage. Servicing these products requires extreme care—otherwise, damage may be inflicted by the very person who is being trusted to fix the product.

In light of all of these changes in the consumer-electronics field, no servicing technician can ignore the need to continually sharpen and update skills. Fortunately, there are a number of places technicians can go to do this. Here's a partial list:

Manufacturers' literature and seminars
Books
Magazines
Community college courses
EIA courses
Correspondence courses
Private technical school courses
EIA and manufacturer videotapes

The wise tech who wants to continue being a tech will take advantage of these courses wherever possible. The wise owner and manager will see that techs have the opportunity to do so.

Of course, we all have excuses. "I don't have the time. I can't afford to fly to another city and stay in a hotel for a week. I can't afford to be away from my business that long." Those are all valid reasons not to attend classes, but if you were to put those arguments on one side of a balance sheet and put the arguments for attending on the other side, you might find that the reasons *for* attending easily outweigh the reasons *against* attending.

If you just can't attend seminars or courses, there are still the home-study courses, books and videotapes. You simply can't afford to let your knowledge and skills become stagnant.

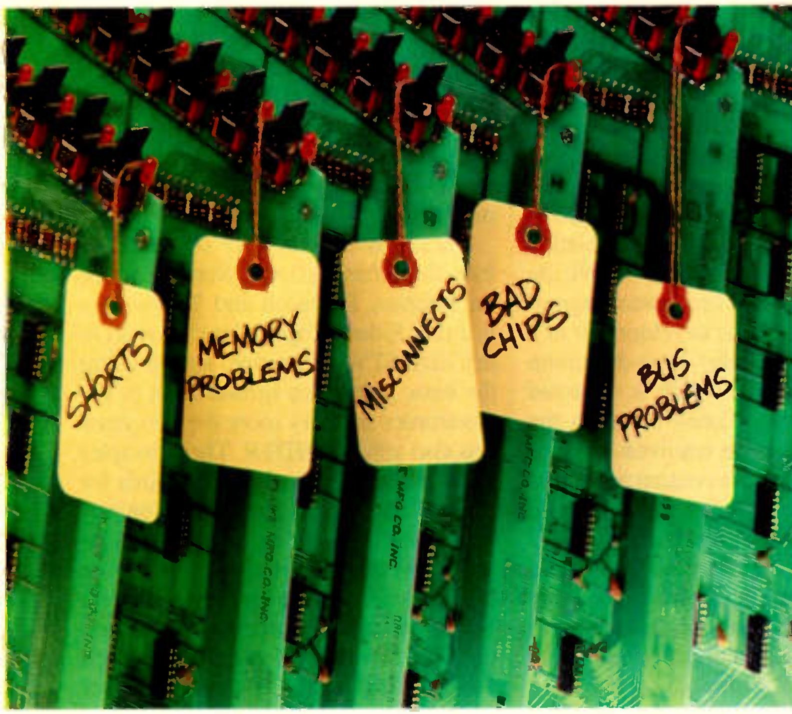
A wise man whose name escapes me at the moment once said that if he had a tree to chop down and a limited time to do it in, he'd spend most of that time sharpening his axe. A servicing technician's skills are his most important tool—his axe. It's a wise technician who spends some time every year sharpening and honing his axe.

Nils Conrad Persson

FLUKE AND PHILIPS - THE GLOBAL ALLIANCE IN TEST & MEASUREMENT

FLUKE®

PHILIPS



Multiple Problems. One Solution.

For microprocessor board troubleshooting and service, nothing expands your diagnostic capabilities — and simplifies your operation — like the new Fluke 90 Series.

This unique μP board tester gives you a complete range of test functions:

- Bus Tests
- Memory Tests
- I/O Tests
- QuickTrace™ Probe Test, to automatically identify and display unknown nodes.

QUICKTRACE
A02

- In all, 16 different preprogrammed tests make the 90 Series a powerful stand-alone troubleshooting instrument.

Add the power of a PC.

Connect the 90 Series' RS-232 port to a PC or terminal and access advanced troubleshooting functions, such as Break-Point and Frame-Point capabilities, memory upload and download, plus external trigger functions. You can save both test sequences and results, building documentation on different boards as you go.

Designed for real-time testing.

The 90 Series consists of three units, each designed for one of the three most commonly used 8-bit processors (Z80, 6809 or 8085).

Each tester clips directly onto the microprocessor, including soldered-in processors. Power is supplied by the Unit Under Test. The UUT continues to operate while diagnostics are executed, so you can even locate intermittent problems.

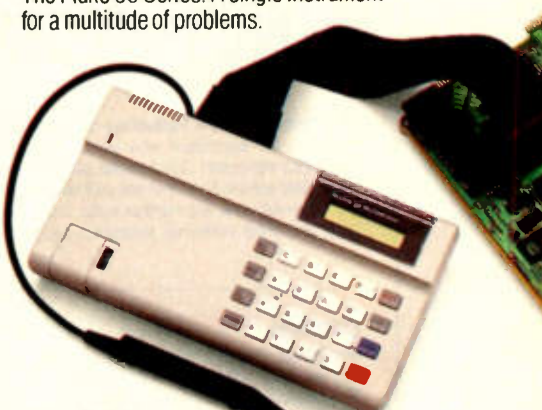
Easy on the technician, easy on the budget.

The 90 Series is small enough (11"x 6" x 3") to find a home on every service bench. Test results are fast and presented in English. Each diagnostic function is selected from a simple-to-follow menu, which greatly reduces training time.

The Fluke 90 Series is ideal for service and repair operations, as well as engineering prototype testing and technician training. And it's ideally priced at $1395 (suggested U.S. list), available from leading electronic distributors.

To find out more about the Fluke 90 Series, or the products that made Fluke the leader in emulative board testing, the 9000 Micro-System Troubleshooter or 9100 Digital Test System, call today at **1-800-44-FLUKE ext. 33.**

The Fluke 90 Series. A single instrument for a multitude of problems.



The 90 Series μP Board Tester

John Fluke Mfg. Co., Inc., P.O. Box C9090, M/S 250C, Everett, WA 98206.
U.S.: 206-356-5400 CANADA: 416-890-7600.
OTHER COUNTRIES: 206-356-5500.

FLUKE®

Circle (4) on Reply Card

News

Triplett offers repair policy

The Triplett Corporation has restructured its repair policy by placing maximum cost limits, which are considerably lower than present industry rates, for repair work on each model in its line of test equipment.

Responding to the problem of "throwaway" test equipment, in which users feel it is cheaper to replace a unit than fix it, the company is placing a cap on repair costs for each digital or analog multimeter, communications product and test-equipment accessory it manufactures. In most cases, the ceilings are approximately half the price of a brand new unit.

EIA/CEG establishes defense fund

The Electronic Industries Association's Consumer Electronics Group (EIA/CEG) has established a 6-figure matching legal defense fund to be made available to the first member company to be sued over marketing digital audiotape (DAT) recorders in the United States. The funds are intended to be used to match company funds needed for company defense in litigation on the legality of importing and marketing DAT recorders. The fund was established in response to the Recording Industry Association of America's intention to sue the first DAT seller.

EIA supports compatibility in HDTV

The Electronic Industries Association Committee on Advanced Television (EIA/ATV) has reached several agreements concerning the development of a technical standard for high-definition television (HDTV), which is expected to be used in the United States in the 1990s. The key issue resolved was that of compatibility—the committee agreed that any system that is adopted should be compatible with the current NTSC system now in operation in the United States. The committee also agreed that no degradation should be discernible in the NTSC signal received by the home viewer, and that a smooth transition to HDTV is necessary to protect both the consumers' and the broadcasters' investments.

The committee has been meeting since the beginning of 1988 to develop a broad industry consensus on key issues related to the development of HDTV standards. The association is working with broadcasters, cable operators, consumers and federal agencies in addition to its manufacturing members.

These resolutions were set forth before the Congressional Subcommittee on Science, Research and Technology in June. Sidney Topol, the chairman of the EIA/ATV committee, testified that the basic principles agreed upon by the electronics industry more than 50 years ago also apply to HDTV. The principles include a single set of TV standards for the United States, a high-definition picture, a service giving as near nationwide coverage as possible, a selection of programs, and the lowest possible receiver cost and the easiest possible tuning. The chairman also pointed out the new opportunities HDTV will create for manufacturers of TVs, tubes, amplification systems, components, transmission systems, satellite and cable TV equipment. ES&T

The how-to magazine of electronics

ELECTRONIC Servicing & Technology

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.

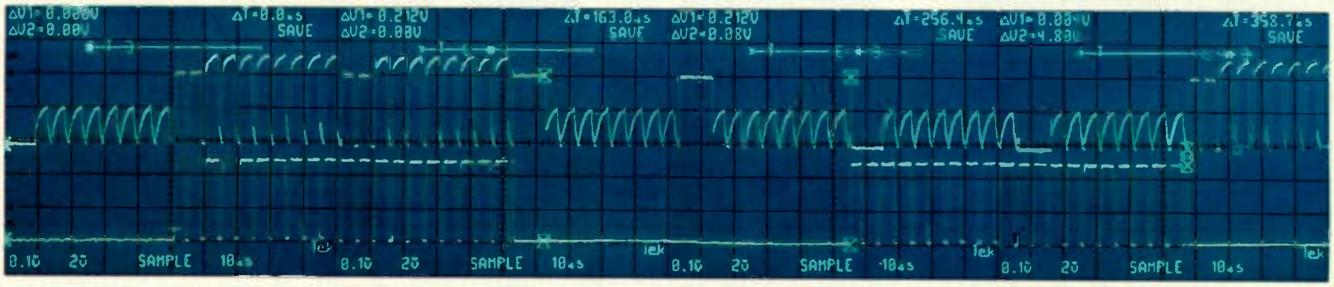
CORRESPONDENCE
Editorial, advertising and circulation correspondence should be addressed to: P.O. Box 12901, Overland Park, KS 66212-9981 (a suburb of Kansas City, MO); 913-888-4664.
Home office fax: 913-888-7243.
Home office telex: 42-4156 INTERTEC OLPK

SUBSCRIPTION PRICES: one year, $19.49; two years, $32.98 in the USA and its possessions. Foreign countries: one year, $23.49; two years, $36.98. Single copy price: $2.50; back copies, $3.00. Adjustment necessitated by subscription termination to single copy rate. Allow 6 to 8 weeks for new subscriptions.

ISSN 0278-9922 $2.00 + 0.00

INTERTEC PUBLISHING CORPORATION

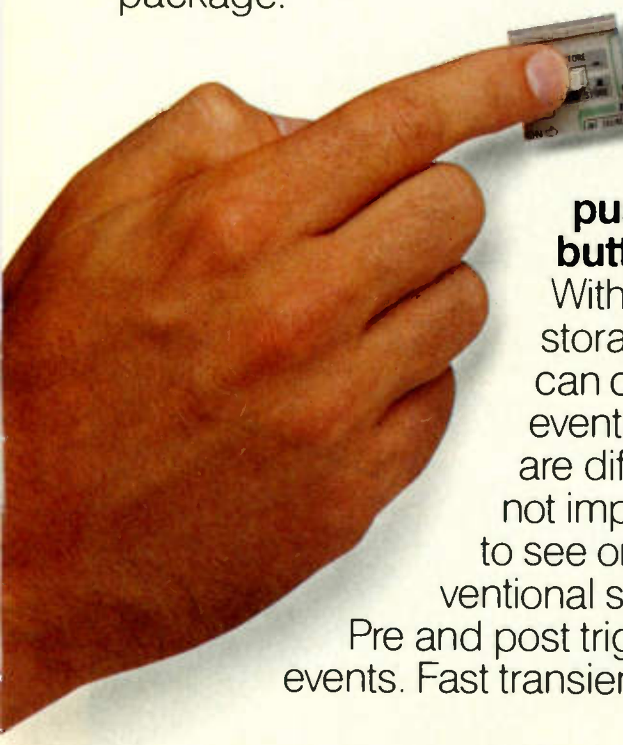
Digital scopes with a



Four screen photos spliced end to end illustrate the benefit of full four-screen capture using the 2230's 4K record length.

Give up real-time capability for storage? Not with Tek!
That's because analog capability is integral to low-cost Tek digital storage oscilloscopes. So you need only one instrument to make all your measurements efficiently. With no trade-offs.

It's another Tek advantage: analog and digital in one familiar, affordable package.



Select either mode at the push of a button.
With digital storage you can capture events which are difficult if not impossible to see on conventional scopes. Pre and post trigger events. Fast transients. Single-shot events. Elusive glitches. Low-speed phenomena.

Any waveform can be viewed for as long as you like. Or stored in 4K of memory for later analysis or comparison to other waveforms. And if there's a question about a digital measurement, just push a button for real-time display analysis.

real-time advantage.

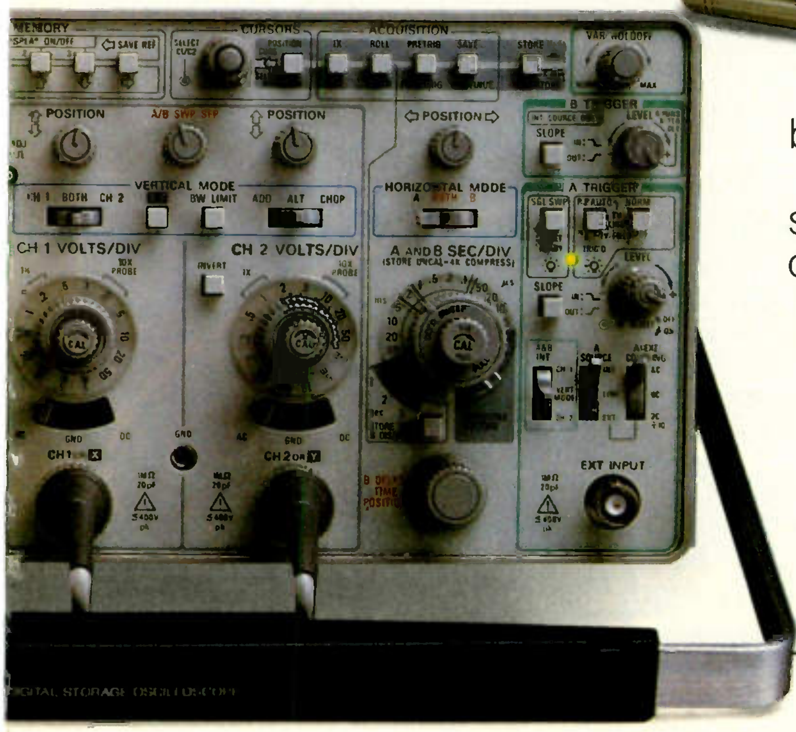
The affordable portables.
These are the world's best-selling digital storage oscilloscopes. And with the new 50 MHz Tek 2210 joining the family, there's now an even better selection—in bandwidth, performance and price.

Select for advanced features such as 100 ns glitch capture at any sweep speed, CRT readout, measurement cursors, multiple acquisition modes and hardcopy output, plus optional GPIB or RS-232C interfaces and software.

These scopes are perfect for first-time digital users. And seasoned operators will appreciate even more their versatility, convenience and value. All backed by Tek quality and a 3-year warranty.

Features	2230	2221	2220	2210
Bandwidth	100 MHz	60 MHz	60 MHz	50 MHz
Max. Sampling Speed	20 MS/s	20 MS/s	20 MS/s	20 MS/s
Vertical Resolution	8-12 bits	8-10 bits	8 bits	8 bits
Record Length	4K	4K	4K	4K
Glitch Capture	100 ns	100 ns	100 ns	No
CRT Readout/ Cursors	Yes	Yes	No	No
GPIB/RS-232-C Options	Yes	Yes	Yes	No
Warranty	3-years on labor and parts including CRT			
Price	$4995	$3995	$2995	$2395

Each scope offers a range of capabilities you'd expect to find only in much more expensive instruments.



Discover the potential. Let Tek show you what you're missing... without making you give up analog to see it. That's the real-time advantage of Tek digital storage.

For easy ordering or more information call Tek Direct:

1-800-426-2200

VISA, MasterCard

Tektronix®
COMMITTED TO EXCELLENCE

Circle (6) on Reply Card

Choosing the right satellite antenna system

Understanding G/T specs will help you choose the right satellite antenna system

By James E. Kluge

Although the term *G/T* is one of the specifications frequently found on a TVRO antenna spec sheet, some antenna buyers just memorize a number to aim for and let it go at that. However, understanding what this specification means will allow a consumer, technician or dealer to choose a satellite antenna receiving system that will provide a good TV picture under all conditions. No one number will do the job: You need to know how the system will be used to choose the proper G/T.

G/T is expressed in units of decibels per kelvin, where G is antenna gain and T is the system noise temperature. (See "What on Earth Are Kelvins?" in the July 1988 issue for an explanation of noise temperature.) G/T represents a figure of merit for TVRO-antenna systems. Although it is probably one of the least understood items on a spec sheet, a typical dealer or consumer does understand that the higher the value of G/T, the better the antenna.

Unfortunately, the characteristic that G/T represents encompasses many aspects of a TVRO system. The G/T can express the gain/temperature ratio of only the antenna, of any portion of the TVRO system, or of the entire TVRO system, including the receiver.

Because gain and noise contributions in the system components between the low-noise amplifier (LNA) output and the TV set do not significantly affect G/T, this ratio is commonly specified from the antenna up to and including the LNA input. In fact, when you see G/T specified, it often does not apply to the antenna alone but will nearly always include the LNA's effective input noise temperature. This means that the G/T rating includes the antenna and the LNA input plus whatever waveguide or passive devices are interconnected between them.

Without delving into TVRO system design, let's take a look at the G/T spec as it applies to the antenna-to-LNA combination contained within the feed/LNB module.

Gain-temperature ratio

TVRO antennas are rated in decibels

Kluge is a technical editor at the Winegard Company.

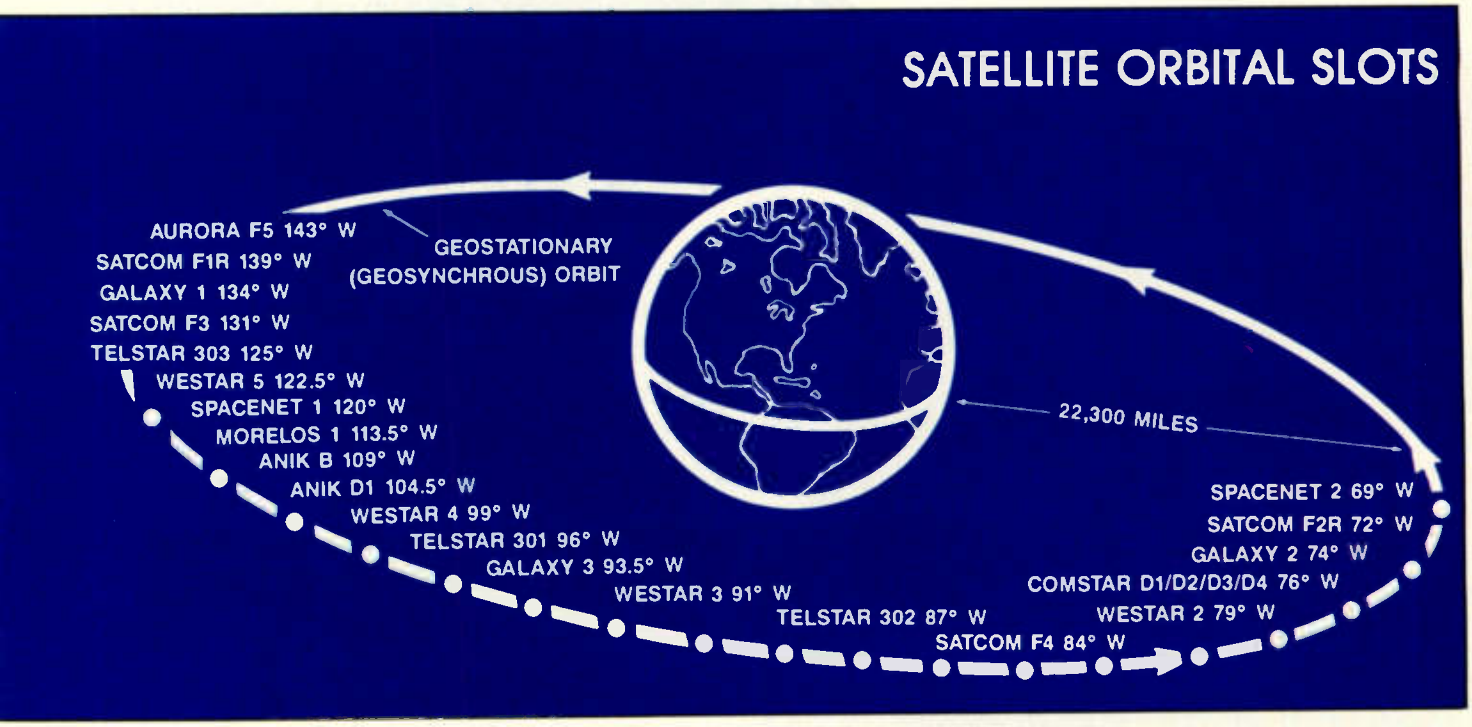


Figure 1. All of the domestic television satellites are located in an orbit directly about the earth's equator between 69° west longitude and 143° west longitude. Because their orbital speed just matches the rotational speed of the earth, each one is, in effect, stationary above a point on the earth.

of gain, which is a function of the antenna aperture (the diameter of the dish). Antenna gain (G) is directly proportional to the area of the reflector, which means that it is proportional to the square of the diameter of the reflector: $G \propto D^2$. The gain of an antenna is a number that compares its performance to the performance of a reference standard antenna. The reference antenna ordinarily used is called an *isotropic antenna* (see the glossary, "Some TVRO terminology," for explanations of any unfamiliar terms you run into in this article). An isotropic antenna is an ideal antenna that radiates or receives equally in all directions.

Let's call the power received by the reflector antenna P_R and the power received by the isotropic antenna P_I. The gain of the reflector antenna in dB is

$$\text{gain (dB)} = 10 \log (P_R/P_I)$$

That is, gain expressed in decibels is equal to 10 times the logarithm of the numeric ratio of the maximum signal power received by the antenna, to the equivalent power received by an isotropic antenna immersed in an identical electromagnetic field. This numeric power ratio is used in G/T calculations.

The symbol T stands for *system noise temperature*, which includes the noise temperature of the antenna and the LNA, as well as the noise temperature of any waveguide and other devices, passive or active, interconnecting the antenna and the LNA.

G/T, then, is a ratio of numerical gain to effective noise temperature in kelvins; this figure is then converted to decibels. The goal of a TVRO system is to maximize G/T, which requires either increasing G by using a larger diameter (and more expensive) antenna, or reducing T by employing a more expensive LNA that has a lower noise temperature. There are cost trade-offs whichever way you choose to go. However, there is a practical lower limit of noise temperature on available LNAs for use with consumer-marketed TVRO systems; that limit is about 65K to 75K.

Signals from a more powerful satellite allow you to relax either of the two options for maximizing G/T. In other words, the true goal of TVRO system design is a maximum *carrier-to-noise ratio*, C/N. The C/N is the ratio of the carrier strength to the noise strength expressed in decibels. The higher the C/N, the higher the S/N and, consequently, the better the TV picture will be.

C/N (in dB) is directly related to G/T. For example, a TVRO system with a G/T of 30dB/K will increase the C/N by 10dB over a system with a G/T of 20dB/K. It is extremely important to maintain a minimum C/N (threshold level) to avoid a rapid deterioration of the S/N ratio in the receiver. Typical values range from 8dB to 15dB.

Antenna noise

Antenna noise temperature, designated T_A, is not a physical temperature but rather an *effective* temperature related to generated noise power. Because the energy radiated by any warm body is directly related to its thermodynamic temperature, the noise power received from it can be specified in thermodynamic temperature units (kelvins). The noise contribution from noise sources outside the system depends on the direction from which the noise arrives relative to the boresight of the antenna. The noise contribution is weighted by the receiving pattern of a particular antenna relative to its maximum on-axis gain.

Thus, antenna noise temperature is a

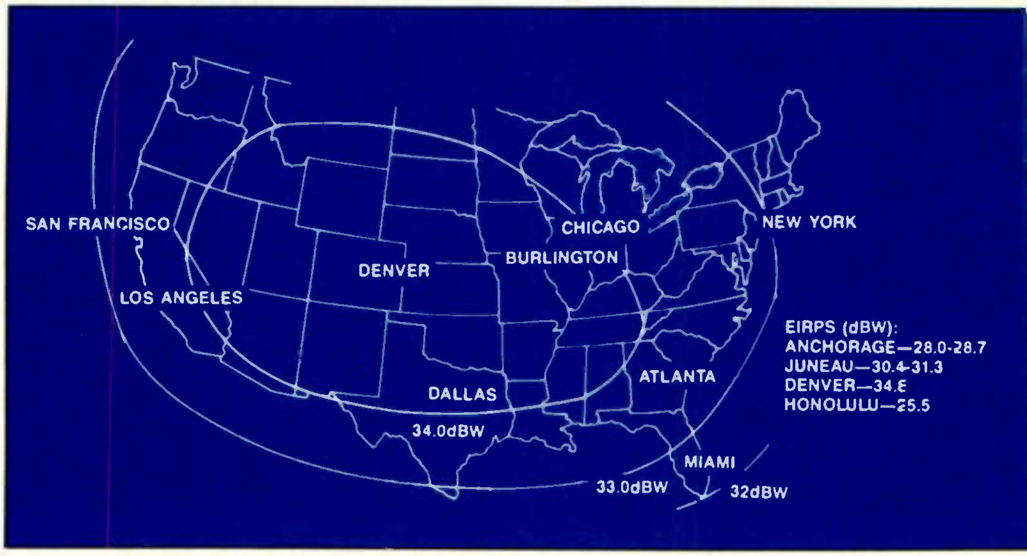


Figure 2. Effective isotropic radiated power (EIRP) is a measure of the relative strength of the satellite TV signal expressed in dBW. This footprint map graphically illustrates how strong the satellite signal is as it reaches various regions of the satellite's coverage area. Each satellite has a different coverage pattern. In many cases, different transponders on the same satellite will show a different EIRP. Where the signal is strongest is the area referred to as the boresight.

function of the look angle of the antenna and its particular ambient environment, as well as the antenna's receiving pattern. The antenna noise temperature varies considerably with elevation angle. The noise temperature is minimum (approximately 4K to 15K) at the antenna's zenith (directly overhead, which is 90 degrees above the horizon) when "looking" at the sky. As the elevation angle is reduced, the noise temperature begins to rise slowly as the side lobes of the antenna start picking up radiated thermal energy from the earth at about 20° to 30° elevation. The noise temperature then rises nearly exponentially toward 290K, which is the earth's ambient reference temperature. Pointing an antenna at the sun (which happens twice annually, in the spring and fall) causes its noise temperature to skyrocket to a point where the noise swamps the desired signal.

