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Industrial electronic controllers:
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