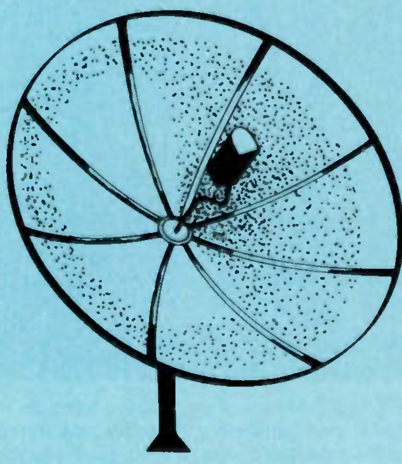
Devices in the signal chain

In a TVRO system, the first device in the signal chain is the antenna. In addi-

Some TVRO terminology

Antenna gain: An antenna is a passive device; it obviously can't have gain. However, some antennas pick up more of the electromagnetic signal and convert it to a larger electrical signal for use by the TVRO system. TV antennas use reflectors and directors to increase the amount of electromagnetic signal picked up from a transmitter in a specific direction. TVRO antennas use a parabolic dish to collect signal over a large area and direct it at the antenna. An antenna using either of these methods aimed at a source of electromagnetic radiation gives a much larger signal than would an antenna that receives signals equally from all directions (an isotropic antenna). The ratio of the power produced by a practical antenna to the power produced by an isotropic antenna when receiving an identical signal is called antenna gain.

Aperture efficiency: The ratio of captured signal to the theoretical maximum for a given dish antenna/feed combination. The design goal is 100% aperture efficiency, but most TVRO dishes perform at only 50% to 80% to attain low noise characteristics and ease of construction. Some VHF/UHF antennas, on the other hand, can approach the 100% goal with an array of reflective elements.



Boresight: The center of the transponder footprint, where signal strength is at its maximum.

dBi: The unit used to express antenna gain. The i shows that this is gain compared to an isotropic antenna.

dBW: The unit that indicates the power of a signal as compared to a reference of 1W.

EIRP: Effective isotropic radiated power, a measure of the relative strength of the satellite TV signal expressed in dBW. This parameter is called *effective* (or equivalent) isotropic radiated power because, although the transmitting antenna at the satellite is directional, the EIRP describes the power that reaches the earth as though the transmitting antenna were an isotropic antenna. A directional antenna directs all its power into producing a signal in one direction. An omnidirectional antenna would have to produce the same signal strength in all directions. Therefore, an isotropic antenna would have to be fed more power to produce the same signal strength at a specific location on earth as is being produced by the actual antenna being used.

Figure of merit: A numerical quantity based on one or more characteristics (of a device or solution) under specified conditions. The figure is used for indicating comparative efficiency or effectiveness. In other words, a figure of merit doesn't tell you, absolutely, anything about what it describes, but it does allow you to compare among similar units.

Isotropic antenna: An idealized antenna that transmits or receives electromagnetic signals equally in all directions. Such an antenna ordinarily would be of little use in an actual application: An isotropic transmitting antenna would waste a lot of power transmitting signal where it wasn't needed; an isotropic receiving antenna would be subjected to a lot of unwanted signals from directions other than the direction of the desired source. An isotropic antenna does, however, make a good reference against which to compare practical antennas.

LNA: Low-noise amplifier. An amplifier that is designed to contribute the lowest practicable amount of noise to an amplified satellite signal. This antenna preamplifier is located directly at the antenna so that the very small satellite signal is amplified before any attempt is made to transmit it to the TV system.

Look angle: The angle above the horizon at your location from which the satellite signal arrives.

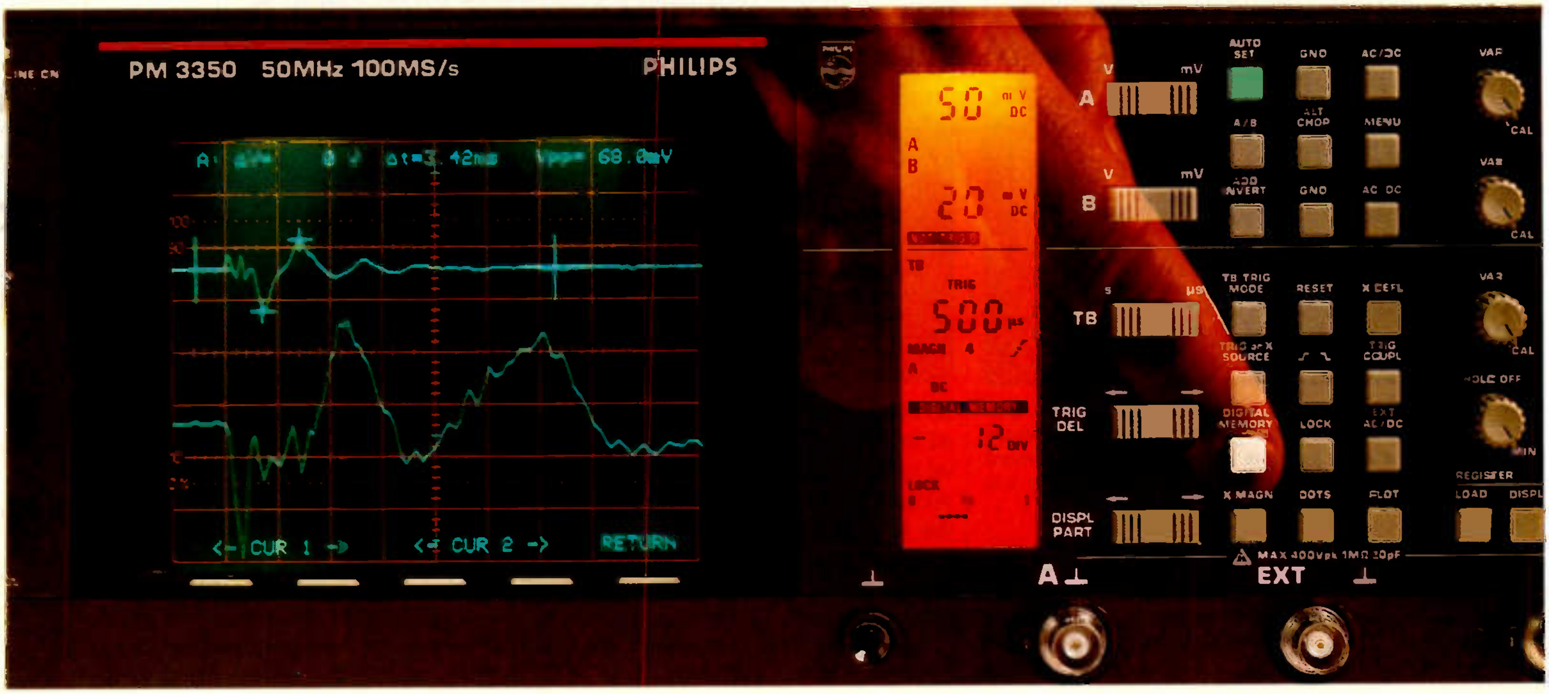
Side lobes: If you look at the response curve of a directional antenna, you ordinarily find that, in the case of a transmitting antenna, it radiates most of its energy in the direction perpendicular to the antenna orientation. In most cases, however, you will find that at some angle to the direction of transmission, on both sides, some smaller amount of energy will be transmitted. A directional receiving antenna will be most sensitive to received signals from the direction perpendicular to its orientation, but it will exhibit some sensitivity to signals coming from some angle on both sides of the line of greatest sensitivity. On the response curve, these measures of power transmitted or sensitivity look like lobes. People who work with antennas have adopted the practice of using the term *side lobes* when speaking of this energy transmitted or received at an angle to the main direction of transmission or reception.

* These definitions have been adapted by the editorial staff of **ES&T** from a number of sources, primarily information provided by Winegard. Any errors that may have occurred should be attributed to the ES&T staff, not the author.

FLUKE AND PHILIPS – THE GLOBAL ALLIANCE IN TEST & MEASUREMENT

FLUKE®

PHILIPS



Breakthrough!
The first fast digital with analog for <$4,000

It's here. The Philips PM 3350 Digital Storage Oscilloscope. High-speed digitizing *plus* full analog capabilities for half what the next-best DSO would cost you. Unbelieveable!

BREAKTHROUGH PERFORMANCE

- *100 MS/s sampling speed* on both channels simultaneously allows you to capture fast phenomena having low repetition rates—even single shots—with excellent resolution. A first in this price range!
- *True 8-bit vertical resolution* offers precise signal display and measurement.
- *Deep reference memory* lets you store and compare wafeforms with ease.
- *Plus, you get full, dual-trace 50 MHz real-time* familiarity at the touch of a button.

FAST, CONFIDENT OPERATION

- *AUTOSET* automatically selects amplitude, timebase and triggering for error-free, instant display of any input signal on any channel—in both digital and analog modes!
- *LCD panel* serves as the text information center, offering clear, at-a-glance alpha-numeric read-out of all instrument settings; saves screen area for uncluttered waveform viewing.
- *Cursors* supply instant voltage, timing, frequency, amplitude and risetime measurements.
- *Softkeys* grant you simple, direct access to over 40 different functions via on-screen menus.
- *IEEE-488 or RS 232 interface* options for fast computer/controller hook-up, data transfer and printing hard copies.

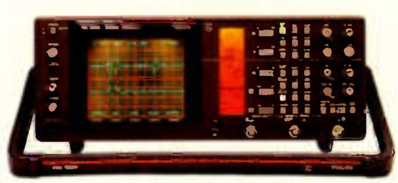
COMPLETE SUPPORT

The Philips PM 3350 comes with a 3-year warranty and all the technical and service assistance you need. From Fluke—the people who believe that extraordinary technology deserves extraordinary support.

TEST THE DIFFERENCE

Call Fluke today at **800-44-FLUKE ext. 77.** And make a break with the past.

John Fluke Mfg. Co., Inc., P.O. Box C9090, M/S 250C, Everett, WA 98206
U.S.: 206-356-5400 CANADA: 416-890-7600
OTHER COUNTRIES: 206-356-5500



PM 3350 • 50 MHz • DIGITAL STORAGE SCOPE

Circle (7) on Reply Card

FLUKE®

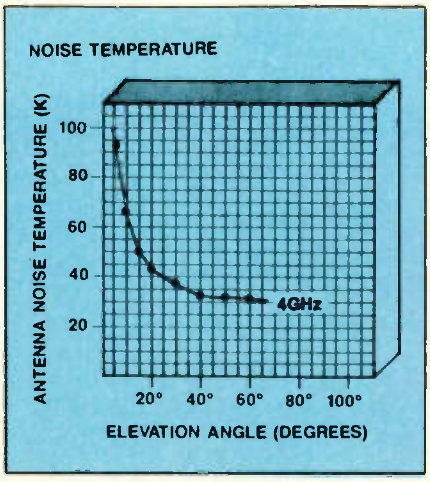


Figure 3. Antenna noise increases very rapidly at elevation angles below about 20° where off-axis antenna response becomes more susceptible to thermal radiation from the earth and ground objects.

Table 1. Typical specifications for a TVRO antenna

dB gain	40.4dBi (Chaparral with Gold Ring)
aperture efficiency	67%
dB gain	39.6dBi (stock Chaparral)
aperture efficiency	56%
beam width (-3dBi)	1.6°
gain/noise temperature	19.8 (80° LNA, Gold Ring)
gain/noise temperature	19.0 (80° LNA, Stock Feed)
2° response	more than 18dB down
side lobes	more than 20dB down
cross polarization	more than 25dB down
F/D ratio	0.283

tion to gathering signal power, an antenna is also a noise source that derives its noise power largely from outside sources such as the sun, the stars, the moon and even the earth. Also associated with an antenna are ohmic losses, which contribute to the antenna's total noise. However, these losses are small and insignificant when compared to the contribution of noise flux from the outside noise sources that are incident on the antenna surface.

The second device in the chain is the waveguide, along with its junctions, which connect the antenna feed to the LNA. The waveguide, being passive, has no gain and, in fact, represents a loss, L. For G/T measurements, the device is referenced to the standard ambient noise temperature, 290K (62.3°F). Its effective noise temperature may vary from 0K for an ideally lossless device to 290K for a very high-loss device (more than 15dB insertion loss); a 1dB insertion loss would correspond to an effective noise temperature of 60K.

The mathematical relationship between loss and effective noise temperature is T = 290 (L-1/L) where L is a ratio of input power to output power (just the inverse of a power-gain formula). L is termed the *power-loss ratio*; it is always greater than one.

Finally, the third device in the signal chain is the LNA. This unit establishes or determines the S/N characteristics for the rest of the TVRO system that follows.

The LNA's gain should be high enough to raise the tiny input signals to an output level that can be downconverted in frequency, then sent along a coaxial cable leading to the receiver indoors without the cable loss overly degrading the C/N ratio. Also, the LNA should have a low enough effective input-noise temperature, T_E, so that its noise does not significantly add to the noise level of the signals it is amplifying. Typical LNA gain is 40dB to 50dB; typical C-band noise temperature ranges from 75K to 100K. If these specs are inadequate, the system requires a larger diameter antenna to boost the carrier level. Keep in mind that not all satellites and transponders are equal; avoid making a decision based on EIRP (see the glossary) of signals from one of the more powerful birds.

Calculating G/T

If the antenna gain (G_A), the antenna noise temperature (T_A) and the system noise temperature (T_S) are known, G/T can be calculated from the expression $G/T = G_A/(T_A + T_S)$. G_A and T_A can be determined from the manufacturer's spec sheet, and the system temperature, T_S, is essentially equal to the LNA noise temperature.

Because G/T is commonly expressed in dB/K, you calculate G/T by adding T_A and T_S (in kelvins), finding the logarithm of the total, multiplying by 10 and subtracting the result from the antenna gain given in dB or dBi.

For example, a 10-foot antenna with an aperture efficiency of 67% has a gain of 40.4dBi. Its minimum noise temperature is 35K. When the antenna is connected to a 100K LNA, the G/T is

$$G/T = 40.4 - 10 \log (35 + 100) = 19.1\text{dB}$$

When the antenna is connected to an 85K LNA:

$$G/T = 40.4 - 10 \log (35 + 85) = 19.6\text{dB}$$

This G/T is a 0.5dB improvement in C/N.

A useful G/T for typical TVRO receiving antennas ought to range between 15dB and 20dB. But what end of that range should you design for?

Determining what G/T you need

To know what G/T you need, you must know what minimum signal level (EIRP) to expect and what minimum C/N ratio you are willing to tolerate. A C/N of 8dB produces a good watchable picture. Below 8dB, the picture quality deteriorates rapidly, so it is wise to allow a margin of safety such as 3dB or 4dB to provide for less-than-ideal conditions (snow, rain, wind, sun transit).

The EIRP at a given location can be determined from your geographical location's footprints, found in published charts. Then C/N can be calculated using the following formula:

$$C/N = EIRP - \text{loss} + G/T - 10 \log B - k$$

where:

EIRP = the expected minimum (worst case) signal, in dBW, from the published footprint.

loss = free-space loss of signals traveling through space (typically 196dB at 4GHz, 205.5dB at 12GHz).

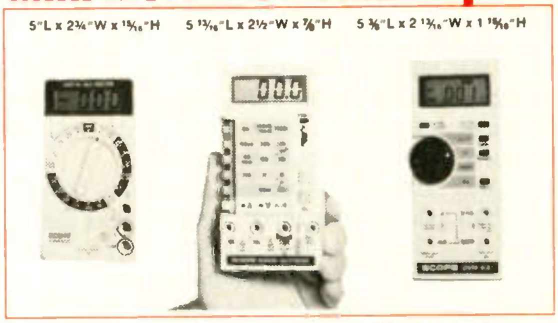
B = the TVRO receiver's bandwidth in hertz (typically 30MHz).

k = Boltzmann's constant, 1.38×10^{-23} (−228.6dB).

For example, using a 10-foot antenna with a G/T of 20dB/K and a bandwidth

Put them to the test

Mini-Meters with Maxi-Specs



SCOPE 3½ Digit LCD Meter
• 0.5% Accuracy • DC Voltage • AC Voltage • DC Current • Resistance • Diode Test • Battery Life 300 Hrs. • Overload Protection: DC 500V, AC 350V, ohms 250V DC/AC.

Model DVM-630 Our Price **$29.95**

Zippered carrying case CC-30 $4.50

NEW! SCOPE 3½ Digit, LCD 8 Function w/ Transistor Tester
• 0.5% Accuracy • Audible continuity and diode test • 10 Amp measurement • Resistance • DC/AC Voltage.

Model DVM-632 Reg. $60.00 Our Price **$44.95**

Zippered carrying case CC-30 $4.50

SCOPE 3½ Digit LCD w/ Autoranging
• 0.5% Accuracy • Auto/Manual range selection • DC Voltage • AC Voltage • AC Current • DC Current • Resistance.

Special

Model DVM-631 Our Price **$49.95**

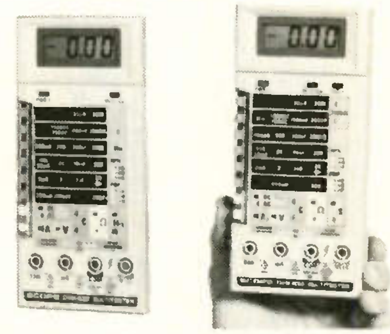
Deluxe carrying case CA-92 $9.95

SCOPE Digital Capacitance Meter
.1 pf to 2000 µf

• Digital LCD display • LSI-circuit • High accuracy: 100 PPM 0.5% • Broad test range • Fast sampling time • Capacitor discharge protection • Compact, lightweight design • One-hand operation.

Model DCM-602 Our Price **$59.95**

SCOPE Digital Multimeters
• Overload protection • Auto-decimal LCD readout • Polarity indication • 300 hr. 9V battery life • Low battery indicator • .5% DC accuracy



• 8 Functions, 37 Ranges including Transistor and Capacitance measurements

Model DVM-636 Our Price **$67.50**

• 11 Function, 38 ranges including Logic Level Detector, Audible and Visual Continuity, Capacitance and Conductance measurements

Model DVM-638 Our Price **$87.50**

CA-92 Deluxe Padded Case for DVM meters $9.95
TL-216 Transistor and Capacitance Test Leads $9.90

NEW! SCOPE Frequency Counters
• 8-digit LED • Compact • lightweight • Automatic range and Hold function • High stability in reference oscillator.

Model FC-7011 100 MHz Our Price **$149.95**

Special

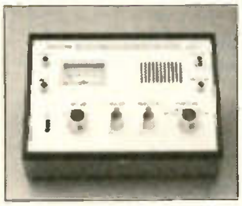
Model FC-7051 550 MHz Our Price **$199.95**

FORDHAM Frequency Counter
• 10 Hz - 150 MHz Range • 7-digit LED display • VHF/HF selection • Gate time 1 sec., 5 sec. • ±1 count accuracy.

Model FC-150 Our Price **$139.90**

NEW FORDHAM Function Generator
• 0.5 Hz - 500 KHz in 6 ranges • Sine, square & triangle wave forms • VCA and VCF inputs • Accuracy ±5% of full scale.

Model FG-202 Our Price **$149.90**



FORDHAM Signal Tracer/Injector
• Easy to operate • VU meter • Two LED mode indicators • 1 KHz test tone • 8 ohm speaker • Test leads.

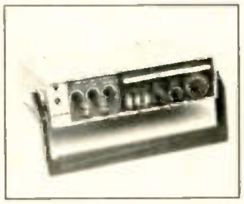
Model SE-610 Our Price **$119.90**

FORDHAM LCR Bridge Meter
• Fully transistorized • 1 KHz signal generator • Measures resistance, inductance, capacitance • High mechanical and electrical stability • Battery operated.

Model LC-340 Our Price **$149.95**

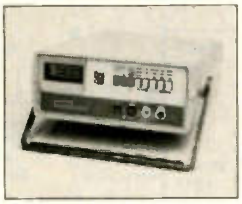
B&K Precision 20 MHz Dual Trace
• Dual/Single trace operation • 1 mV/div sensitivity • Auto/Norm triggered sweep operation with AC, TVH, TVV and Line coupling • Calibrated 18 step time base with 10X magnifier.

Model 2120 Our Price **$399.95**



FORDHAM Sweep Function Generator
• Frequency range 0.2 Hz to 2 MHz • Sine, triangle, square, pulse TTL, wave forms • Frequency accuracy ±5% of length scale • Test leads included.

Model FG-801 Our Price **$219.95**



SCOPE 4½ Digit Bench Digital Multimeter
• 4½ Digit LCD • Automatic (–) negative polarity • Six 1.5V "D" size batteries • Low battery indication • Overload protection • Test lead set, batteries, spare fuse incl.

Model DVM-6005 Our Price **$219.95**

Hitachi 35 MHz Dual Trace Oscilloscope
• Frequency bandwidth DC to 35 MHz • 6 inch CRT with % calibrations • Autofocus • Scale illumination and photographic bezel • Lightweight, compact • Probes incl.

Model V-355 Our Price **$599.95**

SCOPE Pocket Sized Audio Signal Generator
• Sine/square wave patterns • 20 Hz to 150 KHz • Battery operation • Freq. accuracy ±3% or less • Output 1.2V rms max. (no load) • Low battery indicator • Test leads/9V battery incl.

Model RC-555 Our Price **$59.95**

Telephone Orders Now!
Mon.-Fri. 8 a.m.-6:30 p.m. EST. Sat. & Sun. 9 a.m.-3 p.m. EST

ASK FOR FREE CATALOG. Money orders, checks accepted. C.O.D.'s require 25% deposit

Fordham
260 Motor Parkway, Hauppauge, NY 11788

Toll Free **800-645-9518**
In NY State 800-832-1446

Service & Shipping Charge Schedule
Continental U.S.A.

FOR ORDERS	ADD
$25-50	$4.50
$51-100	$5.50
$101-200	$7.00
$201-300	$8.00
$301-400	$9.00
$401-500	$10.00
$501-750	$12.50
$751-1000	$15.00
$1,001-1,250	$17.50
$1,251-1,500	$20.00
$1,501-2000	$25.00
$2,001 and Up	$30.00

Not responsible for typographical errors.

Circle (8) on Reply Card

The farther north the satellite receiving site is, the lower the *look angle*. In Anchorage, Alaska, where the look angle is just above the horizon, ground clutter noise could be significant if an ordinary dish-type reflector is used. A highly directional antenna works better in this situation.

of 30 x 10^6 Hz, assuming a worst-case EIRP of 30dBW, the equation yields a C/N of 7.83dB.

$$C/N = 30 - 196 + 20 - 74.77 + 228.6 = 7.83dB$$

Because most footprints yield an EIRP of 35dBW or more, this figure represents a 5dB margin of safety, so that most of the time (with an EIRP of approximately 35dBW and a G/T of 20dB/K) the C/N will be between 12dB and 13dB, providing excellent picture quality. Under worst-case conditions, when poor atmospheric conditions reduce the EIRP to 30dBW, picture quality will still be acceptable. A 6-foot antenna with a G/T of 15dB would be acceptable for more powerful satellites but unacceptable for many medium-power satellites or fringe areas of the footprint. A larger antenna or a quieter LNA would provide the only solution—a higher G/T.

So G/T becomes important in calculating the C/N ratio. There isn't much you can do to influence the EIRP, the free-space loss, the receiver bandwidth or Boltzmann's constant. But you can select a suitable G/T by making tradeoffs between antenna gain (size) and LNA noise temperature. Always remember, the bottom line is picture quality and clarity. ES&T

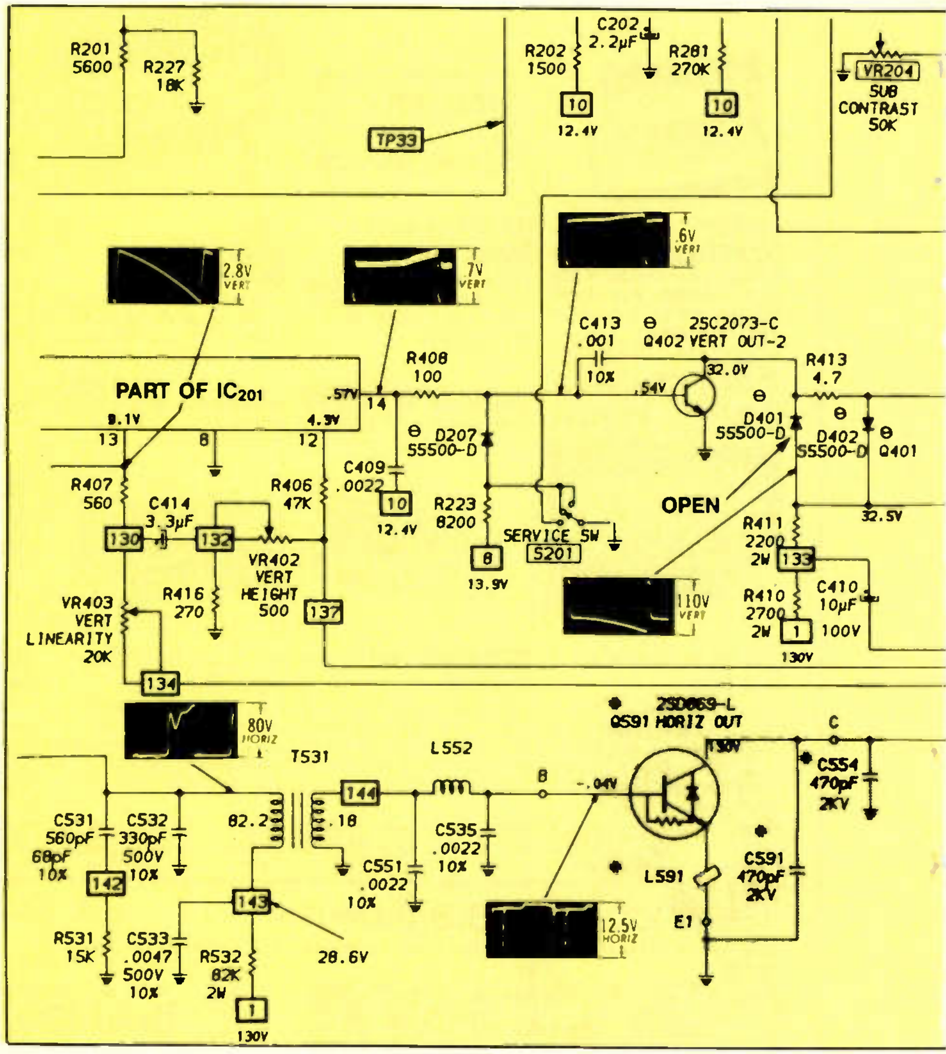
Troubleshooting tips

Vertical foldover Mitsubishi CS1952R (Photofact 2337-2)

This Mitsubishi CS1952R receiver was producing a raster that was folded over at the top and somewhat reduced in height overall. The dc voltage reading at the collector of the second vertical output transistor, Q_{402}, was about 42Vdc—somewhat on the high side of the required 32Vdc. The Q_{402} base voltage was 0.5Vdc, which is about right, according to the schematic. Next, I examined the waveform at the Q_{402} base. The amplitude and dc level were correct, but instead of just one pulse, two closely spaced pulses of excessive width were present during each vertical interval.

The waveform at C_{412} revealed that Q_{402} was amplifying this incorrect base drive and applying it to the deflection yoke. I next examined the waveform at the SYNC/SWEEP/CHROMA/VIDEO integrated circuit (pin 14 of IC_{201}) and found that it had the double pulse as well. At IC_{201}, all of the other waveforms pertaining to the vertical circuit (pins 7, 9, 10, 11 and 13) were normal, with no double pulse. On the basis of these facts, I decided that IC_{201} should be replaced.

I powered up the unit, but the problem remained. Because all of the waveforms at IC_{201} appeared to be correct except for the output at pin 14 (I rechecked them to be certain), I couldn't see any obvious clues as to the cause of the fault. I checked the components in and around the vertical linearity and height controls, thinking that a fault in the feedback circuitry would be responsible, but all components were good. A check of C_{412} revealed that it was leaky. I replaced it, which produced slightly increased height, but the foldover remained.

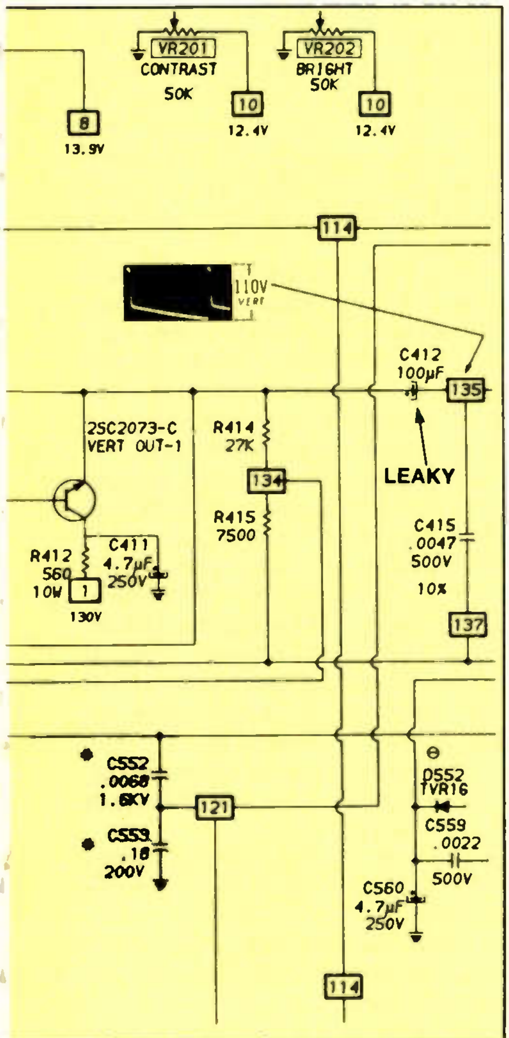


After some time away from the problem, I redrew the output circuit, including Q_{401} and Q_{402}. This redraw revealed a somewhat unusual configuration. The Q_{401} output acts as a current source for the yoke except when the down-going pulse is present at the base of Q_{402}. When the pulse is present, the emitter of Q_{401} and the collector of Q_{401} rise essentially to the supply voltage, about 110V, which brings back the voltage reading at the Q_{402} collector. Recall that this voltage measured somewhat high. A high voltage here indicates a possible problem with the Q_{401} circuit. On the schematic, note that there is a clamping diode, D_{401}, essentially parallel with the base-emitter junction of Q_{401}. This diode allows some of the base current, which would otherwise drive Q_{401}, to be bypassed around it, limiting the gain of the circuit and causing it to conduct less. I removed Q_{401} and tested it on a transistor tester. It was good. When I removed D_{401} and tested it, I found that it was open. Replacing this component and touching up of the height control restored proper operation.

The double pulsing of the IC_{201} pin 14 waveform arose as a result of the feedback circuitry. IC_{201}'s internal oscillator apparently was fooled into resetting (or pulsing) twice during the vertical interval because of the fault in the output circuitry.

Frank Dreher
Flanders, NJ

ES&T



Solving the TV shutdown puzzle

By Bert Huneault, CET

As TV technicians know, shutdown circuits often seem quite puzzling, especially when they are shut down. These circuits are commonly incorporated into modern color receivers to provide protection against potential fire hazards or damage to expensive components when certain parts or circuits fail. The circuits also protect against high CRT beam current or excessively high voltage and potentially dangerous x-rays.

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

SCRs make good crowbars

One way of providing shutdown protection is to incorporate a circuit that, under certain fault conditions, can reduce or completely kill the B+ (V_{cc}) applied to vital stages, thus reducing or removing the power available to those stages so that overheating or excessively high voltage will not occur. Figure 1 shows such a circuit, featuring an SCR and a current-limiting transistor.

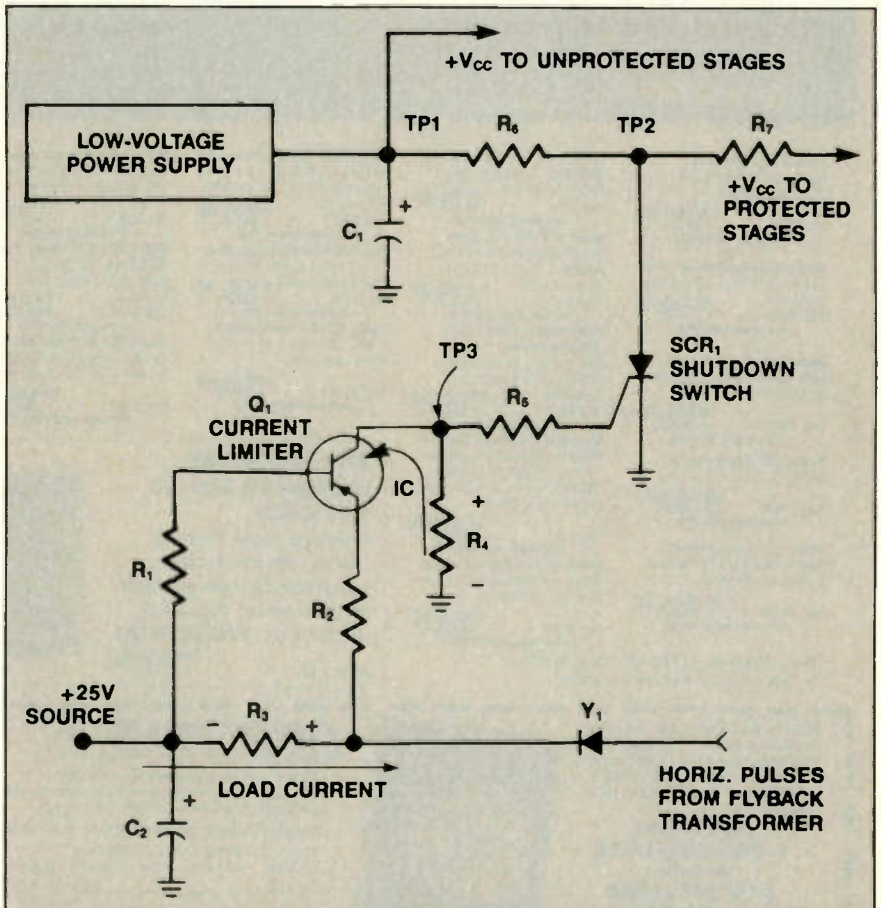


Figure 1. One way of providing shutdown protection is to incorporate a circuit that, under certain fault conditions, can reduce or completely kill the B+ (V_{cc}) applied to vital stages, thus reducing or removing the power available to those stages so that overheating or excessively high voltage will not occur.

Diode Y_1 provides 25V of scan-derived B+ by rectifying flyback pulses from the horizontal-output transformer. This 25V source supplies certain circuits in the receiver. Under normal (no-fault) conditions, the total load current flowing along the 25V line is so low that the voltage drop across low-resistance R_3 is insufficient to forward-bias transistor Q_1. Because Q_1 doesn't turn on, no current flows through its collector load resistor R_4; consequently, the dc voltage at test point TP3 is zero. With no voltage applied to its gate, SCR_1 remains in the off state even though its anode is positive. In other words, the SCR behaves like an open switch and has no effect upon the B+ (V_{cc}) supplied by the low-voltage power supply to the protected and the unprotected stages.

Now, let's assume that a fault such as a short or severe leakage occurs in one of the loads connected to the scan-derived 25V source. Without the protection of the shutdown system, this fault could potentially cause serious damage to the horizontal output circuitry. But have no fear: The protection incorporated in Figure 1 causes the system to shut down safely because Q_1 "senses" the excessive current and activates the SCR. Circuit operation is as follows:

1. The increase in load current (the arrow in the Y_1 cathode circuit, Figure 1) causes the voltage drop across R_3 to rise sufficiently to forward-bias the base-emitter junction of Q_1.
2. Q_1 turns on, and its collector current causes TP3 to become positive in relation to ground.
3. The resulting gate current causes SCR_1 to switch on, effectively grounding TP2 (crowbar action) and removing V_{cc} from the protected stages, which might include audio, vertical and horizontal circuits.

Disabling these circuits (by removing

B+) can prevent x-ray radiation or overheating of the H.O.T. or power transistors, for example. Of course, when the set shuts down this way, there is no sound and no raster, which gives the technician the impression that the set is actually turned off.

Once the set is manually turned off, the SCR resets and remains in the nonconducting state the next time the receiver is turned on—thus restoring the B+ voltage to the protected stages—as long as the fault has been isolated or repaired in the meantime. Otherwise, shutdown will occur as soon as the set is turned on again, preventing raster and sound from coming on.

Because an SCR can switch on in microseconds, this type of shutdown system provides better protection than slower-acting conventional protective devices such as fuses and circuit breakers.

Another shutdown trick

For a little extra action, let's examine a different kind of shutdown circuit. Figure 2 is a simplified schematic of the protection circuitry featured in the RCA CTC108 chassis. This circuit disables the horizontal deflection system by cutting off the horizontal drive if either high voltage or beam current increases beyond certain limits. Transistors Q_{413} and Q_{414} form an x-ray protection latch, and transistor Q_{415} senses excessive CRT beam current.

Zener diode CR_{407} produces a constant reference voltage of +33V at test point TP3. Diode CR_{409} rectifies horizontal pulses from a secondary winding on the flyback transformer. After filtering by C_{421}, the resulting normal dc voltage of about +55V (TP1) is applied to a series voltage divider consisting of R_{434}, R_{436} and the internal resistance of transistor Q_{415}. Q_{415} normally operates in the saturation mode because of heavy forward bias applied to its base from test point TP3 (through R_{454}). Its collector-emitter resistance is, therefore, negligible, and the bottom end of R_{436} is effectively returned to ground.

Thus the total resistance of the voltage divider network is approximately 55kΩ, which results in a dc voltage of about +33V at the R_{434}-R_{436} junction (TP2). This point is connected to the emitter of Q_{413} (PNP), which, together with Q_{414} (NPN), forms an overvoltage latch.

Normally, Q_{413} doesn't conduct because its base is also connected to a 33V source (TP3). No collector current in Q_{413} means no base current for Q_{414}. Consequently, Q_{414} is also turned off and has no bearing on the operation of the horizontal driver transistor. Q_{411} thus operates normally and feeds the usual square-wave drive signal to the horizontal output transistor, resulting in normal deflection and high voltage.

Overvoltage and overcurrent protection

If the high voltage pulses produced by flyback transformer T_{402} have excessive amplitude (potential x-ray hazard), the positive voltage at TP1 rises above 55V, forcing the TP2 voltage to rise above 33V. This increase in voltage forward-biases Q_{413}, whose base voltage is clamped at 33V by zener regulator CR_{407}. Therefore, Q_{413} turns on and its collector provides current for the base of Q_{414}. Thus Q_{414} switches on and its low internal resistance connects the base

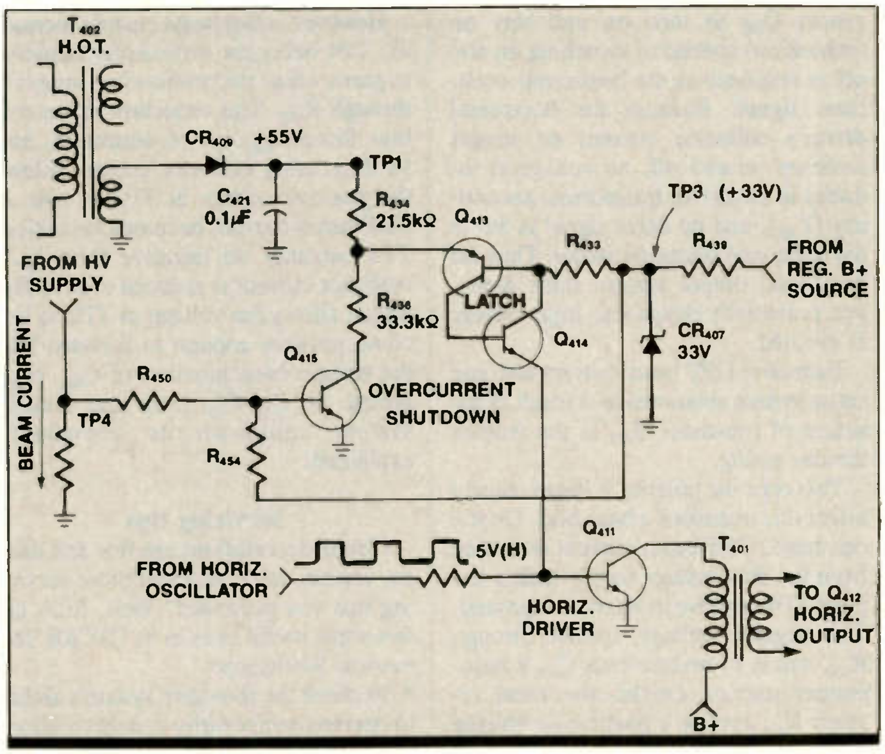


Figure 2. The protection circuitry in this RCA CTC108 chassis schematic disables the horizontal deflection system by cutting off the horizontal drive if either high voltage or beam current increases beyond certain limits. Transistors Q_{413} and Q_{414} form an x-ray protection latch, and transistor Q_{415} senses excessive CRT beam current.

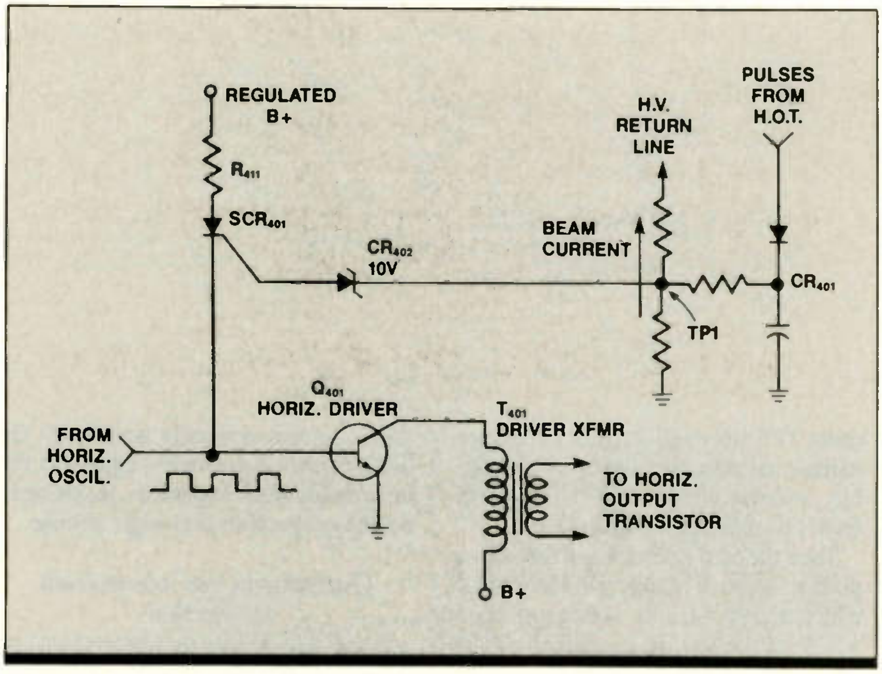


Figure 3. In this RCA CTC126 chassis, the overcurrent shutdown transistor and the overvoltage latch transistors shown in Figure 2 are missing. However, in both chassis, the horizontal deflection system is shut down by cutting off the drive to the horizontal output stage, in response to either overvoltage or overcurrent conditions. The 2-transistor latch has been replaced by a thyristor (SCR_{401}) with a 10V zener diode (CR_{402}) in its gate circuit.

of the horizontal driver transistor to the 33V source (TP3) through resistor R_{433}.

The resulting heavy base current causes Q_{411} to turn on and stay on (saturation) instead of switching on and off in response to the horizontal oscillator signal. Because the horizontal driver's collector current no longer switches on and off, no voltage is induced in the driver transformer secondary (T_{401}), and no drive signal is fed to the horizontal output transistor. Thus the horizontal output system shuts down, and potentially dangerous high voltage is avoided.

Excessive CRT beam current also can cause system shutdown as a result of the action of transistor Q_{415} in the voltage divider string.

Two opposite polarity voltages usually affect this transistor's base bias. On the one hand, CRT beam current returning from the high-voltage supply makes test point TP4 negative in relation to ground. This negative voltage, applied through R_{450}, tends to reverse-bias Q_{415}'s base-emitter junction. On the other hand, resistor R_{454} applies a positive dc voltage to the base of Q_{415} from the +33V reference point (TP3). Under normal beam current conditions, the net result of these two opposing voltages is that the overcurrent shutdown transistor is sufficiently forward-biased to operate in the saturation mode as previously mentioned.

However, when beam current increases, TP4 becomes sufficiently negative to partly offset the positive bias supplied through R_{454}. This reduction in positive bias forces Q_{415} out of saturation, and its decreasing collector current allows the positive voltage at TP2 to rise. If CRT beam current becomes excessive, TP4 becomes so negative that Q_{415}'s collector current is reduced drastically, which allows the voltage at TP2 to become positive enough to forward-bias the emitter-base junction of Q_{413}, triggering the Q_{413}-Q_{414} latch and causing system shutdown as previously explained.

Servicing tips

Circuit descriptions are fine and dandy, you say, but how about those servicing tips you promised? Well, RCA offers some useful ones in its CTC108 Television Workshop:

- To check the shutdown system's ability to operate, temporarily connect a jumper across R_{434} (TP1 to TP2). This causes the dc voltage at TP2 to rise and should trigger the overvoltage latch and cause system shutdown. If it doesn't, the shutdown circuitry should be checked.
- If a fault has caused the system to shut down, turn the power off and short the collector of Q_{415} to ground. Then momentarily turn the set on. If this procedure restores receiver operation, Q_{415} may be defective. If the transistor checks out OK, suspect an overcurrent condition. The horizontal deflection, high voltage and CRT circuitry should then be checked.
- If shorting the collector of Q_{415} to ground doesn't restore receiver operation, try shorting Q_{413}'s base to emitter. This maneuver should turn off the latch. If shutdown persists, suspect a defective Q_{413} and/or Q_{414} transistor or possibly a defective zener diode (CR_{407}). If horizontal system operation is restored, suspect an overvoltage condition and troubleshoot the regulator and/or horizontal output circuits.

Variety is the spice of life

Figure 3 is a simplified schematic of the shutdown circuitry in the RCA CTC126 chassis. It works in much the same way as the circuit in Figure 2. "How's that?" you say. "They don't even look the same." Well, you've got to hand it to TV manufacturers: They don't bore technicians with the same old circuitry in chassis after chassis. For instance, comparing the two circuits, you notice right away that the overcurrent shutdown transistor and the overvoltage latch transistors are missing. (A cost-reduction measure?) Even so, the fact remains that in Figure 3 the horizontal deflection system is still shut down by cutting off the drive to the horizontal output stage, in response to either overvoltage or overcurrent conditions, just as in Figure 2.

In Figure 3, the 2-transistor latch has been replaced by a thyristor (SCR_{401}) with a 10V zener diode (CR_{402}) in its gate circuit. CR_{402} can sense both overvoltage and overcurrent conditions because its cathode is connected to test point TP1, whose dc voltage is determined by a combination of two circuit parameters: beam current flowing up to the high-voltage return line of the high voltage transformer; and horizontal pulses from the flyback transformer, rectified by CR_{401}.

Under normal conditions, the SCR is off because the positive dc voltage at TP1 is not high enough for the zener diode to conduct. Thus the horizontal driver transistor is not affected by the SCR, and the horizontal deflection system operates normally.

If beam current becomes excessive, the positive voltage at TP1 rises. Likewise, if the high voltage increases, the higher amplitude flyback pulses rectified by CR_{401} cause the TP1 voltage to rise. Once the voltage at the cathode of CR_{402} exceeds 10V, the zener diode goes into conduction, providing gate current for SCR_{401}. As a result, the thyristor fires, and its low cathode-to-anode resistance allows B+ to be applied to the base of Q_{401}. The driver transistor becomes saturated. As in the earlier case, this steady current does not induce a voltage in the transformer secondary, thus stopping the drive signal to the horizontal output stage. As a result, the horizontal deflection and high voltage system shuts down and a potentially catastrophic failure is averted.

When in doubt about the procedure, consult the manufacturer's literature. With some sets, the manufacturer warns technicians *never* to force the receiver back on by defeating certain functions of the protective circuitry. Heed that warning.

According to RCA, a useful tip for troubleshooting shutdown problems in this chassis is, if the receiver refuses to start, measure the dc voltage across R_{411}. If it measures 0V, the SCR is obviously not conducting and shutdown has not occurred. In this case, troubleshoot the start-up and horizontal deflection circuitry. But if the voltage across R_{411} measures approximately 3V, SCR_{401} is conducting (shutdown condition). Switch off the receiver and ground the gate of the SCR, then turn the set back on briefly. If the receiver operates, suspect one of the inputs to the shutdown circuit; if the set still doesn't operate, suspect a defective SCR.

Figure 4 shows yet another way of killing the horizontal drive. In this circuit, an SCR is used to ground the base of the horizontal driver rather than connecting the driver to B+.

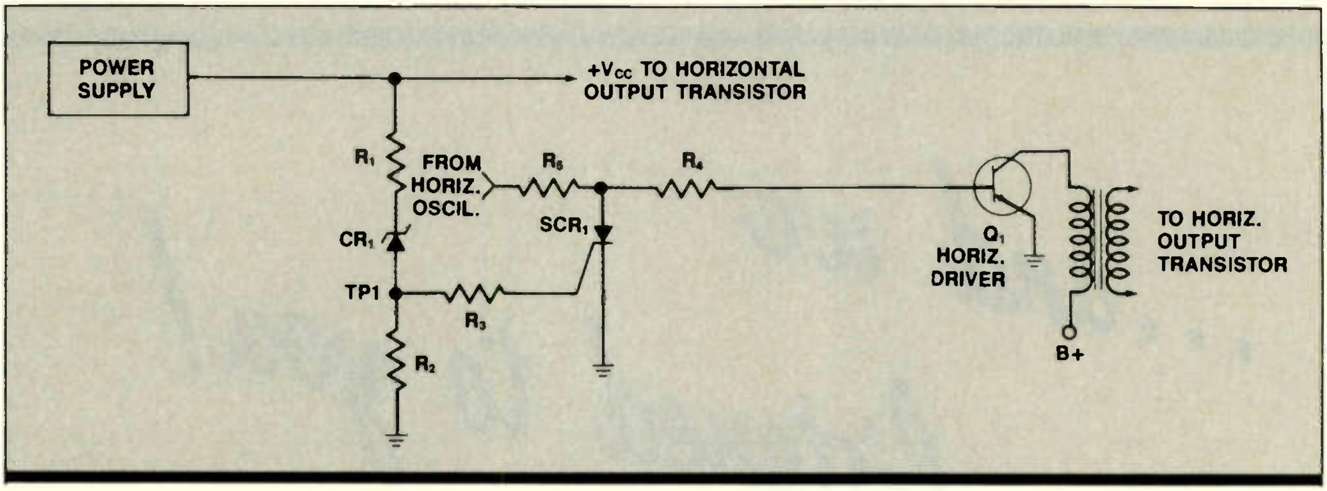


Figure 4. Another way to kill the horizontal drive is to ground the base of the horizontal driver with an SCR rather than connecting the driver to B+. Under normal conditions, zener diode CR_1 doesn't conduct and the dc voltage at TP1 is zero. In this circuit, if the B+ voltage rises high enough to exceed the zener voltage rating of CR_1, the latter conducts and TP1 becomes positive in relation to ground. This triggers the SCR into conduction, effectively grounding Q_1's base. Without horizontal drive, the horizontal deflection and high-voltage system shuts down.

Under normal conditions, zener diode CR_1 doesn't conduct and the dc voltage at TP1 is zero. Although the SCR's anode is somewhat positive (because it is connected to the collector circuit of the horizontal oscillator), the thyristor doesn't conduct because its gate is at 0V potential.

In this circuit, the parameter being sensed is the B+ voltage, which, because it supplies the horizontal output transistor, has a direct influence on the amount of high voltage produced. If the B+ voltage rises high enough to exceed the zener voltage rating of CR_1, the latter conducts and TP1 becomes positive in relation to ground. This triggers the SCR into conduction, effectively grounding Q_1's base. Without horizontal drive, the horizontal deflection and high-voltage system shuts down.

Troubleshooting a dead set

Because of shutdown circuits, and also because the horizontal output circuitry typically supplies scan-derived B+ for several receiver sections (including audio, video and vertical stages), it is possible for trouble in the low-voltage, high-voltage and horizontal circuits to produce the same dead-set symptoms: no picture, no raster and no sound.

When troubleshooting this dead symptom, the technician has to decide whether the set is really dead or merely in shutdown. If the set is in shutdown, is it because a fault in the horizontal section has activated the shutdown circuitry, or has a fault in the shutdown circuit disabled the horizontal section? The typical chicken or egg syndrome.

Keep this tip in mind: When faced with a circuit such as Figure 4 in the shutdown condition, remember that an SCR is a latching device; if some condition has caused the SCR to conduct, as long as the receiver is left on, the SCR will continue to conduct even after the positive gate voltage is removed. If the cause of excessive B+ has been located and remedied, you can remove the shutdown condition by turning the set off for a moment and back on again, or by momentarily connecting a jumper between SCR_1's anode and cathode. Either way, the SCR will switch off. If you wish to eliminate the shutdown circuit, simply take the SCR out of circuit. You can then troubleshoot the low-voltage, horizontal and high-voltage circuits in a normal way until the trouble is found. The SCR can then be put back in circuit.

Microcomputer control

A lot of TV receiver functions are microprocessor-controlled these days, and shutdown protection is no exception. In one example, when the set is turned on, an output line from the CPU chip automatically goes LOW under normal conditions; this LOW logic level switches on the power supply, sending the proper dc voltage (V_{cc}) to the horizontal deflection circuit. If a fault occurs in the horizontal sweep system, killing scan-derived B+, a feedback line to the microprocessor enables the microprocessor to sense the problem and output a logic HIGH on its control line to the power supply, initiating shutdown.

The preceding circuits don't by any means constitute an exhaustive survey of all the TV shutdown circuitry you are likely to encounter, but the circuit descriptions and service hints presented here may better equip you to tackle these ubiquitous circuits, which, all too often, lead technicians in a frustrating vicious circle. A little time spent analyzing the shutdown circuitry and isolating it from the low-voltage, horizontal deflection and high-voltage circuits should pay off by reducing the amount of time you waste chasing your tail.

A word of caution, however: When you defeat a shutdown circuit to see if receiver operation can be restored, keep in mind that components may be damaged. Therefore, be extremely cautious if you defeat the shutdown circuit, and do so only long enough to monitor the high voltage and quickly observe the operation of the receiver. If normal operation is indeed restored and the high voltage is not excessive, you may assume that the defect is in the shutdown circuit.

When in doubt about the procedure, consult the manufacturer's literature. As a matter of fact, with some sets, the manufacturer warns technicians *never* to force the receiver back on by defeating certain functions of the protective circuitry. Heed that warning.

At any rate, solving one of these shutdown puzzles can make you feel pretty good, because you can finally answer that age-old question: "Which came first, the chicken or the egg?" ES&T

Literature

Technical bulletins

"Tech Tips," technical bulletins providing information about *Sencore* products, take a step-by-step approach to troubleshooting applications. Topics include microprocessor and VCR troubleshooting and capacitor testing.

Circle (124) on Reply Card

Rental catalog

Genstar Rental Electronics is offering a brochure of instruments that can be rented for 30 days or more. The company carries products from Anritsu, Atlantic Research, Hewlett Packard, Tau-tron, Tektronix, Telecommunications Techniques and other companies.

Circle (125) on Reply Card

Cross reference for variable transformers

The newly revised and enlarged "Interchangeability Chart" from *Staco Energy Products* includes more than 400 different models. The listing shows equivalent catalog numbers for similar types made by other variable transformer manufacturers. The guide lists model numbers and current ratings from 0.8A to 540A.

Circle (126) on Reply Card

ESD catalog

The "Static Eliminating Systems and ESD Products" catalog from *Chapman* outlines the company's static elimination equipment, including the traditional electrical ionizing bars and passive devices. The catalog also shows the company's ESD product line, which includes bench-top ionizers, static meters and residual voltage meters.

Circle (127) on Reply Card

SYMCURE/Troubleshooting Tips guidelines

ES&T is now paying $60 per page (six different cases of symptoms and their solutions) for accepted Symcure submissions.

The term *Symcure* is a contraction of two words: symptom/cure. Problems that are published in the Symcure department are those that have occurred more than once.

This is the kind of problem you can solve without even a second thought because you've already seen so many of that particular brand and model of set with those symptoms; in almost every case, it will be the same component that fails or the same solder joint that opens.

ES&T is also paying $25 per item for accepted Troubleshooting Tips.

A good Troubleshooting Tip has the following elements:

- It should be a relatively uncommon problem.
- The diagnosis and repair should present something of a challenge to a competent technician.
- It should include a detailed, step-by-step description of why you suspected the cause of the problem and how you confirmed your suspicions—anything that caused you to follow a false trail also should be included.
- It should describe how the repair was performed and any precautions about the possibility of damage to the set or injury to the servicer.

For a Symcures/Troubleshooting Tips kit, which includes examples, submission forms and information, send your name and address to:

Symcures/Troubleshooting Tips editor
P.O. Box 12901
Overland Park, KS 66212

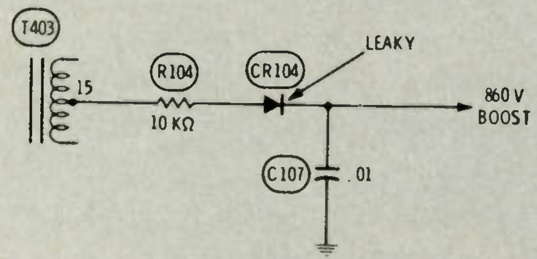
Symcure

Symptoms and cures compiled from field reports of recurring troubles

These Symcures are reprinted from Electronic Servicing *magazine.*

1

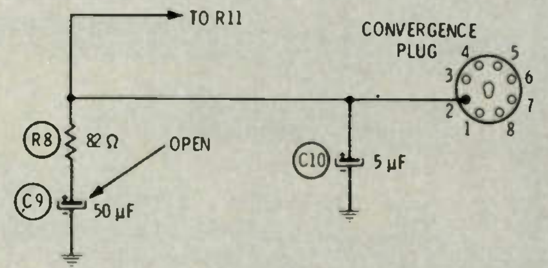
Chassis—RCA CTC58
PHOTOFACT—1365-1



Symptom—Poor gray tracking, and green smear on right of video
Cure—Check CR104 for leakage, and replace it if defective

2

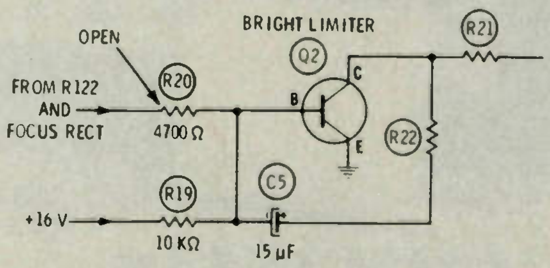
Chassis—RCA CTC51, CTC52 and CTC53
PHOTOFACT—1332-2



Symptom—Vertical misconvergence of bottom half of picture
Cure—Check C9, and replace it if open

3

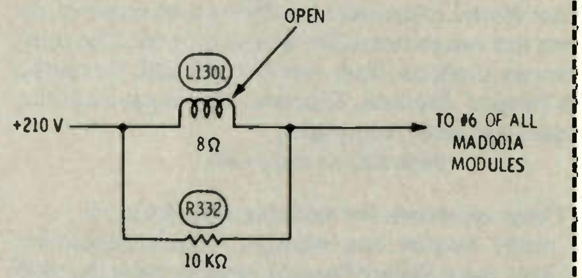
Chassis—RCA CTC48
PHOTOFACT—1300-2



Symptom—Vertical might collapse when brightness is increased
Cure—Check R20, and replace it if open

4

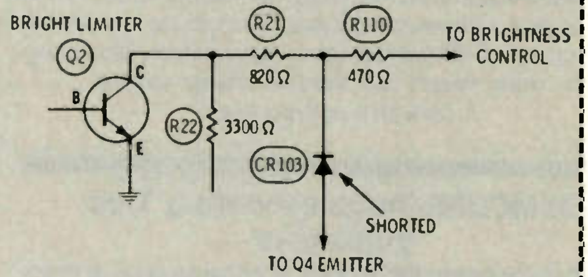
Chassis—RCA CTC58
PHOTOFACT—1365-1



Symptom—Video smear to the right
Cure—Check L1301, and replace it if open

5

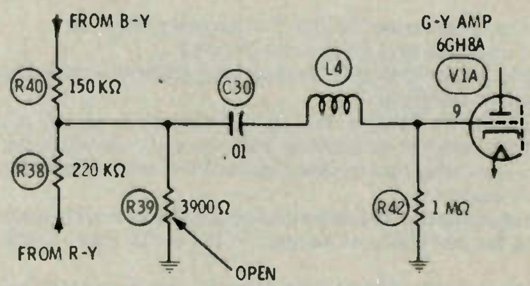
Chassis—RCA CTC48
PHOTOFACT—1300-2



Symptom—No control of brightness
Cure—Check diode CR103, and replace it if shorted

6

Chassis—RCA CTC53
PHOTOFACT—1201-1



Symptom—No green in color
Cure—Check R39, and replace it if open

Editor's note: Please direct inquiries and orders to the publisher at the address given rather than to ES&T.

Understanding Satellite Television Reception, by S.E. Sutphin; Prentice-Hall; 111 pages; $38, hardbound.

This non-technical explanation of satellite technology, written for the novice, shows the early beginnings of the industry and predicts what the future will have to offer for technology and programming. The author also tackles questions about scrambling, DBS, unfair zoning practices and the integrity of the equipment.

Prentice-Hall, Englewood Cliffs, NJ 07632; 800-223-1360.

Handbook of Video Camera Servicing and Troubleshooting Techniques, by Frank Heverly; Prentice-Hall; 416 pages; $16.95, paperback.

This handbook provides theory, operational data and step-by-step techniques for troubleshooting and servicing single-tube color video cameras. More than 400 charts, diagrams, illustrations and photographs show how the cameras work; how to pinpoint malfunctions; how to use test equipment to repair them; and how to remove, reinstall, align and adjust the pickup tube. The book also explains how to set up and build a profitable TV camera service business.

Prentice-Hall, Business and Professional Division, Englewood Cliffs, NJ 07632.

PHOTOFACT

HITACHI
2595-1 . . . . CT2667B, CT2668

MAGNAVOX
2594-1 . . . . . . chassis 25B101 through 25B110, 26B101 through 26B1089

QUASAR
2593-1 . . . . TS9823BK, TU9820BK/21BK/25BD/29BP
2598-1 . . TU9880BW (CH. ADC134)

PHILCO
2597-1 . . . . C3320AW01

RCA
2596-1 . . . chassis CTC136D/G/J/P/AA
2597-2 . . . . . . EPR295A-1/D-1/E-1/V-1 (CH. CTC134A)

SEARS
2593-2 . . . . . . 564.40652650/51/52/53
2594-2 . . . . 562.40802750
2595-2 . . . . 562.42571750
2596-2 . . . . 564.48202750
2598-2 . . . . 564.42122750
2599-1 . . . . 564.48206750/51

ZENITH
2599-2 . . . . . C2500W/02G/04P/06N, C5522G/24G/32G/34G/56G/62G/72G/86G, S6510G/18G, SC2501W/03G/05P/07N/11G/83H, SC5511H/23G/33G/35G/57G/63G/73G/87G/95H, SS6511/G/19G

Technology

Doubling the frame count

Although the broadcasting system used in the United States and other countries performs well in most respects, one problem, flickering, cannot be totally eradicated. However, Toshiba has introduced a TV that can produce clearer and more vivid images than conventional TV without changing any systems or adding any special equipment at broadcasting stations. The image quality of the 30-inch TV, the 30ID1, results from the adoption of the company's *frame double scanning method,* which doubles the number of frames per second used in conventional TVs.

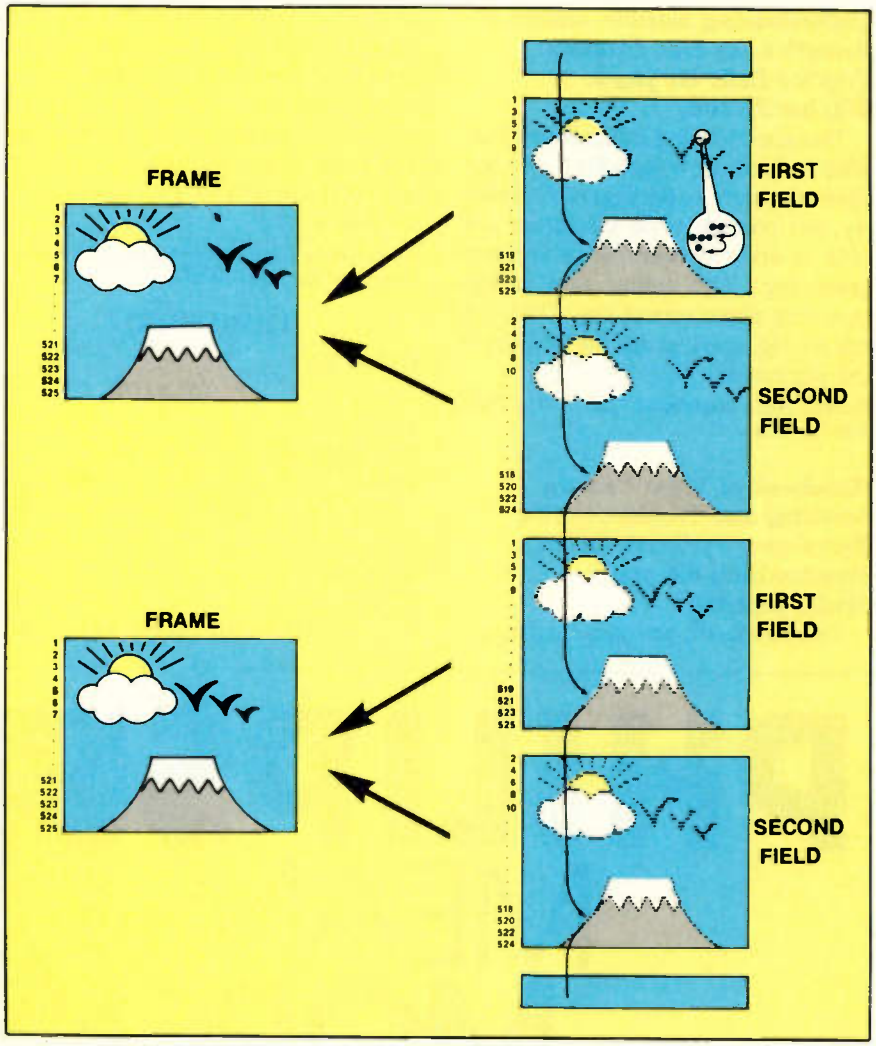


Figure 1. In frame double scanning, flicker is eliminated by filling in the gaps between the scanning lines in the two fields that make a frame. The static images (in this case, the mountain) are filled with the appropriate pixels of the previous field stored in frame memory chips. The mobile images (the flying birds in this example) are filled with the same pixels just scanned in the previous scanning line stored in the line memory chip.

How conventional TVs work

The TV broadcasting system currently used in North America, Korea and Japan is the NTSC (National TV Systems Committee) system, in which 30 still pictures called *frames* are sequentially displayed on a screen every second to form a continuous image. The original frame, which is composed of 525 scanning lines, is divided into two venetian-blind-like pictures, called *fields,* of 262.5 lines, each consisting of alternate lines of the frame. Every second, 60 fields are sequentially displayed to form 30 frames. Because of the nature of human vision, the viewer perceives the frames as a continuous image. The frame is divided to minimize the flickering that would be perceived if 30 undivided frames were displayed per second.

Despite the many advances in the picture quality of the conventional TV system, flickering has not been entirely eliminated, resulting in a less-than-perfect image. For example, flicker sometimes affects the horizontal edge of images such as the edge of a TV announcer's jacket sleeves. On large-screen TVs, which are enjoying increasing popularity, the wider gaps between the scanning lines of each field can, at times, affect picture quality.

Frame double scanning

Toshiba's new system uses frame double scanning, a new scanning method that uses semiconductor technology. LSI memory chips called *frame memories* memorize the field immediately preceding the one on the air at any given instant. The two fields are then composed to create a perfect picture. The result is 60 perfect frames displayed every second instead of 30 imperfect frames.

However, frame double scanning alone would only marginally improve the picture quality of conventional TV. The picture is further improved by *line double scanning.* Consider the continuous image displayed on your TV. Some parts are static, such as a mountain or an armchair, while others, such as a skier or a galloping horse, are in motion. With respect to a moving image, a picture composed of two fields from two different frames would result in a discrepant image. Toshiba's new system eliminates the problem by identifying mobile images and applying line double scanning, in which the picture elements of each field depicting a mobile image are scanned twice, not scanned once and combined with the preceding field.

Frame double scanning and line double scanning are accomplished with three custom LSIs, a 1Mbit image memory chip and a 256kbit line memory chip. The new TV incorporates five 1Mbit image memory chips for frame memory and five line memory chips. ES&T

NAP CHASSIS TYPE E51-56
SCHEMATIC DIAGRAM

Manufacturers' schematics **PROFAX**

3030

NAP CHASSIS TYPE E51-56 COLOR TV

August 1988

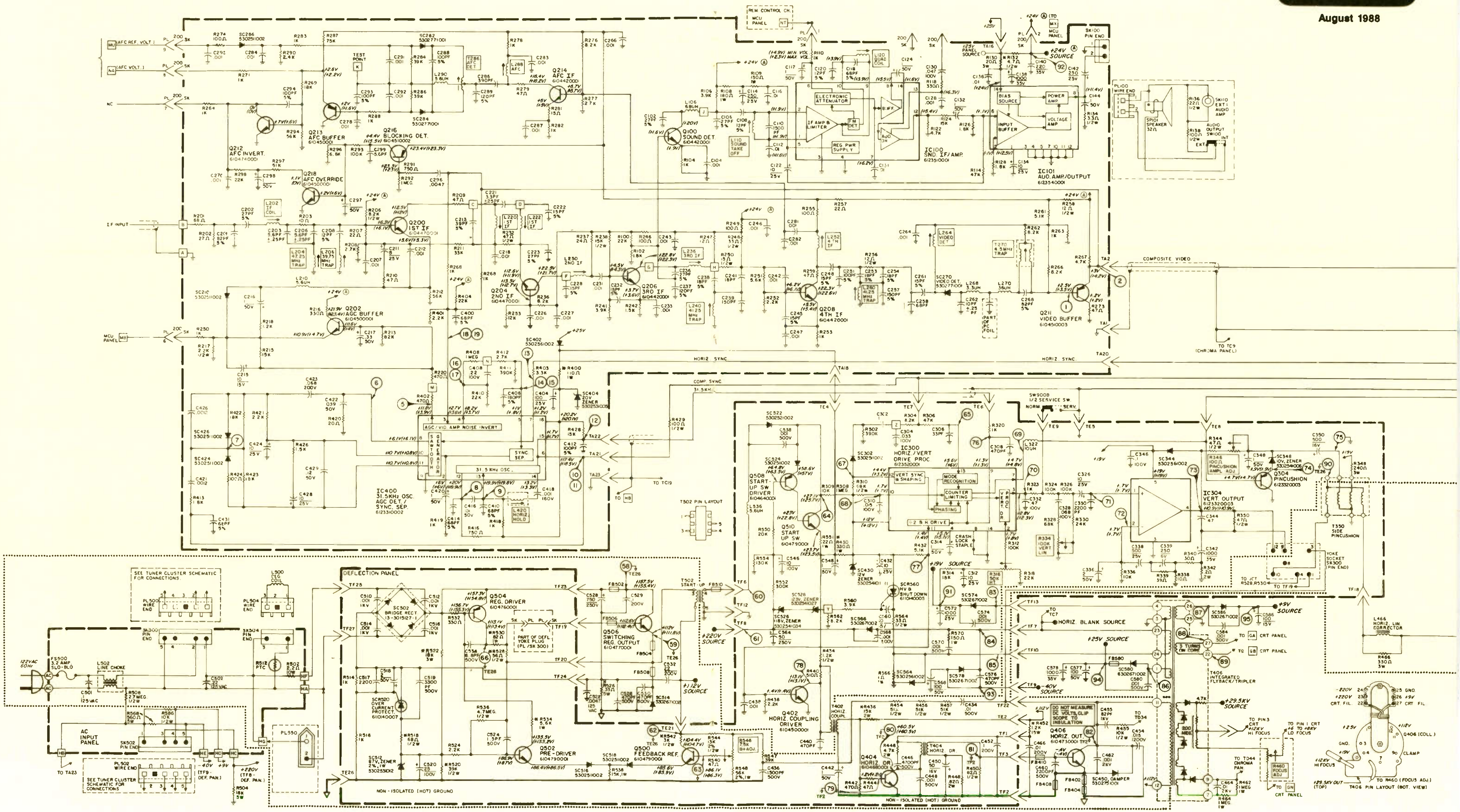
Product safety should be considered when component replacement is made in any area of an electronics product. The shaded areas of the schematic diagram designate the components in which safety is of special significance. It is recommended that only exact cataloged parts be used for replacement of these 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. Especially critical parts in the power circuit block should not be replaced with other makes.

This device has been constructed so that all external conductive parts are isolated from the ac power line. After servicing the unit, perform the safety check listed in service information to ensure that the isolation is still intact.

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

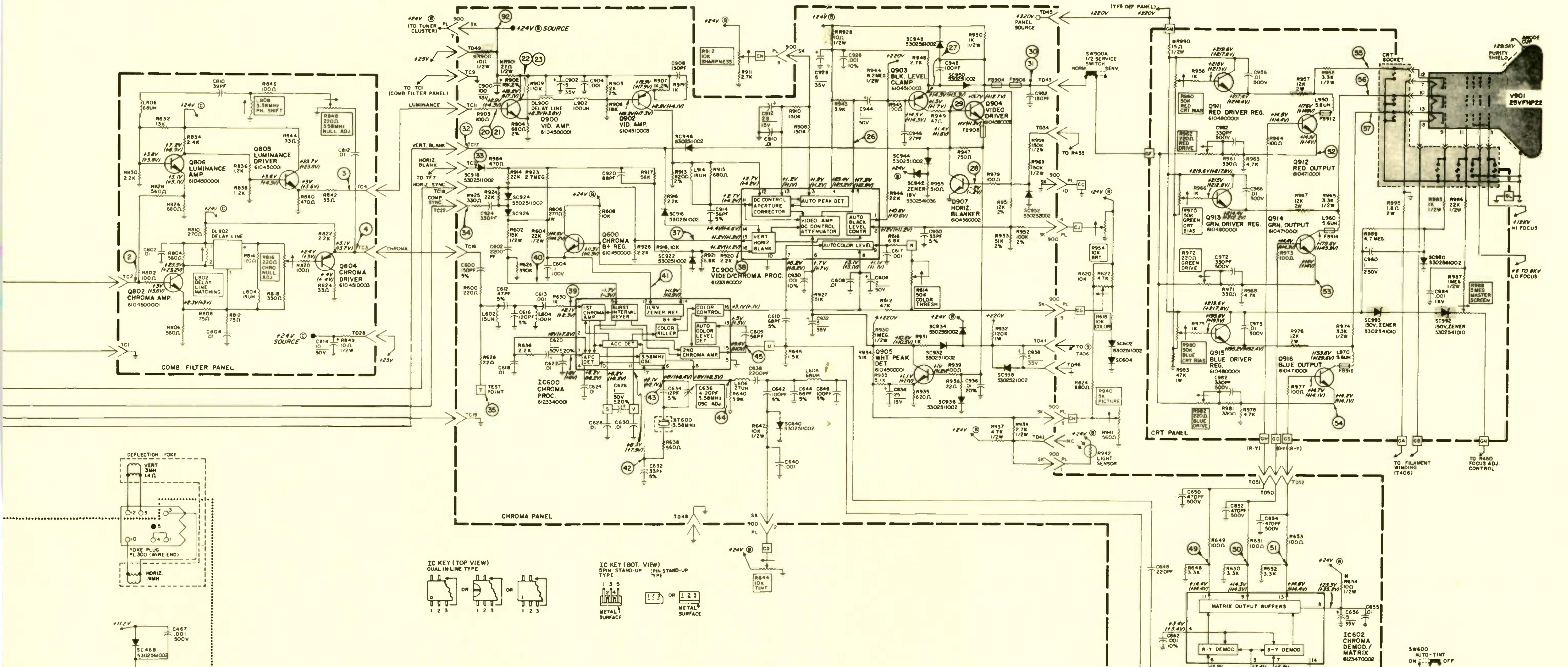
The other portions of this schematic may be found on other Profax pages.

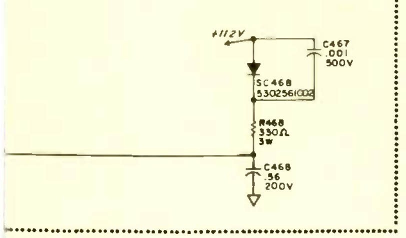


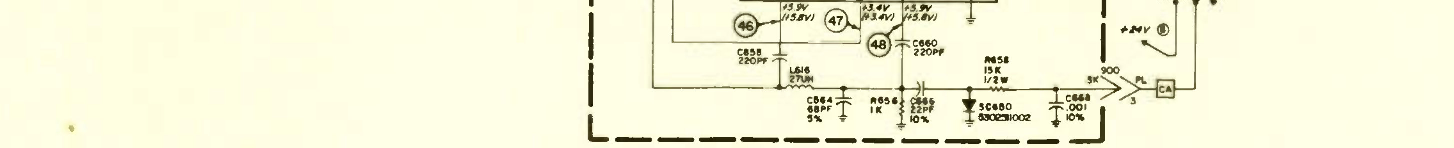
ES&T Manufacturers' schematics PROFAX 3030

NAP CHASSIS TYPE E51-56 SCHEMATIC DIAGRAM

NAP CHASSIS TYPE E51-56 SCHEMATIC DIAGRAM







Product safety should be considered when component replacement is made in any area of an electronics product. 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. Especially critical parts in the power circuit block should not be replaced with other makes.

This device has been constructed so that all external conductive parts are isolated from the ac power line. After servicing the unit, perform the safety check listed in service information to ensure that the isolation is still intact.

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.

NOTES:

1. •••• CIRCUITS LOCATED WITHIN INDICATED DOT PATTERN ARE CONDUCTIVELY CONNECTED TO ac LINE.
2. * INDICATES FLAME RETARDANT.
3. ALL RESISTORS ARE 5% AND/OR ¼W UNLESS OTHERWISE SPECIFIED.
4. ALL CAPACITORS IN MFD, 50V TYPE UNLESS OTHERWISE SPECIFIED.
5. +24V A SOURCE—ON IF PANEL.
6. +24V B SOURCE—ON CHROMA PANEL.
7. +24V C SOURCE—ON COMB-FILTER PANEL.

INDICATES NON-ISOLATED (HOT) GROUND.

INDICATES LINE ISOLATED GROUND.

Reprinted by permission of NAP Consumer Electronics Corporation
Copyright 1988, Electronic Servicing & Technology, P.O. Box 12901, Overland Park, KS 66212.

ES&T Manufacturers' Schematics PROFAX 3029

HITACHI CT1344 BASIC SCHEMATIC DIAGRAM

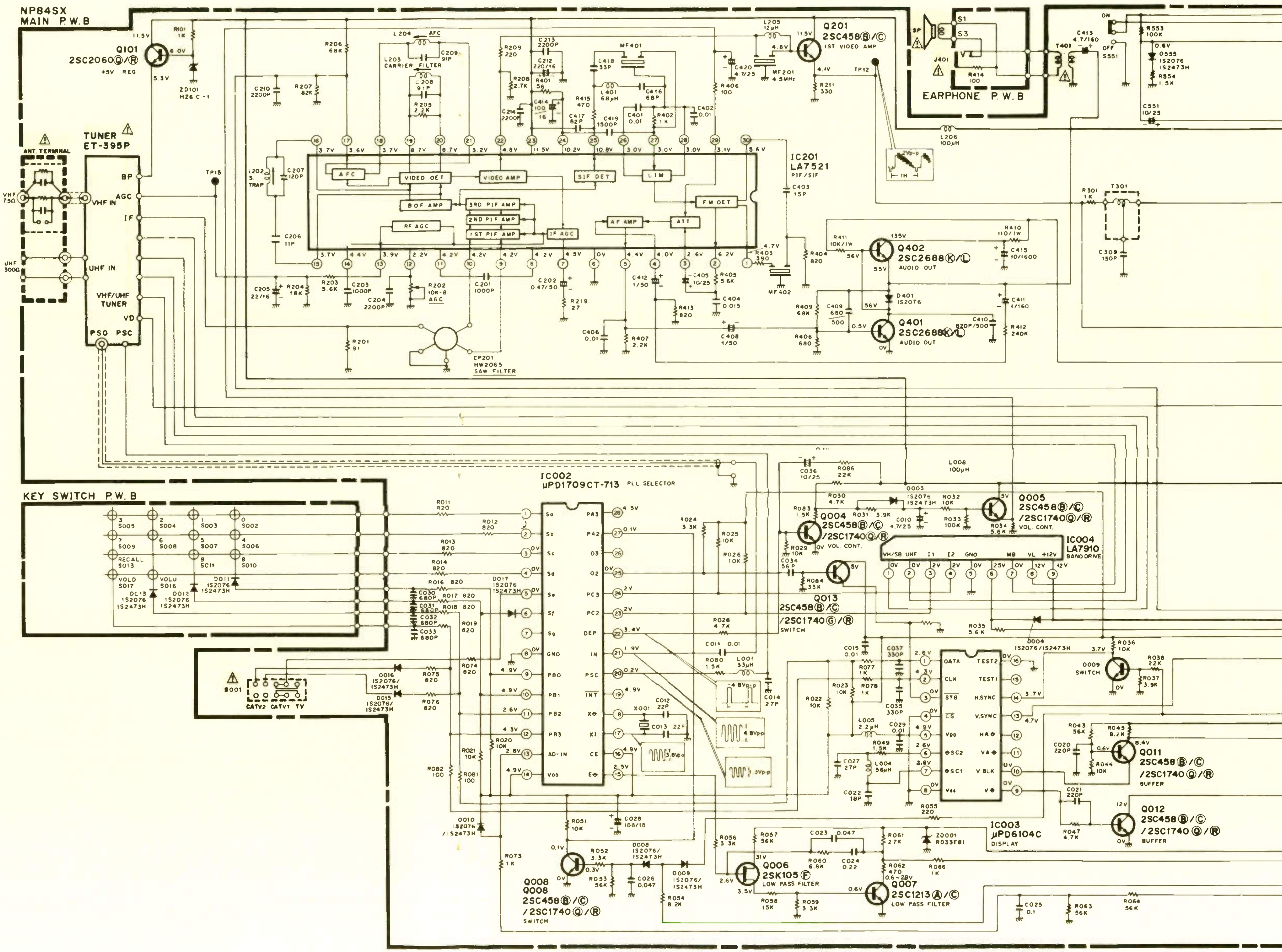
Product safety should be considered when component replacement is made in any area of a receiver. Components marked with a ! and shaded areas of the schematic diagram designate sites where safety is of special significance. It is recommended that only exact cataloged parts be used for replacement of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

- 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 (100k/V).
- If R974, R975 or R976 opens, replace all three resistors.

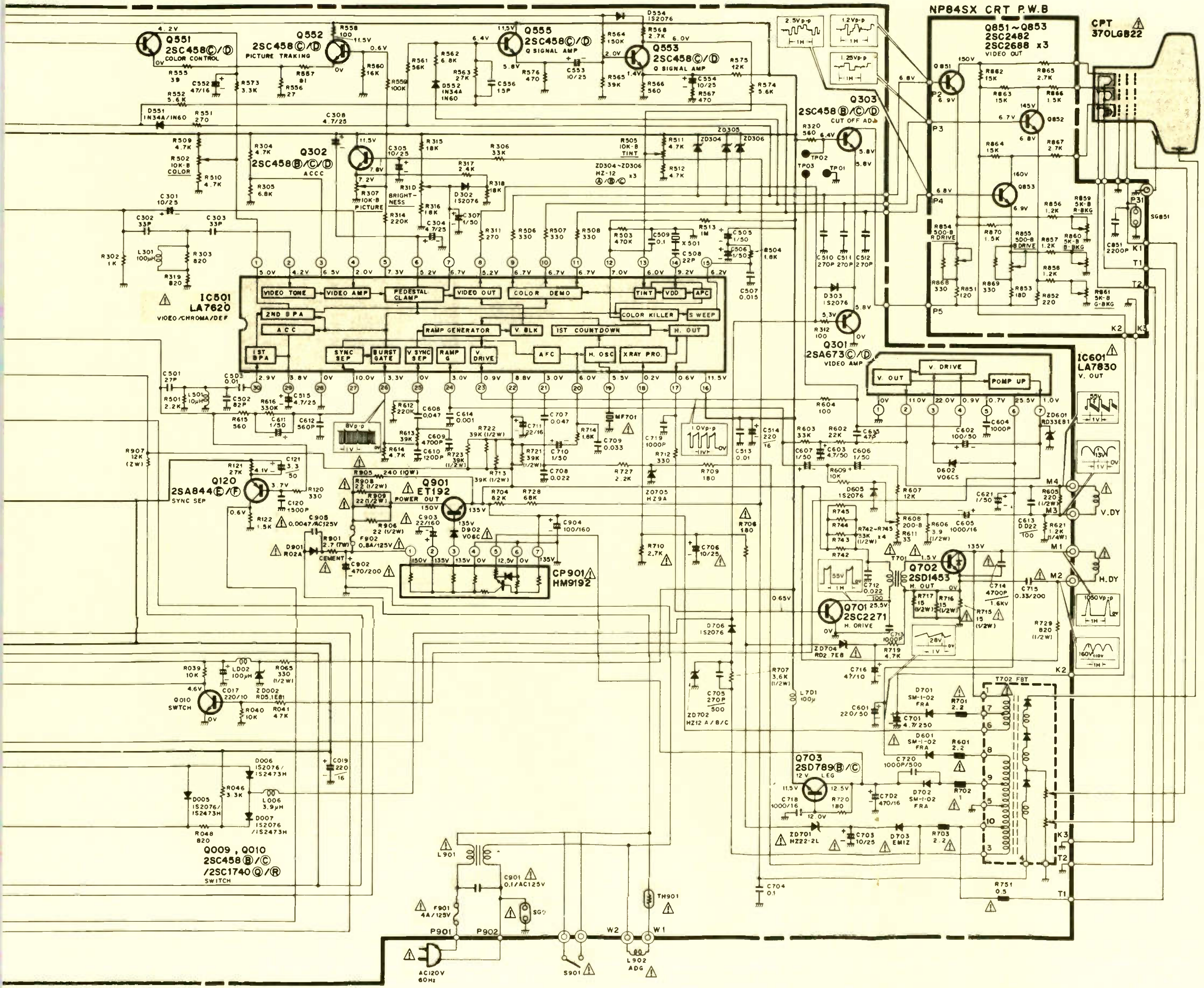


Reprinted by permission of the Hitachi Corporation of America
Copyright 1988, Electronic Servicing & Technology, P.O. Box 12901, Overland Park, KS 66212.

ES&T Manufacturers' schematics PROFAX 3029

HITACHI
CT1344
CHASSIS
COLOR
TV

August 1988



HITACHI CT1344 BASIC SCHEMATIC 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 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.

- 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 (100k/V).
- Voltage taken on a complex color bar signal including a standard color bar signal.

ES&T Manufacturers' schematics PROFAX

August 1988

Schematic

Hitachi

Test your electronics knowledge

By Sam Wilson, CET

You are obviously a top-level technician—it's obvious because you subscribe to ES&T. That makes it possible for you to keep up with the state of the art. Did you skip over something in one of the issues? Here are ten questions on material covered in the first five months of 1988.

1. At the collector of the horizontal output stage, you should measure the regulated dc voltage that is specified on the schematic. You should also see pulses that repeat every 63.5μs. How wide are the pulses? (Caution: Your scope must be able to handle pulse amplitudes as high as 120V to 150V.)

2. Which of the following best describes the main use of buffers in microprocessor systems?
(A) They protect the microprocessor from high-voltage spikes.
(B) They prevent the oscillator from being drawn off frequency by changing loads.
(C) They are used for temporary storage of input and output data.
(D) There is no such thing as a buffer in a microprocessor system.

Wilson is the electronics theory consultant for ES&T.

3. At one time, 3D pictures taken with camcorders tired the viewer's eyes because of the flicker phenomenon. The 3D-CAM system by Toshiba has eliminated the flicker by
(A) Increasing the horizontal line frequency.
(B) Increasing the normal viewing speed for standard video to 60 pictures per second per eye.

4. The rise time of a square wave delivered to an oscilloscope vertical input terminal is 0.01μs. Assuming a perfect square wave, what is the approximate bandwidth of the scope vertical amplifier?

5. You can buy low-priced DVMs with resistance accuracy measurements of 1% or better. The problem is that the highest resistance range has been limited to a maximum of 2MΩ. What simple procedure can be used to extend the range to 20MΩ or beyond?

6. You need to replace a defective 100Ω resistor. You don't have the 2% type that was originally used, but you have a 100Ω 20% resistor that measures exactly 100Ω on the DMM. Can you use that 20% resistor as a replacement?

7. What defines the resolution of a digital storage oscilloscope?

8. A Johnson counter is an example of
(A) a synchronous counter.
(B) an asynchronous counter.

9. A soldering iron should be tinned at
(A) the highest possible temperature.
(B) the lowest possible temperature.

10. Gamma is a term that has been used to represent common-collector current gain. However, the most widely accepted use of the term has been for
(A) beta cutoff frequency.
(B) alpha cutoff frequency.
(C) emitter efficiency.
(D) upside-down transistor operation.

Answers are on page 53.

Continuing your electronics education

By Conrad Persson

There probably was a time when you learned a profession or a trade, then pretty much went out and did the work for a lifetime with almost no updated training. If such a time once existed, those days are gone forever. Today, almost any kind of employment that requires knowledge and/or skills requires the practitioner to update his knowledge constantly.

Take a look at the automotive world, for example. Many of today's mechanics were brought up in a world of carburetors, rear-wheel drive, drum brakes and non-electronic ignitions. Most of those mechanics have had to become familiar with fuel injection, transaxles, constant-velocity joints, disk brakes, electronic ignitions and other electronic engine controls.

Or how about medicine? In just the past few years many types of surgery have become considerably different than they once were. Orthopedic surgeons are now using arthroscopic techniques to perform joint surgery through a small incision instead of opening the entire joint. Still in the experimental stage is angioplasty, a technique in which surgeons can clean out fatty deposits in coronary arteries without opening the chest cavity.

Even office workers are having to learn to cope with a host of innovations: personal computers, facsimile machines and more.

Everywhere, advances in technology are changing the way we live and work, and most people, especially those involved in servicing the new technological marvels, must continually update their knowledge if they want to avoid becoming obsolete.

There are few places where the consequences of these technological advances are more strongly felt than in the field of consumer electronics servicing.

Persson is editor of ES&T.

It's almost overwhelming just considering them, never mind trying to learn enough about them to fix them. Start with TV, for example. Components are getting smaller, more and more functions are being built into integrated circuits, and more high-tech extras are becoming standard—remote control, microprocessor control, stereo sound, projection TV and LCD display screens.

Add to that the complexities of VCRs, compact discs and digital electronic tuning in audio systems, and servicing becomes hard to handle. But wait, that's just the beginning. Today, the electronically well-equipped home also features a personal computer or two, and the way things are going, it wouldn't be much of a surprise to see a lot of homes with copiers and facsimile machines in the near future. And then, of course, there's home automation.

Someone, namely the consumer electronics servicing technician, is going to be expected to fix all that. Good luck!

Where to turn

Fortunately, today's technicians don't face the problem of training alone. A lot of people know that it's in their best interests if technicians are around who know how to fix today's complex electronic products. After all, consumers get testy if the widget they just bought fails to widge. Manufacturers of today's consumer electronics products want to have competent technicians on hand to fix their products. Private and public schools stand to increase their revenues handsomely if they can attract students. Publishers can sell a lot of books if they are able to publish good, helpful texts that will help technicians learn to understand and fix consumer electronics products.

As you might expect, there has been

a great deal of effort in these areas. Manufacturers and their organizations are churning out training materials and scheduling classes. Schools are increasing the availability of servicing courses. Book publishers are cranking out quantities of technical books.

Setting a goal

Most consumer electronics servicing technicians, overwhelmed by the new technology, are aware that they need to upgrade their skills. The problem boils down to answering two questions: "What do I need to learn?" and "How do I go about learning it?"

It's important to analyze these questions thoroughly to determine beforehand exactly what it is you need to study. It's not enough to just say "I need to learn more about VCRs," then charge off to find a book, a home-study course or a local school that might offer a course on VCRs. Do you just want an overview on VCR technology for starters? Or do you really have a pretty good idea of how VCRs work, and what you really need is a course in servos?

Once the specific goals are set, the next consideration becomes how to achieve them. One simple but effective method might be to contact other technicians in your area. If you have a skill that they lack and vice versa, you might be able to arrange for a session in which you educate each other.

Studying on your own

Another simple, although less effective method is to buy a book on the subject and study it yourself. Depending on a number of factors, including the complexity of the subject, the quality of the book and your own self discipline, this experience might bring anything from complete understanding of the material to a sense of total frustration. Home-study courses offer a major improvement over studying from books. The material is broken down into study units, someone tells you what is expected of you, and you get feedback through regular tests.

Enrolling in schools and seminars

If time and money permit, a more ef-

EIA/CEG VCR workshops

Locations	Dates
Video Technical Institute 1806 Royal Lane Dallas, TX 75229	Oct. 3-8, 1988 March 20-24, July 31-Aug.4, Nov. 6-10, 1989
United Electronics Institute 3924 Coconut Palm Drive Tampa, FL 33619	Sept. 26-30, 1988 March 27-31, June 26-30, Sept. 25-29, 1989
Illinois Technical College 506 S. Wabash Ave. Chicago, IL 60605	May 1-5, Aug. 28-Sept. 1, 1989
Video Technical Institute 2828 Junipero Ave. Long Beach, CA 90806	Aug. 1-5, Nov. 14-18, 1988 May 15-19, July 31-Aug. 4, Oct. 2-6, 1989

fective way to learn is through structured class and lab courses. Here again, there are many avenues. Public and private technical schools throughout the country offer a selection of courses from the most elementary introductory courses to detailed theory and design. If you have the time and the budget to travel, manufacturers of home electronic equipment offer seminars on the operation and servicing of specific items.

In addition, manufacturers of test equipment and tools such as multimeters, oscilloscopes and soldering tools often offer instruction in using their products. Some have books and pamphlets that help you understand what you can do with their products. Other manufactures and trade associations offer formal courses of study, both through home-study curricula and through seminars that travel to different areas of the country so you can be taught by the experts near your own home. For example, NESDA/ISCET is offering a VCR course in Syracuse, NY, Aug. 22-26. (For more information, contact NESDA/ISCET at 817-921-9061 or -9101.)

The EIA/CEG is offering a free resident VCR service training program for technicians currently employed in private industry by an independent sales and/or service organization that acts as an authorized servicer of one or more manufacturers of consumer electronics products. The 40-hour, 5-day course covers electrical and mechanical functions of playback, recording and servo control for VHS and Beta formats. Dates and locations are listed on page 43. (To register, send a letter on company letterhead to the EIA's Product Services Department at the address given in the trade association section of the accompanying sidebar.)

Identifying the available resources

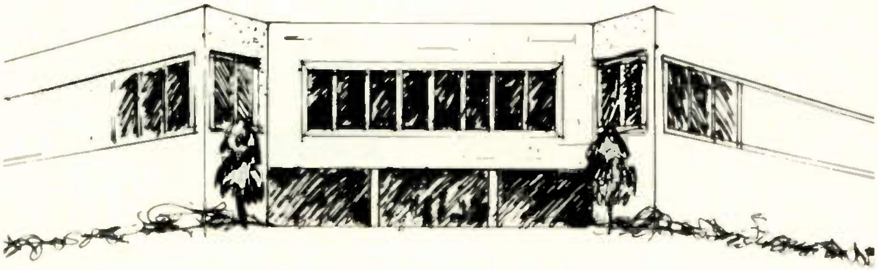
A local school will have just the course you need listed in its catalog, or one of the book publishers might have the book or series of books that can fill

in the gaps in your knowledge. Maybe one of the associations related to home electronics-equipment manufacturing, sales or service will have just the information you need; if nothing else, they may be able to point you in the right direction.

Why not try experimentation?

Many of today's consumer electronics products are electromechanical, and it's frequently the mechanical portion of these products that cause problems. In understanding a mechanical system, it's frequently useful just to open the unit up and watch how things work or even to introduce some problems to see what happens. I wouldn't suggest this approach to learning with a $600 hi-fi VCR, but some of the low-end units cost in the neighborhood of $200. If you take a look at the cost of books or seminars these days (or even just the cost of lodging at a hotel while you attend a free seminar), $200 is pretty cheap for a unit you can take apart, observe, check with your DMM and oscilloscope, and possibly get a pretty good education from.

The following text lists a number of correspondence schools, publishers and associations you might want to contact for further information on what educational opportunities they have to offer.



Trade associations

Electronic Industries Association/
Consumer Electronics Group
(EIA/CEG)
2001 Eye St. N.W.
Washington, DC 20006
202-457-4919 (8715)

Electronics Representatives
Association (ERA)
20 E. Huron
Chicago, IL 60611
312-649-1333

Electronic Technicians Association
(ETA)
604 North Jackson St.
Greencastle, IN 46135
317-653-3849

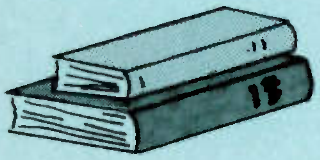
Musical Instrument Technicians
Association, International
8216 Audrain Drive
St. Louis, MO 63121-4504
314-389-3290

National Association of Business and
Educational Radio (NABER)
1501 Duke St., Suite 200
Alexandria, VA 22314
703-739-0300

National Association of Retail
Dealers of America (NARDA)
National Association of Service
Dealers (NASD)
10 East 22nd St.
Lombard, IL 60148
312-953-8950

National Electronic Distributors
Association
35 East Wacker Drive
Suite 3202
Chicago, IL 60601
312-558-9114

National Electronic Servicing
Dealers Association (NESDA)
2708 W. Berry St.
Ft. Worth, TX 76109
817-921-9062



Technical book publishers

Hayden Book Company
Rochelle Park, NJ 07662

McGraw-Hill Book Company
1221 Avenue of the Americas
New York, NY 10020

Prentice-Hall
Route 9W
Englewood Cliffs, NJ 07632
201-767-5937

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

Tab Books
P.O. Box 40
Blue Ridge Summit, PA 17214
717-794-2191

Van Nostrand Reinhold Company
135 W. 50th St.
New York, NY 10020

Home study

Cleveland Institute of Electronics
1776 E. 17th St.
Cleveland, OH 44114

Cook's Institute of Electronics Engineering
Desk 15
P.O. Box 20345
Jackson, MS 39209

Electronic Institute of Brooklyn
4823 Ave. N
Brooklyn, NY 11234

Grantham College of Engineering
2500 S. La Cienega Blvd.
Los Angeles, CA 90034

Heath/Zenith
P.O. Box 167
Hilltop Road
St. Joseph, MI 49085

National Institute of Technology
1701 W. Euless Blvd.
Euless, TX 76039

National Technical Schools
456 W. Santa Barbara Ave.
Los Angeles, CA 90037

NRI Training for Professionals
McGraw-Hill Continuing Education Center
3939 Wisconsin Ave.
Washington, DC 20016

Private trade schools

National Association of Trade and Technical Schools
2251 Wisconsin Ave. N.W.
Washington, DC 20007

ES&T

Unusual uses for varactor diodes

By Joseph J. Carr, CET

When is a diode not a diode? When it's a capacitor.

Although diodes serve many different functions in electronic circuits, servicers might be surprised by some of the ways diodes are used. Some of those uses are expected because of the nature of PN junctions. Other diode functions, such as diodes used as capacitors in modern electronic equipment, come as quite a surprise.

Special enhanced-capacitance diodes intended for this operation are called by several names, perhaps the most common of which are *varactor* (variable reactor) and *varicap* (variable capacitor). Although varactors are specially designed for use as electrically variable capacitors, all PN junctions exhibit the variable junction capacitance phenomena to some extent. I have even used ordinary, low-leakage 1A silicon rectifier diodes as varactors in laboratory experiments.

Carr, an electronics engineer, has published several books of electronics and is a frequent contributor to ES&T.

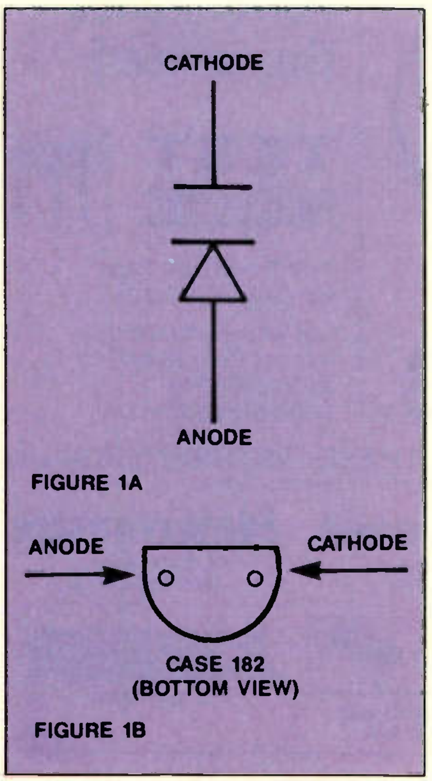


Figure 1. Figure 1A shows the usual circuit symbol for varactors. In some cases, the "capacitor" at the top end of the "diode" symbol has an arrow through it to denote variable capacitance. Varactors come in several different standard diode packages, including the 2-terminal "sorta-like-transistor" Type 182 package shown in Figure 1B.

Figure 1A shows the usual circuit symbol for varactors (although several other symbols also are used). In some cases, the "capacitor" at the top end of the "diode" symbol has an arrow through it to denote variable capacitance. Varactors come in several different standard diode packages, including the 2-terminal "sorta-like-transistor" Type 182 package shown in Figure 1B. Some variants have a beveled edge on the package to denote which is the cathode. In other cases, the package style will be like other forms of diodes. I have seen varactors in almost every form of diode package, up to and including the package used for 50A to 100A stud-mounted rectifier diodes.

How do varactors work?

Varactors are specially made PN junction diodes designed to enhance the control of the PN junction capacitance with a reverse-bias voltage. Figure 2 shows how this capacitance is formed. A PN junction consists of P- and N-type semiconductors placed in juxtaposition with each other, as shown in Figure 2A. When the diode is forward-biased, the charge carriers (electrons and holes) are forced to the junction interface, where positively charged holes and negatively charged electrons annihilate each other (causing a current to flow). But under reverse-bias situations, such as those shown in Figure 2, the charges are drawn away from the junction interface.

Figure 2A shows the situation where the reverse bias is low. The charge carriers are drawn only a little way from the junction, creating a thin, insulating depletion zone that acts as an insulator between the two charge-carrying P- and N-regions. This situation fulfills the criterion for a capacitor: two conductors separated by an insulator. Figure 2B shows the situation where the reverse bias is increased. The depletion zone is increased, which is analogous to increasing the separation between plates.

The varactor is not an ideal capacitor. (But then again, "real" capacitors aren't ideal either.) Figure 3 shows the equivalent circuit for a varactor. Figure 3A shows the actual model circuit; Figure 3B shows one that is simplified but, nonetheless, valuable to understanding the varactor's operation. The equivalent

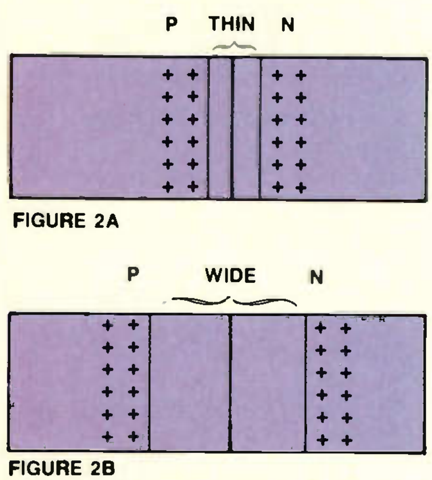


Figure 2. Varactors are specially made PN junction diodes designed to enhance the control of the PN junction capacitance with a reverse-bias voltage. When the diode is reverse-biased, the charges are drawn away from the junction interface. If the reverse bias is low, as in Figure 2A, the charge carriers are drawn only a little way from the junction, creating a thin, insulating depletion zone that acts as an insulator between the two charge-carrying P- and N-regions. If the reverse bias is increased, as in Figure 2B, the depletion zone is increased.

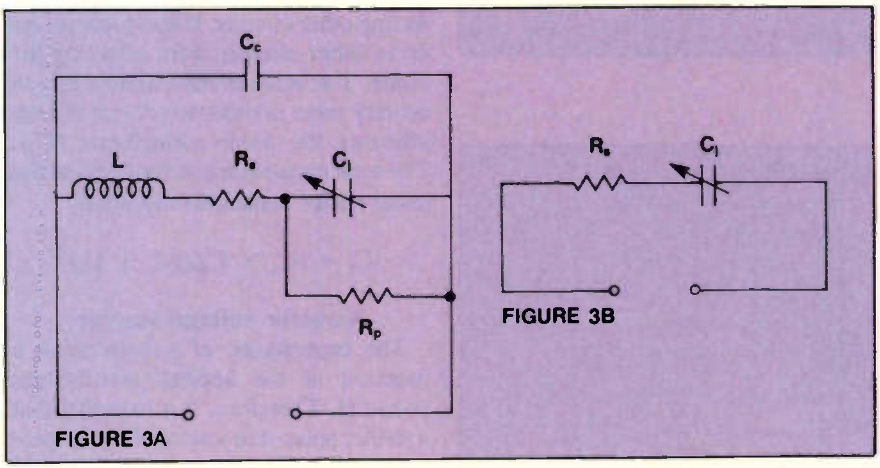


Figure 3. The equivalent circuit for a varactor: Figure 3A shows the actual model circuit; Figure 3B shows one that is simplified but, nonetheless, valuable to understanding the varactor's operation. The equivalent circuit in Figure 3B is based on the assumption that certain parameters shown in Figure 3A are negligible.

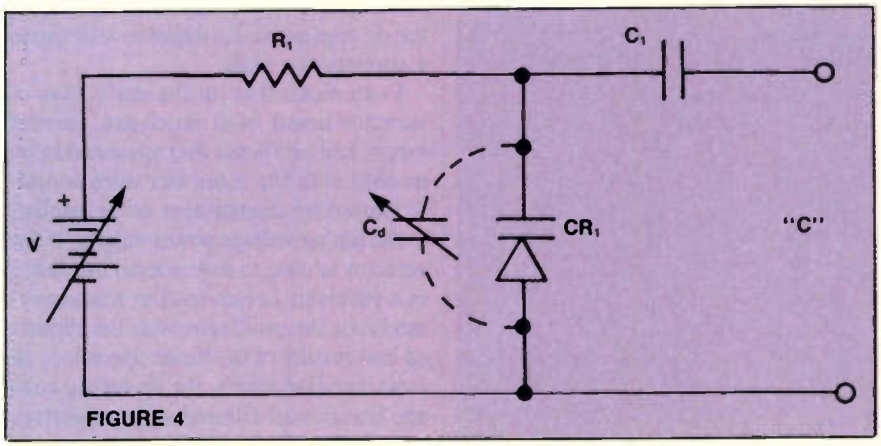


Figure 4. In a typical test circuit for the varactor, a variable dc voltage is applied as a reverse bias across the diode. A series resistor limits the current should the voltage exceed the avalanche or zener points and also isolates the diode from the rest of the circuitry. Without a high-value resistor in series with the dc supply, stray circuit capacitances and the power-supply output capacitance would swamp the typically low value of varactor capacitance. The capacitor at the output (C_1) is used to block the dc from affecting other circuits; it also prevents the dc in other circuits from affecting the diode.

circuit in Figure 3B is based on the assumption that certain parameters shown in Figure 3A are negligible.

Figure 4 shows a typical test circuit for the varactor. A variable dc voltage is applied as a reverse bias across the diode. A series resistor limits the current should the voltage exceed the avalanche or zener points (which could destroy the diode) and also isolates the diode from the rest of the circuitry. Without a high-value resistor (10kΩ to 1MΩ is the normal range; 100kΩ is typical) in series with the dc supply,

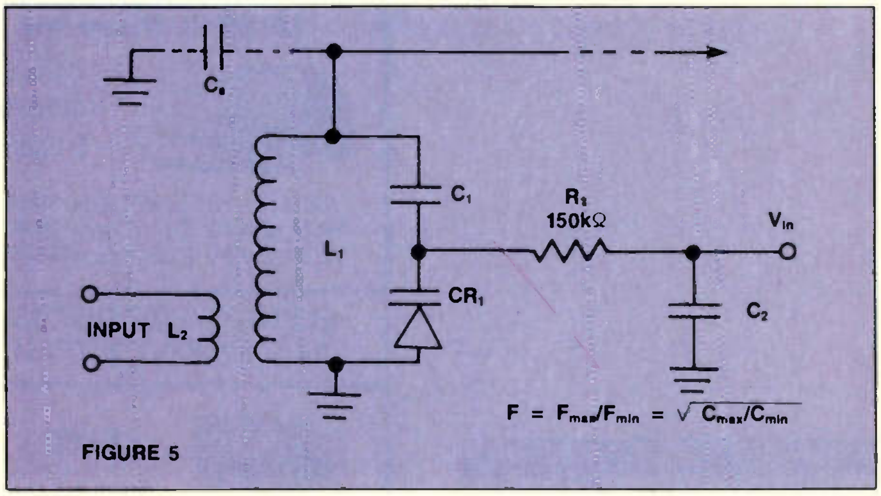


FIGURE 5

Figure 5. In this typical varactor-tuned LC tank circuit, the link-coupled inductor (L_2) is used to input RF to the tank. The principal LC tank circuit consists of the main inductor (L_1) and a capacitance made up from the series equivalent of C_1 and varactor CR_1. In addition, you also must take into account the stray capacitance (C_s) that exists in all electronic circuits. Capacitor C_2 is used to filter the tuning voltage, V_{in}.

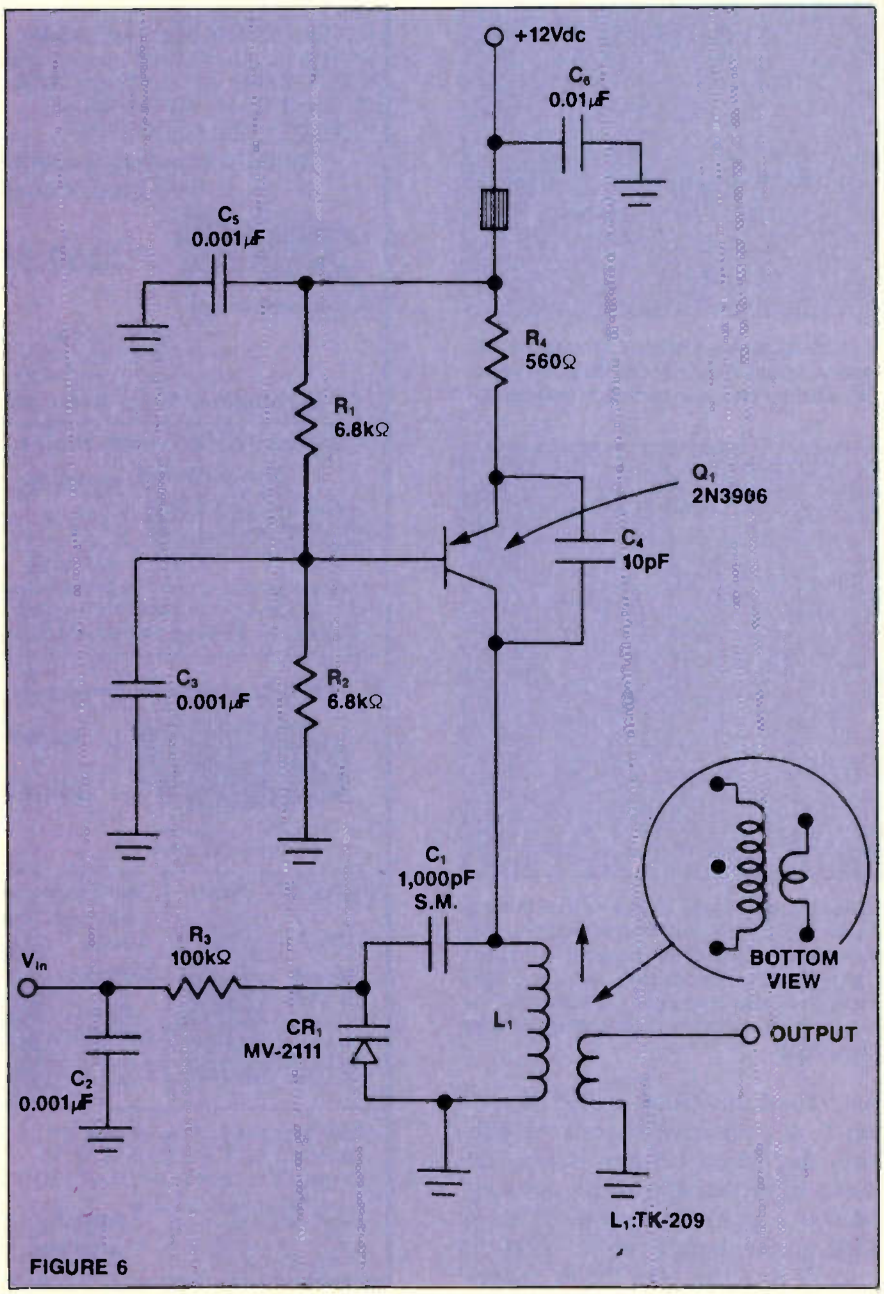


FIGURE 6

stray circuit capacitances and the power-supply output capacitance would swamp the typically low value of varactor capacitance. The capacitor at the output (C_1) is used to block the dc from affecting other circuits; it also prevents the dc in other circuits from affecting the diode. The value of this capacitor must be very large in order to prevent it from affecting the diode capacitance (C_d). The total capacitance is found from the usual series capacitors equation:

$$C_t = (C_1 \times C_d)/(C_1 + C_d)$$

Varactor voltage sources

The capacitance of a varactor is a function of the applied reverse-bias potential. Therefore, it is essential that a stable, noise-free source of bias is provided. If the diode is used to tune an FM tuner or a TV tuner, for example, drift will result if the dc potential is not stable. Noise also affects the operation of varactors. Any component that varies the dc applied to the varactor will cause a capacitance shift.

I can recall that, in the early days of varactor-tuned hi-fi receivers, several tuners had problems that appeared to be trouble with the tuner but were actually caused by intermittent noise applied to the tuning voltage power supply. If the varactor is used to tune a local oscillator in a receiver, noises tend to frequency-modulate the oscillator, with the expected bad results of the tuner operation. In most varactor tuners, the dc tuning voltage line is well-filtered with capacitors in order to eliminate this problem. Of course, the drift could be eliminated by using a voltage regulator dc power supply for the tuning voltage.

Servicers should be especially wary of varactor-tuned circuits in which the tuning voltage is derived from the main

Figure 6. In this PNP transistor operated as a variable frequency oscillator, coil L_1 is actually an untuned RF transformer designed for use as a 49MHz coil in TV IF amplifier circuits; the actual frequency of operation depends on the parallel capacitance across the primary of L_1.

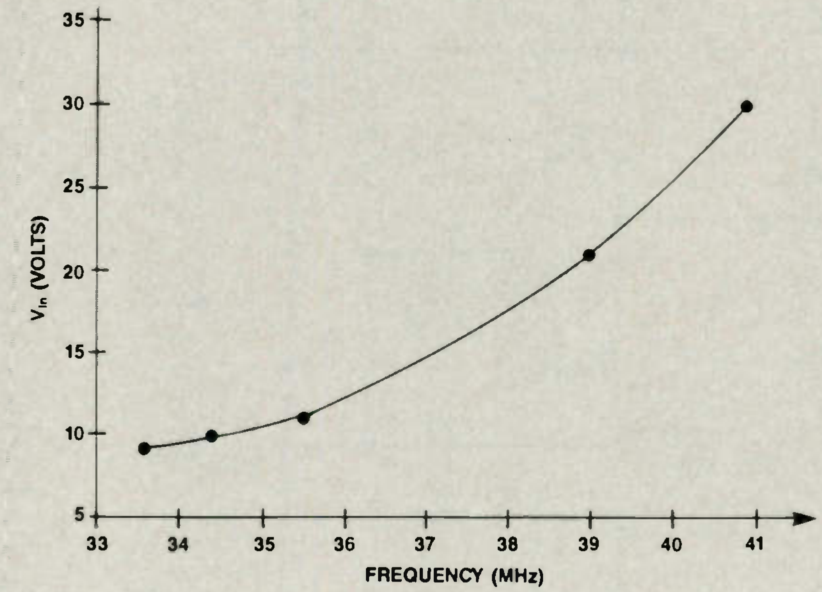


FIGURE 7

regulated power supply without an intervening regulator that serves only the tuning voltage. Dynamic shifts in the regulator's load, variations in the regulator voltage and other problems can create local oscillator drift problems that are actually power-supply problems and have nothing to do with the tuner despite the apparent symptoms.

The specifications of any varactor are given in two ways. First is the nominal capacitance taken at a standard voltage (usually 4Vdc, but I also have seen 1Vdc and 2Vdc used). The other is a capacitance ratio expected when the dc reverse-bias voltage is varied from 2Vdc to 30Vdc (or whatever the maximum permitted applied potential is for that

Figure 7. Because the resonant frequency of an LC-tuned tank circuit is a function of the square root of the inductance-capacitance product, the maximum/minimum frequency of the varactor-tuned tank circuit varies as the square root of the capacitance ratio of the varactor diode. This value is the ratio of the capacitance at minimum reverse bias to the capacitance at maximum reverse bias. As a result, the tuning characteristic curve (voltage vs. frequency) is basically a parabolic function.

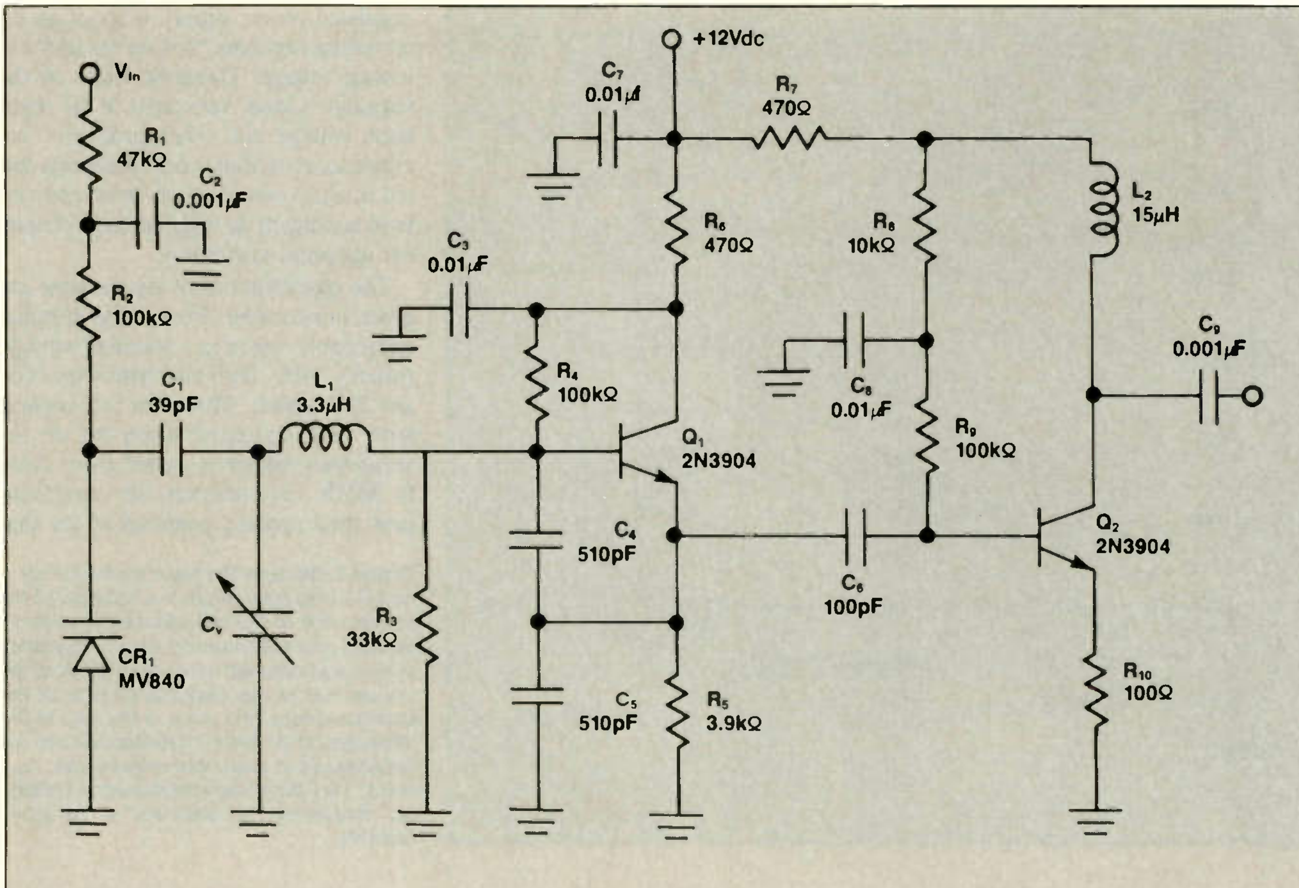


FIGURE 8A

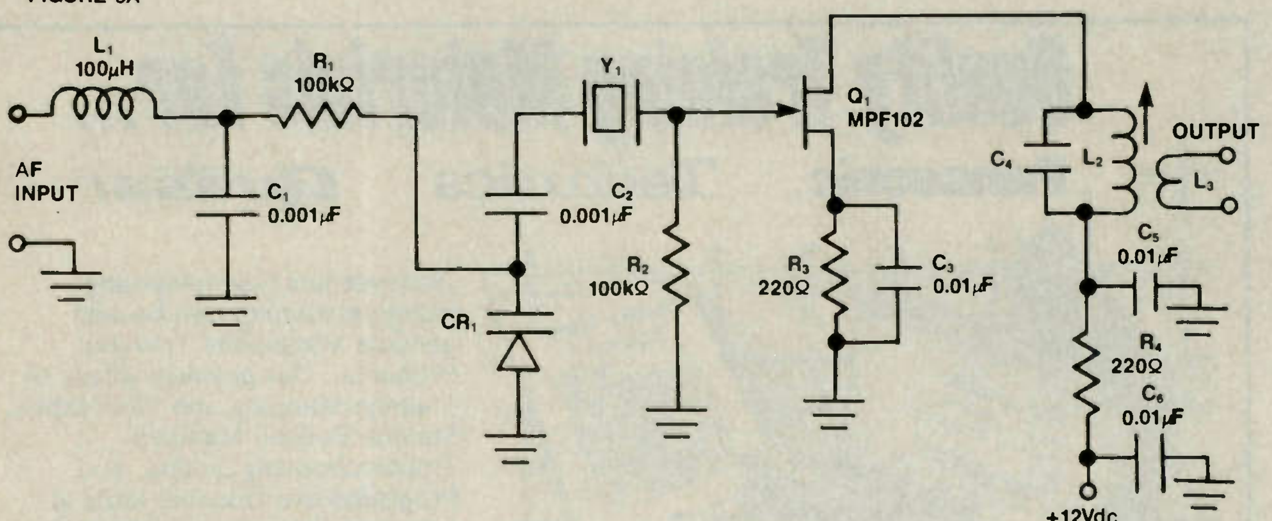


FIGURE 8B

Figure 8. The varactor-tuned oscillator circuit in Figure 8A is LC tuned, and a varactor (CR_1) makes up a portion of the total tank capacitance. The variable capacitor (C_v) also is used as the main tuning capacitance. The varactor capacitance is used to shift the resulting operating frequency in accordance with the applied ac signal (V_{in}). The output RF signal is either frequency-modulated or swept, depending upon whether V_{in} is an audio signal or sawtooth. In the low-powered, crystal-controlled FM transmitter in Figure 8B, the crystal will oscillate at a specific frequency that is somewhat dependent upon circuit capacitance. By varying the capacitance, you also can vary the frequency of oscillation. In this form of transmitter circuit, the crystal can be directly modulated.

diode). The NTE replacement line type 614 is typical. According to the *NTE Replacement Guide and Cross-Reference*, the 614 has a 3:1 "C_2/C_{30}" capacitance ratio and a nominal capacitance of 33pF at 4Vdc reverse-bias potential.

Varactor-tuned LC tank circuits

Varactors are electronically variable capacitors. In other words, they exhibit a variable capacitance that is a function of a reverse-bias potential. This phenomena leads us to several common applications in which capacitance is a con-

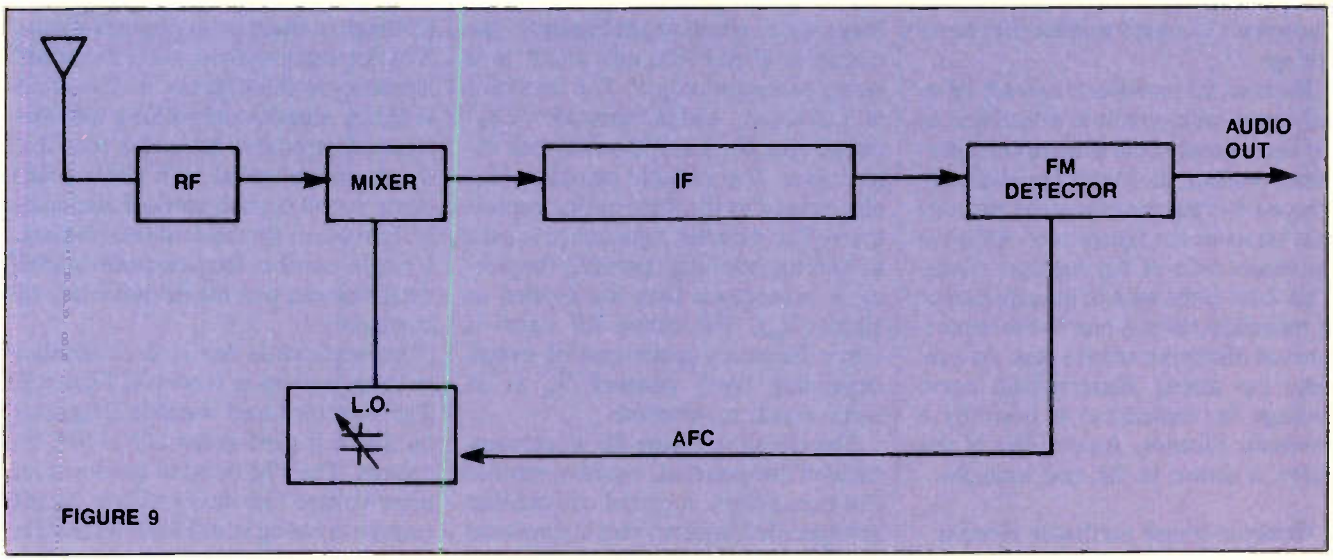


Figure 9. The varactor-tuned variable frequency oscillator is used as the LO in FM receivers. The FM detector produces an error voltage that indicates how far off center the tuning is and feeds it back via the automatic frequency control (AFC) line to the tuning voltage input on the tuner. The AFC voltage drives the LO operating frequency to the center-tune condition.

sideration. Figure 5 shows a typical varactor-tuned LC tank circuit. The link-coupled inductor (L_2) is used to input RF to the tank when the circuit is used for RF amplifiers and, in many oscillator circuits, to output RF signal to other circuitry. The principal LC tank circuit consists of the main inductor (L_1) and a capacitance made up from the series equivalent of C_1 and varactor CR_1. In addition, we also must take into account the stray capacitance (C_s) that exists in all electronic circuits. (It is, incidentally, the stray capacitance that usually makes technology-school students think their lab experiments "prove" that the theory formulas are all wet.) The blocking capacitor and series resistor functions were discussed above. Capacitor C_2 is used to filter the tuning voltage, V_{in}.

Because the resonant frequency of an LC-tuned tank circuit is a function of the square-root of the inductance-capacitance product, the maximum/minimum frequency of the varactor-tuned tank circuit varies as the square root of the capacitance ratio of the varactor diode. This value is the ratio of the capacitance at minimum reverse bias to the capacitance at maximum reverse bias. As a result, the tuning characteristic curve (voltage vs. frequency) is basically a parabolic function. An example of this curve is shown in the next example.

Varactor-tuned oscillator circuits

Figure 6 shows a circuit that I built and tested while researching this article. It consists of a PNP transistor operated as a variable frequency oscillator. Coil L_1 is actually an untuned RF transformer (Toko TK-209) designed for use as a 49MHz coil in TV IF amplifier circuits; the actual frequency of operation depends on the parallel capacitance across the primary of L_1. By using a Motorola MV-2111 varactor (47pF at 4Vdc), I found that the circuit oscillated at frequencies from 33.5MHz to 40.9MHz as the applied dc varied from +8Vdc to +30Vdc. Oscillations ceased above and below these potentials (a result of "junkbox" engineering—a little care in design could make the circuit oscillate over the entire range). Note the roughly parabolic shape of the tuning characteristic in Figure 7.

Two additional varactor-tuned oscillator circuits are shown in Figure 8. The circuit in Figure 8A was found in a sweep generator project. The oscillator is LC-tuned, and a varactor (CR_1) makes up a portion of the total tank capacitance. The variable capacitor (C_v) also is used as the main tuning capacitance. The varactor capacitance is used to shift the resulting operating frequency in accordance with the applied ac signal (V_{in}). The output RF signal is either frequency-modulated or swept, depending upon whether V_{in} is an audio signal or sawtooth.

The circuit in Figure 8B is representative of low-powered, crystal-controlled FM transmitters. A crystal will oscillate at a specific frequency that is somewhat dependent upon circuit capacitance. When buying crystals, always specify the calibration capacitance at which the frequency is guaranteed. By varying that capacitance, you can also vary the frequency of oscillation. In this form of transmitter circuit, the crystal can be directly modulated. Varactors also are used in reactance modulator circuits. The range of linear modulation is limited both by the crystal characteristics and by the normal non-linearity of the varactor V-vs.-C curve. Thus, a low-frequency oscillator typically is used, and then a chain of frequency multipliers raises both the operating frequency and the deviation (delta-F) to the proper level.

For example, a 165MHz FM transmitter requiring 6kHz deviation can be built using a 6.876MHz crystal oscillator operating at a deviation of 0.25kHz (250Hz); a chain of multipliers giving X24 frequency increase raises the center frequency to 165MHz and the deviation to 6kHz. A traditional problem with this classical transmitter design has been that the deviation varied with channel because not all crystals worked identically. In modern synthesized transmitters, a single variable frequency-modulated oscillator can provide deviation for all channels.

An application that is more familiar to most readers is shown in Figure 9. The varactor-tuned variable frequency oscillator is used as the LO in FM receivers. The FM detector produces an error voltage that indicates how far off center the tuning is and feeds it back via the automatic frequency control (AFC) line to the tuning voltage input on the tuner. The AFC voltage drives the LO operating frequency to the center-tune condition.

Varactors as frequency multipliers

The last varactor application may be less well known: Varactors can be used as frequency multipliers. In some microwave and UHF applications, very high local oscillator frequencies are needed. However, such signals are difficult to generate in primary oscillators. As a result, some circuits use a lower-frequency HF or VHF oscillator to generate the signal and then multiply it to the operating frequency. For example, one MDS downconverter receives 2.145GHz and outputs the video signal on VHF at 70MHz. The local oscillator for that device is 2,075MHz (2,145−70 = 2,075MHz). A 340.33MHz local oscillator is well within the range of normal TV-type technology, and this frequency can be multiplied (×6) to 2,045MHz by using a doubler and a tripler circuit in cascade. Figure 10 shows a varactor tripler circuit. The input circuit is tuned to the input (fundamental) frequency by either an LC-tuned tank circuit or a micro-strip line. The output is similarly tuned but to a harmonic (N × F_1) of the input frequency.

Variable capacitance diodes are used to tune or control most modern FM and TV receivers. They also are found in FM transmitters, communications receivers and a host of other products. Knowing varactor characteristics and circuits can help the electronics servicer zero-in on potentially misleading trouble symptoms.

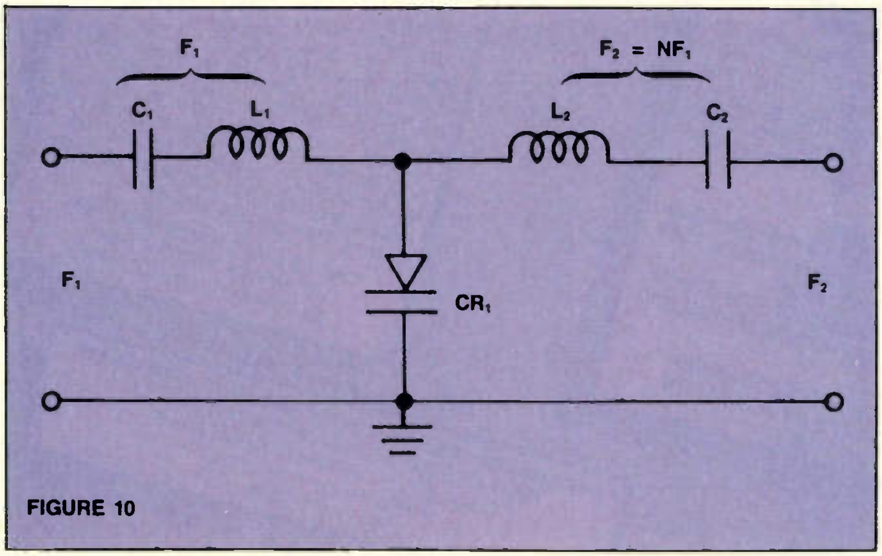


Figure 10. In this varactor tripler circuit, the input circuit is tuned to the input (fundamental) frequency by either an LC-tuned tank circuit or a micro-strip line. The output is similarly tuned but to a harmonic (N x F_1) of the input frequency.

Quiz answers

Questions are on page 41.

1. 12μs. (See "Servicing Voltage Regulators" by Gregory D. Carey, CET, in the January 1988 issue.) If the pulses are less than 12μs wide, a capacitor between the emitter and collector of the output stage is probably open.

2. C—Buffers in microprocessor systems are used for temporary storage of input and output data. (See "Troubleshooting Microprocessor-based Circuits" by Tom Allen in the January 1988 issue.) Buffers do the same thing in computer systems.

3. B—The viewing speed is increased to 60 pictures per second per eye. (See "Three-dimensional Camcorder" in the February 1988 issue.) The new system shows each picture twice. This advance is accomplished by using digital memory technology.

4. 35kHz. (See "Test Your Electronics Knowledge" in the February 1988 issue.) The calculation of approximate bandwidth is accomplished by dividing 0.35 by the rise time.

5. Connect a 2MΩ resistor across the ohmmeter output. (See "Extending DVM Ohmmeter Ranges" in the March 1988 issue.) The article suggests a simple graph for quick readings.

6. No. (See "Creating Resistor Values" by Art H. Myerson in the March 1988 issue.) According to an editor note in this article, the tolerance tells you how far the resistor value may vary in normal use.

7. The number of bits. (See "An Oscilloscope Update" by Conrad Persson in the April 1988 issue.) The greater the number of bits, the smoother the waveform looks.

8. A—a synchronous counter. (See Computer Corner, "The Ripple Counter," by Christopher H. Fenton in the April 1988 issue.) Synchronous counters clock all of the flip-flops on and off at the same time.

9. B—the lowest possible temperature. (See "Choosing a Soldering Iron" in the May 1988 issue.) Tinning should be done at the lowest possible temperature because corrosion occurs faster at higher temperatures.

10. C—emitter efficiency. (See "What Do You Know About Electronics" in the May 1988 issue.) Emitter efficiency and common-collector current gain are two different definitions of transistor gamma.

ES&T

What do you know about electronics?—

Network theorems and laws

By Sam Wilson, CET

I have been asked (maybe challenged is a better word) to discuss all of the major network theorems and laws without using math. In other words, what do these theorems and laws mean strictly from the standpoint of practical applications?

I want to say that, from my viewpoint, I think these theorems and laws are best understood when they are supported by math. However, I do recognize that too often they are submerged in fancy mathematical footwork, and the real message is lost.

So, here we go. It's going to take about 12 issues, so get a good hold on your chair.

The maximum power transfer theorem

All power sources (such as batteries, ac generators and car engines) have internal resistance (or friction). If they didn't, we could have perpetual motion machines. The internal resistance (or friction) dissipates power. That power is lost to the outside world.

From the viewpoint of electricity, the question to be answered is: How does the internal resistance affect the amount of power you can get to the outside world?

The maximum power transfer theorem for dc systems says that the *maximum* power that you can get out of a battery (or any dc generator) occurs when the load resistance equals the internal resistance of the source.

Wilson is the electronics theory consultant for ES&T.

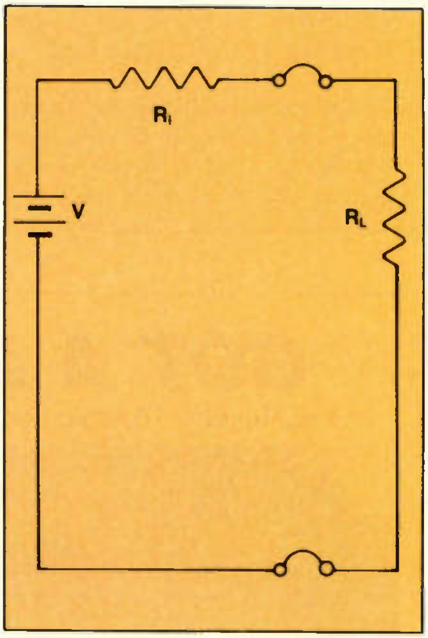


Figure 1. Maximum power is transferred from a source to a load if the load resistance, R_L, is made equal to the internal resistance of the source, R_i.

In its simplest form, the load resistance (R_L) in Figure 1 must equal the internal resistance (R_i) in order for that load resistance to get the maximum amount of power. If R_L is a light bulb, then it will glow brightest if the resistance of the filament equals the internal resistance of the source.

However, that is only half of the story. The efficiency of any system is equal to the output power (P_L) divided by the total power ($P_i + P_L$).

Whoa! There goes the math again.

The efficiency of any system is a measure of how well the power source is able to get power to the outside world. When the power delivered is maximum, the efficiency is only 50%. The higher the load resistance, the higher the efficiency.

If you want to design a flashlight, you want two things: a lot of power delivered to the light bulb so it glows brightly, and high efficiency so the batteries will last a long time. Unfortunately, you can't have high power transfer and high efficiency. They are called tradeoffs. You have to decide how much of each you are willing to settle for. You can't get around the problem by making the bulb's resistance higher because you will need more power (I^2R) to get your desired brightness.

There I go with the math again. Give me a little time to practice and I'll get better at this job.

Sometimes you want maximum power, and efficiency isn't so important. The internal resistance of a lead-acid battery is low. If you want the battery to deliver enough power to the starter motor, the starter motor resistance had better not be high.

The maximum power transfer theorem for ac is about the same, but we use bigger words to explain it. The internal opposition of the generator is an impedance made up of resistance and/or capacity.

Figure 2 shows an example. In this case, the internal impedance is made up of resistance and capacity. In other sys-

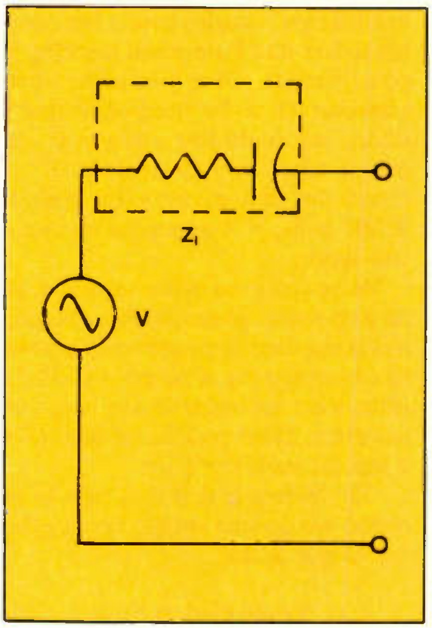


Figure 2. In the case of an ac circuit, the internal impedance of the source consists of the resistance plus any capacitive and/or inductive reactances.

tems, the internal impedance could be resistance and inductance.

Now, how do we get the maximum power to the outside world? It's easy. Make the load resistance equal to the internal resistance (as before). Use an inductance to resonate with the internal capacitance so that you have a series resonant circuit. (I'm not going to say make $X_L = X_C$ because I'm getting better at not using math.) See Figure 3.

In a series-resonant circuit, the inductive reactance equals the capacitive reactance. Their effects cancel and the circuit acts as though they aren't present. Only the resistance is to be considered. In this case, the internal resistance and load resistance values are equal. Therefore, maximum power is transferred.

Remember, capacitance and inductance do not dissipate power, so when you cancel them, you aren't changing the amount of power transferred. Power is dependent *only* on the internal and load resistances.

In a bipolar transistor (or tube or FET) circuit, the source of power can

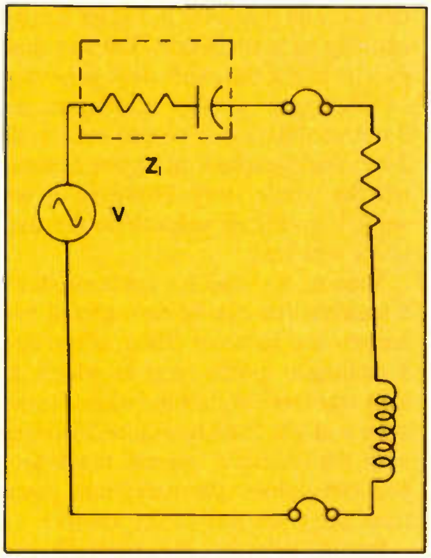


Figure 3. In the case of an ac circuit with a capacitive internal impedance, in order to transfer the maximum power to the outside world, make the load resistance equal to the internal resistance and use an inductance to resonate with the internal capacitance so that you have a series resonant circuit.

be thought of as being the amplifying device. The generator in Figure 2 might actually be a transistor. You can think of it as being the *equivalent generator*. In the real world, transistors are 3-terminal devices. For that reason, the 2-terminal generator in Figure 2 doesn't tell the whole story. However, it will work if you limit yourself to the transistor and load.

Suppose the load for the transistor is a speaker that can be represented by a resistor and inductor. Then, if you have a conjugate match (one in which the load resistance equals the source resistance and the load reactance resonates with the source's internal reactance), you can deliver the maximum power from the transistor to the speaker.

Sounds easy, but two tradeoffs rear their ugly heads. We've already talked about one. At maximum power transfer, the efficiency is only 50%. If the equipment is battery operated, the operating time is reduced by the maximum power transfer. The second tradeoff has to do with fidelity. It turns out that when you operate a transistor (or tube or FET) under maximum power transfer conditions, you may also get maximum distortion.

So you can get maximum power transfer in an ac system by using a conjugate match. However, you may not want it.

You will need to know about the maximum power transfer theorem when you read about some of the other theorems and laws in this series.

Some old business

In the April 1988 issue, Rapid Roy Delange asked about a neutral isolator. He sent a newspaper clipping that claims milk production increased by 700 pounds per cow when "neutral isolators were installed." Does that sound like a lot of bull? No. We're talking about the udder kind here.

Roy L. Mott, Sr., CET of Thomasville, AL, solved the problem. He wrote a nice letter explaining that the neutral isolator is nothing more complicated than an isolation transformer. Seems the cows were getting shocks from the milking machines, and it made concentration on their work very difficult.

In the May 1988 issue I discussed the fact that a transistor amplifier beat an op-amp in a lab face-off. The contest was conducted by Glen Langley of West Palm Beach, FL.

A nice letter from Garth Fisher of Walla Walla College in the state of Washington defends the op-amp. He says the op-amp has advantages that were not used in the contest.

Don't pick an op-amp to do a bipolar transistor's job. It is easy to get pulled into op-amp designs because they are simple to do.

For those of you who also disputed the outcome, here is my answer to Mr. Fisher: "You asked what frequencies were used for the comparison between the op-amp and transistor amplifier. The test that gave the best comparison was a sweep analysis. Sweeping from 0Hz to over 150,000Hz, the Bode plots were displayed on an oscilloscope.

"To make a fair comparison, the gains of both amplifiers were set equal, and, I believe, a gain of 10 was used. That gave the operational amplifier a broad response. However, the transistor amplifier showed a much wider response.

"The high input impedance of the op-amp did not give it any serious advantage in this case. Langley used a B&K function generator with a 75Ω output. That value was low compared to the input impedance of either amplifier.

"Had input impedance been a factor, Langley could have added two resistors and a capacitor (around 10 cents) and made a bootstrap circuit. That procedure would have made a respectable high-input impedance.

"To be fair, long-tail bias can be used with a bipolar circuit. After all, the op-amp requires a positive and a negative power supply, so that would not be counted against the bipolar. Using long-tail bias eliminates the 0.6V forward drop problem.

"The differential input of the op-amp is definitely an advantage unless, as in the comparison test, the op-amp is being used as a single-input amplifier. In that case, low drift and differential input is not an advantage.

"As you say, the cost factor is open to challenge. Langley used a fast design procedure that I use when teaching bipolar circuits. Once you know which transistor is to be used—and that is where you could lose some time—the design takes only 10 minutes. If you dilute that design time by building 10,000 units, it is no longer an important factor.

"As you have no doubt surmised, the op-amp comes in second place because it is being used in an application where its advantages are of no use. I think that is the most important lesson in this experiment: Don't pick an op-amp to do a bipolar transistor's job.

"My feeling is that it is easy to get pulled into op-amp designs because they are simple to do."

Transmission lines

I have never had occasion to delve into all of the facets of power transmission lines. I recently had an assignment that required me to do just that.

I do remember that a signal delivered to an open-end transmission that is infinitely long will pass on to infinity with no loss. I've never been able to test that to make sure it is true.

In a book titled "Communications Circuits" by Ware and Reed (Wiley 1947) the authors shorten the line (considerably) to 2,000 miles. They consider a cable pair of that length made of #19 AWG copper wire. The input signal frequency is assumed to be 796Hz.

They calculate that a 1A signal introduced at one end would result in an output of 10^{-97}A. This means that one electron would arrive at the receiving end every 500×10^{68} *years*! You can think of this fact in a different way. If you needed 1μW at the receiving end, you would have to have an input at the other end equal to 10^{188}W! That's enough power to light 10^{186} 100W light bulbs. You can see the advantage of using amplifiers along the line.

Have you ever worked on a smearer?

I know you'll think I made this up, but there is a circuit called a *smearer*. OK, I'll admit I ran across it in an electronics dictionary that got its start in England, but it was sold in the United States by Penguin Reference Books. A smearer, according to this dictionary, is a circuit used to remove the overshoot of a pulse.

Solder-wick dispenser

The Wickgun, *HMC's* desolder braid dispenser, prevents the braid from becoming contaminated by finger oil or dirt. The dispenser is manufactured from static dissipative material and features snap-in replacement of pre-loaded cassettes with 15 feet of braid.

Circle (75) on Reply Card

Telecom test set

The AR-180T, a telecom test set, has been announced by *American Reliance*. Features include level and noise measurements, ac and dc volts, dc current, resistance and audio continuity beeper. The unit is switchable between either 600Ω terminated or bridge measurements at 1MΩ impedance.

Circle (76) on Reply Card

Dial torque gauge

The model TQ-1800 dial torque gauge from *Tentel* is designed to evaluate the clutch and brake torque performance for optimum tape handling. A motorized

torque driver simulates the 9.5cm/sec U-Matic tape pulling speed. Torque measurements may be made either clockwise or counter-clockwise directly on the supply or take-up spindle.

Circle (77) on Reply Card

SMD removal system

O.K. Industries has introduced the SMT-WC, a hand-operated SMD removal system that features a variable temperature controller, a tweezer-action handpiece, a stand and various high-thermal capacity tips. Temperatures range from 330°F to 740°F.

Circle (78) on Reply Card

Self-contained cleaning products

Chemtronics has introduced a line of self-contained cleaning products. The pads and swabs, which are saturated with measured amounts of cleaning agents and filtered to less than 0.2 microns, are sealed in individual tear-open, foil packets. Optic Prep, Screen Prep, Chempad, Gold Guard Pad, TF Pad and Chemswab are products included in the line.

Circle (79) on Reply Card

Breakout box

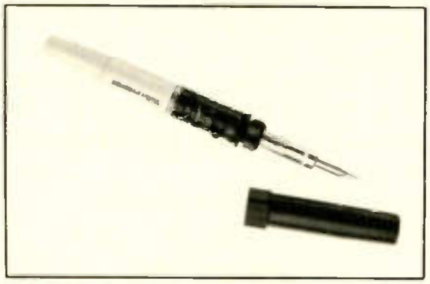
The Easy BOB model 725 breakout box from *Beckman Industrial* tests RS-232 transmission lines with 15 dedicated line-monitor locations and a spare LCD set for monitoring other lines. Each side of the BOB has a 3-inch ribbon cable with a dual-gender DB25 connector to facilitate hookup. The unit is an unpowered breakout box and does not use batteries.

Circle (80) on Reply Card

Continued on page 58.

Self-igniting Pyropen

The WPA-2 cordless, butane-gas-powered, self-igniting Weller Pyropen has been introduced by *CooperTools* for



use as either a soldering iron or a hot-air gun. The 4.4-ounce unit can operate for about three hours per butane fill up. Varying the gas flow controls the temperature, which ranges from 650°C to 1,202°C when the unit is used as a hot-air gun, and 250°C to 500°C when it is used as a soldering iron.

Circle (81) on Reply Card

Digital storage device

B&K-Precision has introduced a device that converts an analog oscilloscope to a digital storage device. The model 2501 digital storage adapter provides dual-channel operation, waveform storage, magnification capabilities and 10 megasample per second sampling; an output connector can be used with a hard-copy plotter. Digital storage is 2,048×8. Vertical resolution is 8-bit.

Circle (82) on Reply Card

Menu-driven multimeter

The Professional Series model 560 menu-driven multimeter from *Simpson* features autoranging; data logging on any selected range with 2,150 measurement memory (battery back-up); a 500kHz frequency counter; and REL, continuity and diode checks with an audible beeper. The dual-LCD format features a 5-digit, 52-segment measurement display and a 4-line menu/programming display.

Circle (83) on Reply Card

Aerosol chemicals

Philips ECG has introduced an assortment of cleaning, lubricating, shielding and testing agents, including circuit refrigerant, heavy-duty flux remover, contact cleaner and an all-purpose degreaser and wash. The aerosol cans are individually color-coded to facilitate identification and are available in different aerosol sizes and in bulk containers.

Also available are 1- and ½-pound spools of solder, which consists of a 60/40 tin-lead alloy and contains 2% rosin flux in three internal channels. Both sizes are available in 0.062-inch, 0.047-inch and 0.032-inch gauge diameters.

Circle (84) on Reply Card

Coaxial tool kit

Mouser Electronics has announced its Strip'n Crimp coaxial tool kit, which contains a dual-crimping tool, a simplex cable stripper, 10 plugs and cable sleeves in various sizes.

Circle (85) on Reply Card

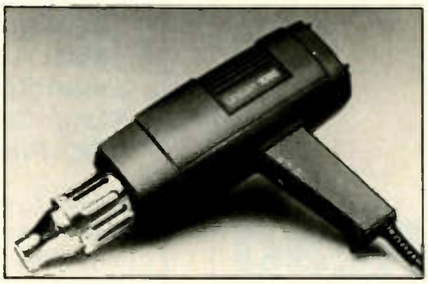
Wire strippers

T-Stripper wire strippers, introduced by *Ideal Industries* in both standard and premium models, accommodate 10 AWG to 30 AWG solid and 8 AWG to 26 AWG stranded copper or aluminum wire. The line includes the T-10, which slits cable jackets and then strips the conductors; the T-12 or T-14, which simultaneously strips two conductors; a 90° stripper with 90° offset blades; and adjustable V-Notch strippers.

Circle (86) on Reply Card

Dual-temperature heat gun

Ungar's 1095 1,000W heat gun has two temperature settings (790°F and 1,200°F) of flameless heat. The 22-



ounce gun reflows solder, loosens adhesives, applies heat-shrinkable materials, cures epoxy, heats liquids, shapes plastics and more. It has a heat-concentrating nozzle with stainless steel shielding, a permanent magnet motor and a reinforced, mica-insulated heating element.

Circle (87) on Reply Card

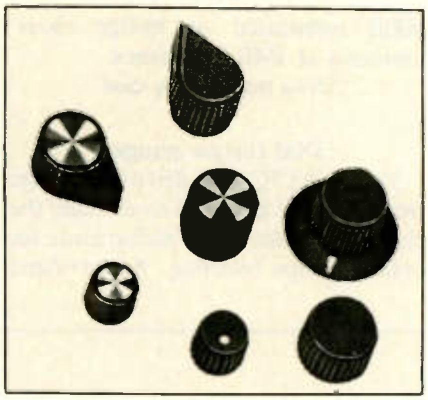
RF network analyzers

Direct Conversion Technique is offering a line of portable, automatic vector network analyzers that measure linear impedance, VSWR and other performance parameters of components, antennas and circuits. The analyzers function in the 100kHz to 4GHz bands and are made up of a tunable frequency source, a reflected voltage signal sampler and a amplitude/phase measurement module. Options include analog or digital displays and interfacing to other equipment.

Circle (88) on Reply Card

Commercial and mil-spec knobs

A line of mil-spec and commercial-type instrumentation knobs have been introduced by *Keystone Electronics.*



Mil-spec knobs, which are made of polycarbonate, are manufactured in 26 variations of the five most widely used styles and are available in 0.125 and 0.250 diameters. The commercial knobs, made of ABS thermoplastic with spun aluminum inlays, are available in 32 variations of the six most popular styles and come in 0.125 and 0.150 shaft diameters.

Circle (89) on Reply Card

DMMs

The 3200 series DMMs from *C.G. Soar* have a 3,200-count full scale with a high-speed, 32-segment analog bar-graph display. Features include autoranging, audible continuity/diode test, range hold and data hold; an adaptor mode, which can be used with the company's 9300 series adaptors, allows ac/dc current measurements and capacitance, temperature and transistor testing.

Circle (90) on Reply Card

Logic analyzer

Tektronix has introduced the modular 1230 logic analyzer, which is configurable from 16 to 64 acquisition channels. The analyzer offers four 2K deep memories behind every acquisition channel and supports most microprocessors. It has up to four time bases, an auto-compare mode and trigger-in and trigger-out signals that provide paths for system interaction.

Circle (91) on Reply Card

Portable pattern generator

Leader Instruments Corporation has announced the LCG-412B, a battery-operated, portable pattern generator. It

weighs less than 14 ounces, including six AA power cells, and features 75% color bars, dot, crosshatch and full raster signals of 100% white, red, green and blue. The unit features RF output on U.S. broadcast VHF and UHF channels in addition to $1V_{p\text{-}p}$ video output into a 75Ω load.

Circle (92) on Reply Card

Productivity organizer manual

Lynco Publications has announced a computerized version of the *Productivity Organizer* manual. The floppy disk, which contains a menu-driven, automated template for use with Lotus 1-2-3, version 2.0 or later, provides a quick method for recording and analyzing service technician productivity statistics. The disk requires an IBM or compatible PC, 256K RAM and a copy of Lotus 1-2-3, release 2.0 or later.

Circle (93) on Reply Card

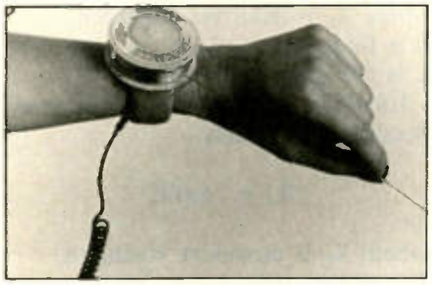
Elevating table

The Economy Regal mechanical elevating table, introduced by *Regal Equipment Company*, features two storage shelves and an adjustable top surface with four self-locking Acme screw thread posts. A high-speed stud operates at 3/8-inch turn for light loads. A low-speed stud operates at 1/8-inch turn for heavy loads. The table is equipped with phenolic wheels and a foot-operated lock.

Circle (94) on Reply Card

Solder dispenser

The Solderstat solder dispenser from *SGW* cuts soldering time by as much as



40%, according to the company. It attaches to any elastic or velcro static-control wrist strap and dispenses up to ¼ pound of solder directly from the wrist.

Circle (95) on Reply Card

SCSI bus test system

The 5380 SCSI bus test system from *DTR* allows engineers in product development and vendor evaluation to analyze devices that can be interfaced through the small computer system interface (SCSI). The tests for each unit are based on diagnostic libraries supplied by manufacturers. A 3½-inch flexible disc drive allows custom test generation. The panel can be enhanced to include bar code systems for factory floor tracking and data collection.

Circle (96) on Reply Card

Jumper boxes

B & B Electronics has designed jumper boxes that allow users to assemble custom RS-232 interfaces. A small PC board provides the solder pads for each line from both 25-pin connectors. The boxes have twenty jumper wires and are equipped to tap signals from the RS-232 line. Three models are available: the model 232MFJB with one female and one male connector; the model 232MMJB with two male connectors; and the model 232FFJB with two female connectors.

Circle (97) on Reply Card

ES&T

Audio Corner

Knowing your specs

By Conrad Persson

Specifications are an important part of the information available about a product. For example, the nominal voltage on an appliance tells you what electrical systems you can safely use that product on. If you try to operate an appliance designed for 120Vac on a 240V system, you'll probably get a lot of smoke.

On the other hand, specifications are frequently nominal, which means that, over some portion of the conditions under which it is used, the actual performance of the unit will be close to that specification. Nominal voltages for ac appliances have risen over the past several years. The typical household ac voltage used to be 110V. At some point, the nominal voltage on most systems was raised to 115V. And wasn't it at 117V for a while? Now it's at 120V. Strangely enough, ac appliances that were manufactured years ago with a nominal 110V specification seem to work well enough at 120V and will probably work pretty well over a voltage range of somewhere below 100V to about 130V or even higher.

That's the good news about specifications: They're really ball-park numbers, with a fair amount of tolerance.

That's also the bad news about specifications because, being inexact, they sometimes defy definition.

Defining speaker impedance

The good news/bad news trade-off is especially true for audio specifications. In fact, in talking to a colleague here, I suggested that, as often as not, audio specs aren't necessarily even in the ballpark, and sometimes it's a wonder if the specification and reality are in the same town. He corrected me and said it's remarkable if the spec and the reality are in the same *county*.

Take speaker impedance, for example. A typical speaker has an input impedance of 8Ω. Just what does that mean? Well, for starters, if you take a DMM and set it on OHMS, then take a reading across the speaker's terminals, you'll read considerably less than 8Ω. But you knew that. Speaker impedance is complex impedance, describing a combination of resistance, inductive reactance and capacitive reactance.

But, you say, inductive and capacitive reactance are frequency dependent. Inductive reactance is defined by the formula:

$$X_L = 2\pi FL$$

where X_L is inductive reactance.
F is frequency.
L is the value of inductance.

Likewise, capacitive reactance is defined by the formula

$$X_C = ½\pi FC$$

where X_C is capacitive reactance.
F is frequency.
C is the value of capacitance.

The nominal (there's that word again) audio frequency range is given as 20Hz to 20kHz. Substituting these two widely differing values of F into the equation for inductive reactance, you get:

$$X_L(20Hz) = 2\pi FL = 2\pi(20)L$$
$$X_L(20kHz) = 2\pi FL = 2\pi(20{,}000)L$$

Taking a ratio of the two equations:

$$X_L(20kHz)/X_L(20Hz) = 2\pi(20{,}000)L/2\pi(20)L$$

The π's cancel, the L's cancel and the 2s cancel, leaving a ratio of 20,000/20, or a thousand-fold difference in inductive reactance between the two extremes of audio frequency. So what does the nominal speaker impedance mean?

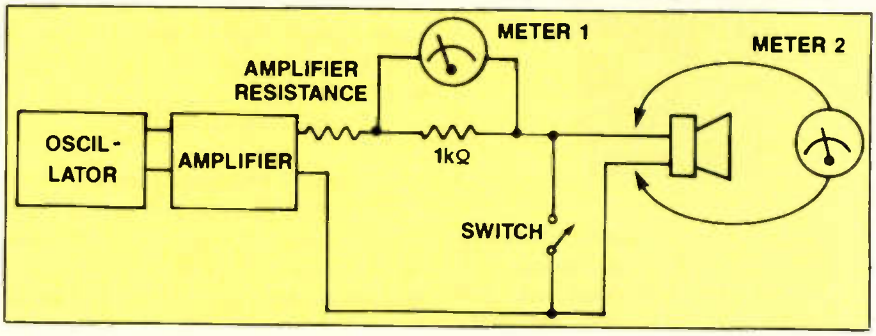


Figure 1. At a given frequency, you close the switch and adjust the amplifier controls for a 10V reading at meter 1. A voltage of 10V across the 1kΩ resistor means that the current through it is 10mA. The second step is to open the switch and read the voltage across the speaker inputs. This voltage is caused by the 10mA of current through the speaker. The impedance of the speaker at that frequency will be the meter voltage divided by the current.

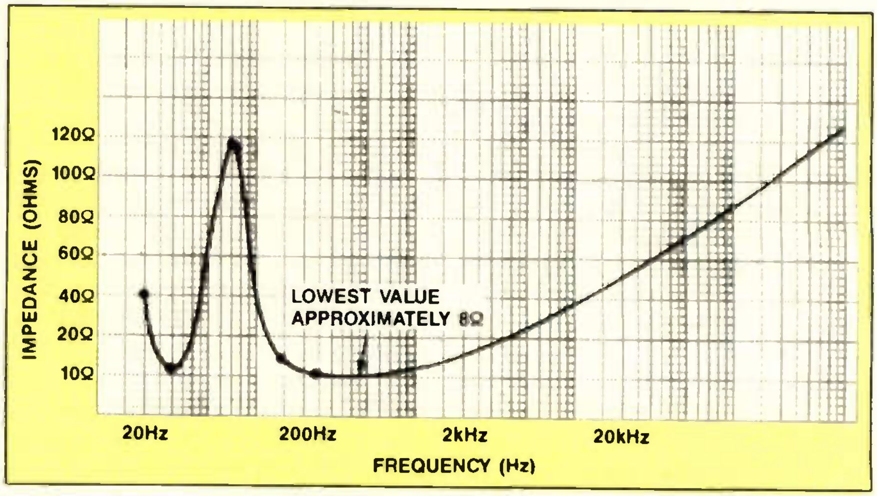


Figure 2. If you perform the measurement technique described in Figure 1 at frequent intervals across the audio spectrum, you will get a graph of the impedance of the speaker vs. frequency, such as this fictitious example. It will vary considerably, but the lowest impedance you find *should* be somewhere around the nominal impedance specified by the manufacturer.

Persson is editor of ES&T.

Of course, things are far more complicated than this, and looking at speaker impedance requires that we consider the speaker coil's dc resistance and the contributions of inductive reactance and capacitive reactance. The formula for complex impedance, taking into account all of these factors, is:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

If you were to plug some real-world loudspeaker values into this formula, you would find that the impedance would vary considerably with frequency, probably never exceeding 100Ω. In fact, the maximum impedance probably would be considerably less than that. The minimum impedance you would encounter would be somewhere around the value specified by the manufacturer as nominal.

To sum up, the nominal impedance of an audio system loudspeaker is somewhere near the minimum impedance that the speaker will present to the power amplifier. The manufacturer is stating that the loudspeaker will work properly with an amplifier that is specified to operate with a speaker of that impedance. In other words, if the amplifier manufacturer specifies the performance of an amplifier with an 8Ω load, and you have an 8Ω speaker, the system can be expected to work reasonably well (provided, of course, that the amplifier is capable of providing enough power to drive the speaker).

Measuring loudspeaker impedance

One way of measuring loudspeaker impedance is using the so-called *constant current* method. This method consists of driving the speaker with a power amplifier in series with a resistor that is large compared to the output impedance of the amplifier and the impedance of the speaker. You then use a variable oscillator capable of producing signals over the audio frequency range.

Take a look at Figure 1. At a given frequency, you close the switch and adjust the amplifier controls for a 10V reading at meter 1. A voltage of 10V across the 1kΩ resistor means that the current through it is 10mA. The second step is to open the switch and read the voltage across the speaker inputs. This voltage is caused by the 10mA of current through the speaker. The impedance at that frequency will be the meter voltage divided by the current:

$$Z = V_M/0.01A = V_M \times 100$$

So, a simple way to determine the speaker's impedance for a given meter reading is to multiply the reading by 100.

If you perform this measurement technique at frequent intervals across the audio spectrum, you will get a graph of the impedance of the speaker vs. frequency. (See Figure 2 for a fictitious example.) Again, you will note that it will vary considerably, but the lowest impedance you find *should* be somewhere around the nominal impedance specified by the manufacturer. ES&T

Interfacing computers to the analog world—Part III

By Joseph J. Carr, CET

Last month we looked at the digital-to-analog converter (DAC), which is a device for converting a binary digital number (word) to a proportional analog voltage or current output signal. This month we will take a look at the DAC's opposite number: the analog-to-digital (A/D) converter, which sometimes includes DACs as a component.

Of the many techniques for performing an A/D conversion, only a few basic types are of interest to us: single- and dual-slope integrators, which we'll cover here, counters (or servos) and successive approximation methods.

Single-slope integration ADCs

Most digital panel meters (DPM) or digital multimeters (DMM) use either single- or dual-slope integration for the A/D conversion process. An example of a single-slope integrator is simple, but is limited to those applications that can tolerate accuracy of only 1% to 2%.

Carr, an electronics engineer, has published several books on electronics and is a frequent contributor to ES&T.

The single-slope integrator A/D converter in Figure 1A consists of five basic sections: a ramp generator, a comparator, logic, a clock and an output encoder. The ramp generator is an op-amp Miller integrator circuit with its input connected to a stable, fixed reference voltage source. This reference source makes the input current I_{ref} essentially constant, so the voltage at point two will rise in a nearly linear manner, creating the voltage ramp.

The comparator is merely another op-amp, but it has no external feedback loop. The gain in that instance is essentially the open-loop gain of the device selected and is typically very high even in low-cost op-amps. When the analog input voltage V_x is greater than the ramp voltage, the output of the comparator is saturated at a logic HIGH level. The logic section consists of a main AND gate, a main-gate generator and a clock. The waveforms associated with these circuits are shown in Figure 1B.

When the output of the main-gate generator is LOW, switch S_1 remains closed, so the ramp voltage is zero. The main-gate signal at point one is a low-frequency square wave with a frequency equal to the desired time-sampling rate. When point one is HIGH, S_1 is open, so the ramp will begin to rise linearly. When the ramp voltage is equal to the unknown input voltage V_x, the differential voltage seen by the comparator is zero, so its output drops LOW.

The AND gate requires all three inputs to be HIGH before its output can be HIGH also. From times T_0 to T_1, the output of the AND gate will go HIGH every time the clock signal is also HIGH.

The encoder section, in this case an 8-bit binary counter, will then see a pulse train with a length proportional to the amplitude of the analog input voltage. If the A/D converter is designed correctly, the maximum count of the encoder will be proportional to the maximum range (full-scale) value of V_x.

Several problems are found in single-slope integrator A/D converters:

- The ramp voltage may be non-linear.
- The ramp voltage may have a slope that is either too steep or too shallow.
- The clock pulse frequency could be wrong.
- Noise may cause changes in the apparent value of V_x.

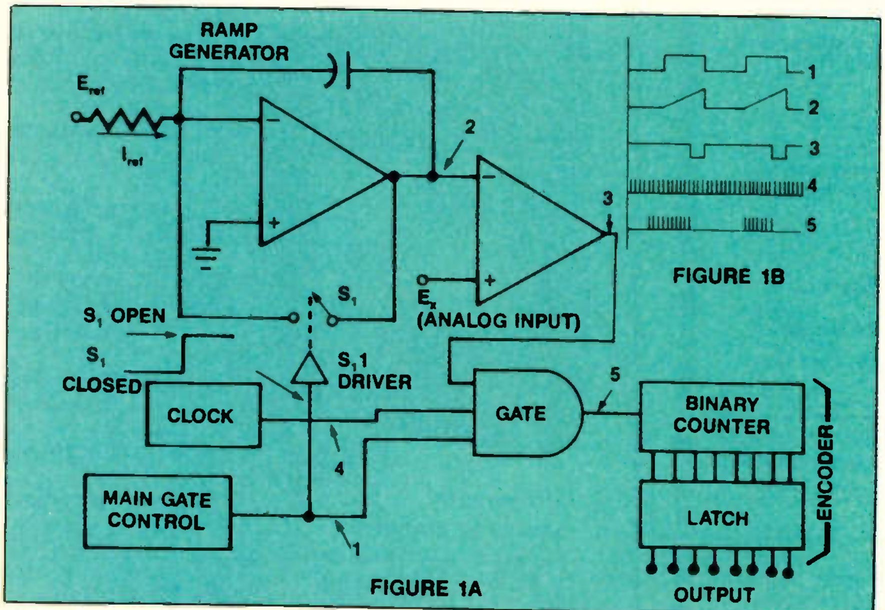


Figure 1. The single-slope integrator A/D converter in Figure 1A consists of five basic sections: a ramp generator, a comparator, logic, a clock and an output encoder. The waveforms associated with the circuits pointed out by the circled numbers are shown in Figure 1B.

Dual-slope integrators

Many of the problems with single-slope integrators are corrected by the dual-slope integrator in Figure 2. This circuit also consists of five basic sections: an integrator, a comparator, a control logic section, a binary counter and a reference current or voltage source. An integrator is made with an op-amp connected with a capacitor in the negative feedback loop, as was the case in the single-slope version. The comparator in this circuit is also the same sort of circuit that was used in the previous example. In this case, however, the comparator is ground-referenced, using just one active element.

When a START command is received, the control circuit resets the counter to 00000000, resets the integrator to 0V (by discharging C_1) and sets electronic switch S_1 to the analog input. The analog voltage creates an input current to the integrator; that current causes the integrator output to begin charging capacitor C_1, which means the output voltage of the integrator will begin to rise. As soon as this voltage rises a few millivolts above ground, the comparator output snaps HIGH-positive. A HIGH comparator output causes the control circuit to enable the counter, which begins to count pulses.

The counter is allowed to overflow, and this output bit resets switch S_1. The graph in Figure 2B shows the integrator charging during the interval between the START command and the overflow of the binary counter (T_1-T_0). At time T_1, the switch changes the integrator input from the analog signal to a precision reference source. At the same time, the counter overflows and again has an output of 00000000 (maximum counter plus one more count is the same as the initial condition). It will, however, continue to increment as long as the comparator output is HIGH. The charge accumulated on capacitor C_1 during the first time interval is proportional to the average value of the analog signal that existed between T_0 and T_1.

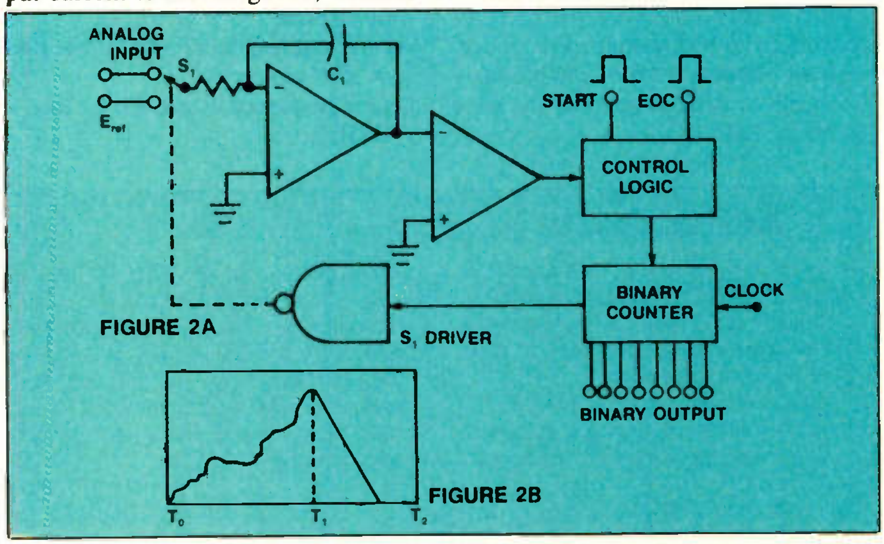


Figure 2. The dual-slope integrator consists of five basic sections: an integrator, a comparator, a control logic section, a binary counter and a reference current or voltage source. The graph in Figure 2B shows the integrator charging during the interval between the START command and the overflow of the binary counter (T_1-T_0).

Capacitor C_1 is discharged during the next time interval (T_2-T_1). When C_1 is fully discharged, the comparator will see a ground condition at its active input and will change state and make its output LOW. Although the low output causes the control logic to stop the binary counter, it does not reset the binary counter. The binary word at the counter output at the instant it is stopped is proportional to the average value of the analog waveform over the interval T_1-T_0. An *end-of-conversion* (EOC) signal is generated by this circuit to strobe the microprocessor or other instrument, which indicates the output data is both stable and valid and, therefore, ready for use.

Next month, we'll cover two A/D converters, the servo and the successive approximation converter, that use DACs for a reference voltage. ES&T

Video Corner

Elements of video optics

By Carl Bentz

This material was adapted from "Elements of TV Optics," published in Broadcast Engineering, *August 1986. Information for this article was provided by Angenieux, Canon, Fujinon, Schneider and Tamron.*

To fully understand video-camera operation, you must be familiar with two types of devices and circuits: those that convert light to electronic signals, and those that manipulate these electronic signals. You also should be familiar with the optics (the lenses) that gather the light, which ultimately becomes the video picture. The next several installments of Video Corner will discuss video camera optics.

Bentz is the TV technical editor for *Broadcast Engineering* magazine.

Waves or particles

Light seems complex because it simultaneously exhibits two sets of properties: the properties of a wave as well as the properties of particles. To explain camera-tube or CRT operation, it's easier to think of light in terms of the photon theory of energy particles, or packets, with momentum. For optical systems—lenses, mirrors and prisms—it's easier to think in terms of the wave nature of light.

Wavelengths or frequencies of electromagnetic energy (light is a form of electromagnetic energy) define light and its color. The wavelength of a particular color of light is related to its frequency by the formula

$$l = C/f$$

where:

C is a constant value, 3×10^8 m/s, the velocity of light in meters/second in free space;

l is the wavelength in millimicrons ($1m\mu = 10^{-9}$ meters);

f is the frequency in terahertz ($1THz = 10^{12}Hz$).

Reflections

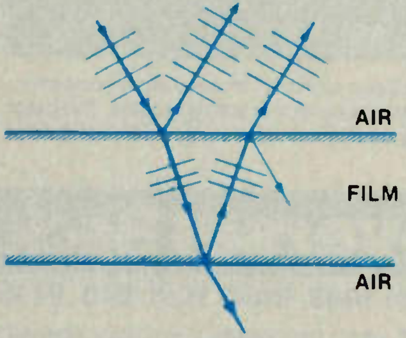
Mirrors reflect light by bending light rays back into the medium they came from. If the surface is flat (planar), a sharp image of the reflected object appears to a viewer located at any distance from the mirror surface. The light waves are bent but remain relatively parallel to one another. If the surface is non-planar, or curved, the waves reflect in various directions. Depending on the type and smoothness of the curve, the image may be enlarged or reduced in size and may be inverted (appear upside-down). The light strikes the surface at an angle called *the angle of incidence*; light leaves the surface at an angle called *the angle of reflection*. The two angles, measured from a line perpendicular to the surface, are equal. This law of physics is never broken, even if the surface is not smooth.

Flat glass mirrors may be constructed to reflect from the front surface (first point contacted by the light) or from a rear silver-plated surface. Except for special-effects work, the double image resulting from a rear-surface mirror would be undesirable. Therefore, camera optical systems use metallic mirrors or glass with a polished plated layer on the front surface.

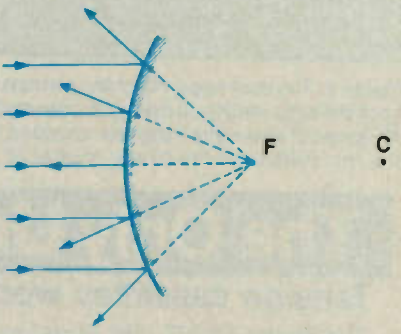
A concave mirror, such as those found in reflecting telescopes, causes light rays to converge at a focal point in front of the mirror. Images seen between the focal point and the mirror surface are enlarged and erect, while images viewed from beyond the focal point are inverted.

The convex mirror creates a virtual image behind the surface. The image is always erect and is smaller than the image created with a plane mirror. Automobiles frequently use convex rear-view mirrors because they allow a wider angle of view than plane types provide.

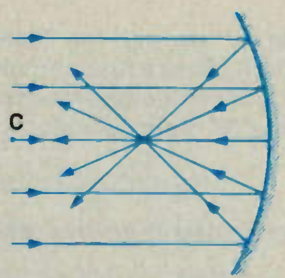
Another highly efficient reflector is found in some types of prisms. Although seldom used in video optics, the double Porro prism with 45x-45x-90x angles allows realignment of light for easier viewing in high-quality binoculars. Porro prisms are sometimes used for special-purpose lenses; for example, they are sometimes used to shorten a very long focal length to a more manageable physical length.



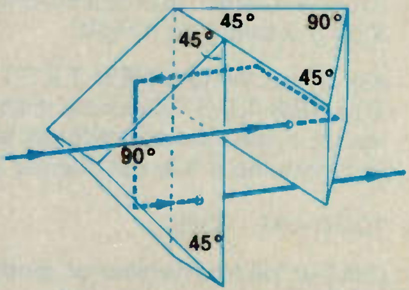
The angle of incidence is equal to the angle of reflectance, both measured from the normal, which is a line meeting the reflecting surface at an angle of 90°.



A concave mirror causes light waves to be reflected and converged at a focal point in front of the mirror.



A convex mirror causes light to be reflected divergently toward its source. A virtual image appears behind the mirror.



Although rarely used in TV optics, the double Porro prism with 45°-45°-90° angles allows realignment of light for easier viewing in high-quality binoculars.

Visible light wavelengths range from 400mμ to 700mμ. Light waves with wavelengths longer than the wavelength of red light (700mμ) are infrared; lightwaves of wavelengths shorter than the wavelength of violet light (less than 400mμ) are ultraviolet. White light is a composite of energy with many different colors or all the wavelengths between these limits.

When light travels through a medium other than free space, such as glass, its speed changes. This speed factor is what allows an optical device to bend light.

When light strikes

When light waves strike the boundary between two media of different densities, one of two things may happen. (See Figure 1 and the sidebar on reflection). The light may be reflected from the surface boundary, or it may pass into the new medium.

When we think about reflection, we usually think of mirrors, within which an image seems to appear. Reflection also occurs from rough surfaces, but the light becomes diffused; the directions taken by the reflected light rays are no longer parallel. Instead of an apparent image, we see the reflecting surface itself, formed from those light rays that are reflected relatively perpendicular from the surface. When light strikes a junction between two transparent media, at least some of the light is reflected. In fact, beyond a certain critical angle of incidence, all light is reflected. To reduce reflection, coatings may be applied. For a lens, the coating may result in increased efficiency. Coatings of calcium or magnesium fluorides reduce reflectance to 1% or 2% of the incident light.

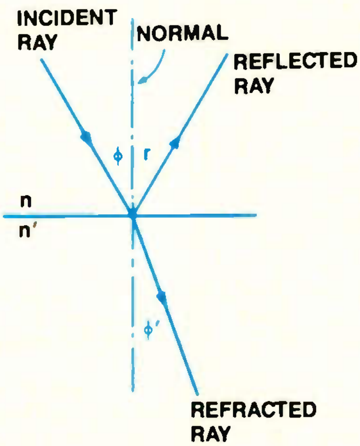


Figure 1. When light waves strike the boundary between two mediums, the rays are either refracted, or passed through the surface, or they are reflected back.

When non-reflected light passes the junction between the two media, the properties of the new medium dictates the result. If the material is transparent (clear glass, for example), light passes through and rays remain relatively parallel. The object acting as the source of the light waves is visible through the glass.

The next installment of Video Corner will cover the nature of the media from which video-camera lenses are made, the components of lenses, and apertures and f-stops. ES&T

Readers' Exchange

Editor's Note: Readers' Exchange items are published in the order they are received. We are happy to offer this service at no charge to you, our readers, but we ask that:

- Items are typed (or *legibly* written).
- You include your name and address on the same page as your ad (envelopes and contents are often separated). Please also include your telephone number (specify if you don't want it published). Using your peel-off label is a good idea.
- You limit any ad to no more than three items. If space demands, ads will be edited to roughly four lines in the magazine.
- Mail to: Readers' Exchange, Electronic Servicing & Technology, P.O. Box 12901, Overland Park, KS 66212.

Please remember that **ES&T** is in production six weeks to two months *ahead* of publication date.

WANTED

Hickok model 292X-AL signal generator, next-to-new condition. Please send your price. *Paul Capito, 637 W. 21st St., Erie, PA 16502.*

Sams Photofacts, #1767 and up. State price and condition. *Johnnie Hoggatt, Hogatt Home Appliance, 617-19 Archer, Marshall, IL 62441; 217-826-5122 days.*

Schematic for Panasonic model RS-818S stereo. Schematic no longer available. Photocopy is fine. *Kenneth S. Weber, 1249 Bellaire Blvd., Bellevue, NE 68005.*

B&K 2040 CB signal generator, Calrad Variac 0-130Vac, CB42, good condition, with manuals and accessories. Reasonable prices. No collect calls. *K.W. Lawson, Star Route Box 41, Nemo, TX 76070; 817-645-8381.*

Heathkit information to install an SB10 in a DX100 transmitter; service manual for Sony model KV 1930R TV; man for Navy TCS-8 transceiver or power supply; Swan Electronics equipment, dead or alive; tubes: 6LF6, 6HF5, 6GK6, 7360, 8950. *George R. Jarrett, N5016 Idaho Road, Newman Lake, WA 99025.*

Sencore SG165 AM/FM stereo analyzer in good shape. *Jim Patrick, 69 Main St., Greenwich, NY 12834; 518-692-9366 days, 518-692-2855 evenings.*

Sencore VA-48 analyzer. Must be EC with all manuals and leads. Will buy best offer received before August 1st. Send price to include shipping. *Tim Rowell, 1200 Barton St., Johnson City, TN 37601.*

Service manuals for Sony U-Matic VCRs, models VO-2800 and VO-2850. Photocopies OK or send and I will copy and return. *Robert Cowardin, 1218 Lane Drive, Cary NC 27511; 919-836-5912 days.*

B&K 520 or 530 transistor checker; Optoelectronics 800MHz counter; function generator; Simpson 260 800MHz service monitor; Motorola TEK-7 meter. *R. Riddel, 2412 S. Bowen Road, Arlington, TX 76015.*

Used Sencore equipment. Send list or call. *Cahill Electronics, P.O. Box 568, Kingston, NH 03848; 603-642-4292.*

Test equipment such as an ac isolated, adjustable power supply; an FM signal generator; a transistor tester, etc. *Ed Herbert, 410 N. Third St., Minersville, PA 17954.*

Schematic or service manuals for a B&K model 1074 TV analyst and a Hewlett Packard model 410B VTVM. Will pay for copy or buy outright. *Ben C. Boell, RFD 1, Box 128M, Republican City, NE 68971; 308-799-5135.*

Radio Retailing magazines. Will pay $1 per issue for issues dated before 1943. *Doug Heimstead, 1349 Hillcrest Drive, Fridley, MN 55432; 612-571-1387.*

NRI microcomputer/digital electronics servicing course—will buy or trade my NRI TV/audio

Coming Up in ELECTRONIC Servicing & Technology

September

Multimeter Update: Here's an overview of some of the features on the newest crop of multimeters on the market. You'll find out what you can now do with meters that couldn't be done before.

Automotive Electronics Servicing: ES&T explores some of the new electronic circuits found in today's cars.

October

Preventive Maintenance Update: Some products, especially products like audiocassette recorders, VCRs, turntables and disc drives, should be periodically cleaned, lubricated and adjusted. ES&T tells you which of these consumer electronics products should be given preventive maintenance, and how to do it.

Servicing Mechanical Components: Many consumer electronics products have mechanical components. ES&T tells you what some of these mechanical components are, what can go wrong with them, and how to fix them when problems occur.

November

Power Conditioning Equipment Update: Today's consumer electronic products are susceptible to damage from power line spikes, surges, sags and dropouts. ES&T describes for you some of these problems and tells you about the kinds of equipment available to solve them.

Wire and Cable: ES&T provides information on the different kinds of wiring products and their characteristics.

Plus ES&T's Regular Monthly Departments course. *J. Kostalek, 3141 Lodwick Drive, Warren, Ohio 44485; 216-898-4145.*

FOR SALE

B&K model 1470 5-inch scope, dual-trace, triggered sweep, 20MHz, with two probes and manual, $150; Leader model LDM 3½-digit ship DDM, $50. *Harry Hoffman TV, 2743 Ocean Ave., Brooklyn, NY 11229; 718-891-8010.*

Philco TV 4YC90 modules; complete Philco TV 3CR40, 4CS71, 3CN20; Magnavox model 1C6104 portable TV; many RCA CTC 74 parts; Zenith 14CC16 complete. *D.J. Aijala, 50 Fir Circle, Babbitt, MN 55706.*

B&K model 1570 70MHz, dual time base, quad trace with manuals and diagrams, $900; B&K model 1246 digital TV color pattern generator with manual, $90; Heath model IT5230 TV picture tube checker and rejuvenator with universal adaptor and manual, $100. *Kenneth Schultz, 1045 Heavenridge, Essexville, MI 48732; 517-893-5918.*

Hitachi 35MHz, dual-trace scope, in box, $375; Lectrotech 10MHz single-trace scope-vectorscope, $125; Lafayette CRT tester-rejuvenator, $50; B&K 1076 TV analyst, $50; B&K 707 tube testers, have three, $25 each; Albia 550MHz frequency counter, $75; B&K Senior Voltohmyst, have three, $75 each; B&K 465 CRT rejuvenators, have two, $25 each. Add shipping. *Service Center, 603 E. Oak St., Santa Maria, CA 93454; 805-925-8774 day time, Mon.-Fri.; 805-925-2173 evenings and weekends.*

Sencore VA 62 universal video analyzer; VC 63 VCR tester accessory; NT64 pattern generator; EX 231 expander jack, complete with manuals and cables. *Craig Schwan, 20432 Hollywood, Harper Woods, MI 48225; 313-772-8345.*

Sams Photofacts, TV series #1300 through #1829, $950; CB series over 100, $300 for all or $5 each—call or write for numbers. *Frank Wolff, 6 White St., Topsham, ME 04086; 207-729-0566.*

Sams TV Photofacts, #859 to #1664, includes metal files, $2,400 or best offer. Add shipping. *Bellevue Radio & TV, 109 W. Center St., Bellevue, OH 44811; 419-483-7180.*

B&K 1472C dual-trace scope, $250; B&K 290 TVOM, $115; DMM NLS #3.5A, $30; B&K 1248 color generator, $100; Conar transistor tester, $35; Conar signal generator, $35; 70 tubes in boxes, $70. All include manuals and are in excellent condition. You pay shipping. Money orders or bank checks only. For appointment call 718-375-3640, Len Elgart, after 5 p.m. *Leonard Elgart, 1811 Quentin Road, Brooklyn, NY 11229.*

Hickok model 610A universal TV-FM alignment signal generator, $50; Sams Photofacts, #69 through #496, all 275 sets for $100; Triplett model 690 portable transistor tester, $20; Lectrotech model TT-250 transistor analyzer, $50; Philco model 7050 tube tester, tests old tubes also, $30. All equipment includes manuals and is in good condition. Add shipping to all prices. *John Brouzakis, 247 Valley Circle, Charlerol, PA 15022; 412-483-3072.*

RCA tuner modules MSC, MST and MCR (send SASE for complete list); magazines: ES&T Nov. 1981-Dec. 1984, E/T Dealer June 1976-March 1982, Electronic Servicing Jan. 1977-Oct. 1981, P.F. Reporter Jan. 1964-Dec. 1967, approximately 200 pieces, $10 plus shipping. *M.E. Andrews, Jr., Box 91, Exeter, RI 02822.*

3,500 tubes, mostly new, will sell separately or for best offer; assorted yokes and flybacks. *Dick Yasko, 407 E. Main St., Fremont, WI 54940; 414-446-2239.*

Heathkit model 10-4550 10MHz, dual-trace oscilloscope, $150; model 1G5228 color-bar generator, $50; B&K model 1077B TV analyst, $95; Mark IV tuner subber, $20; other test equipment. *Gene Bartley, 1805 Sylvia, Arkadelphia, AR 71923; 501-246-7234.*

ES&T

Classified

Advertising rates in the Classified Section are $1.55 per word, each insertion, and must be accompanied by payment to insure publication.

Each initial or abbreviation counts as a full word.

Minimum classified charge $30.00.

For ads on which replies are sent to us for forwarding (blind ads), there is an additional charge of $35.00 per insertion to cover department number, processing of replies, and mailing costs.

Classified columns are not open to advertising of any products regularly produced by manufacturers unless used and no longer owned by the manufacturer of distributor.

SAVE TIME

For fast, accurate service, please remove the Peel-Off Label (which is used to address your magazine) and affix it to the Reader Service Card, the Address Change Card, or to any correspondence you send us regarding your subscription.

Ad Index/Hotline

ELECTRONIC SERVICING & TECHNOLOGY (ISSN 0278-9922) is published monthly for $19.49 per year by Intertec Publishing Corp., 9221 Quivira Rd., Overland Park, KS 66215. Second-class postage paid at Shawnee Mission, KS and additional mailing offices. POSTMASTER: Send address changes to ELECTRONIC SERVICING & TECHNOLOGY, P.O. Box 12960, Overland Park, KS 66212.

ADVERTISING SALES OFFICES

ELECTRONIC Servicing & Technology

KANSAS CITY, MISSOURI
Greg Garrison, Sales Manager
P.O. Box 12901
Overland Park, KS 66212
Phone: (913) 888-4664
Fax: (913) 888-7243
Telex: 42-4156 INTERTEC OLPK

OXFORD, ENGLAND
Nicholas McGeachin
Roseleigh House, New Street
Deddington, Oxford OX5 4SP
Phone: (0869) 38794
Telefax: (0869) 38040
Telex: 837469 BES G

TOKYO, JAPAN
Haruki Hirayama,
EMS, Inc.
Sagami Bldg., 4-2-21, Shinjuku,
Shinjuku-ku, Tokyo 160, Japan
(03) 350-5666
Telex: 2322520 EMSINCJ
Cable: EMSINCPERIOD

FREWVILLE, SOUTH AUSTRALIA
John Williamson
Hastwell, Williamson, Rep. Pty. Ltd.
109 Conyngham Street
Frewville 5063
South Australia
Phone: 799-522
FAX: 08 79 9735
Telex: AA87113 HANDM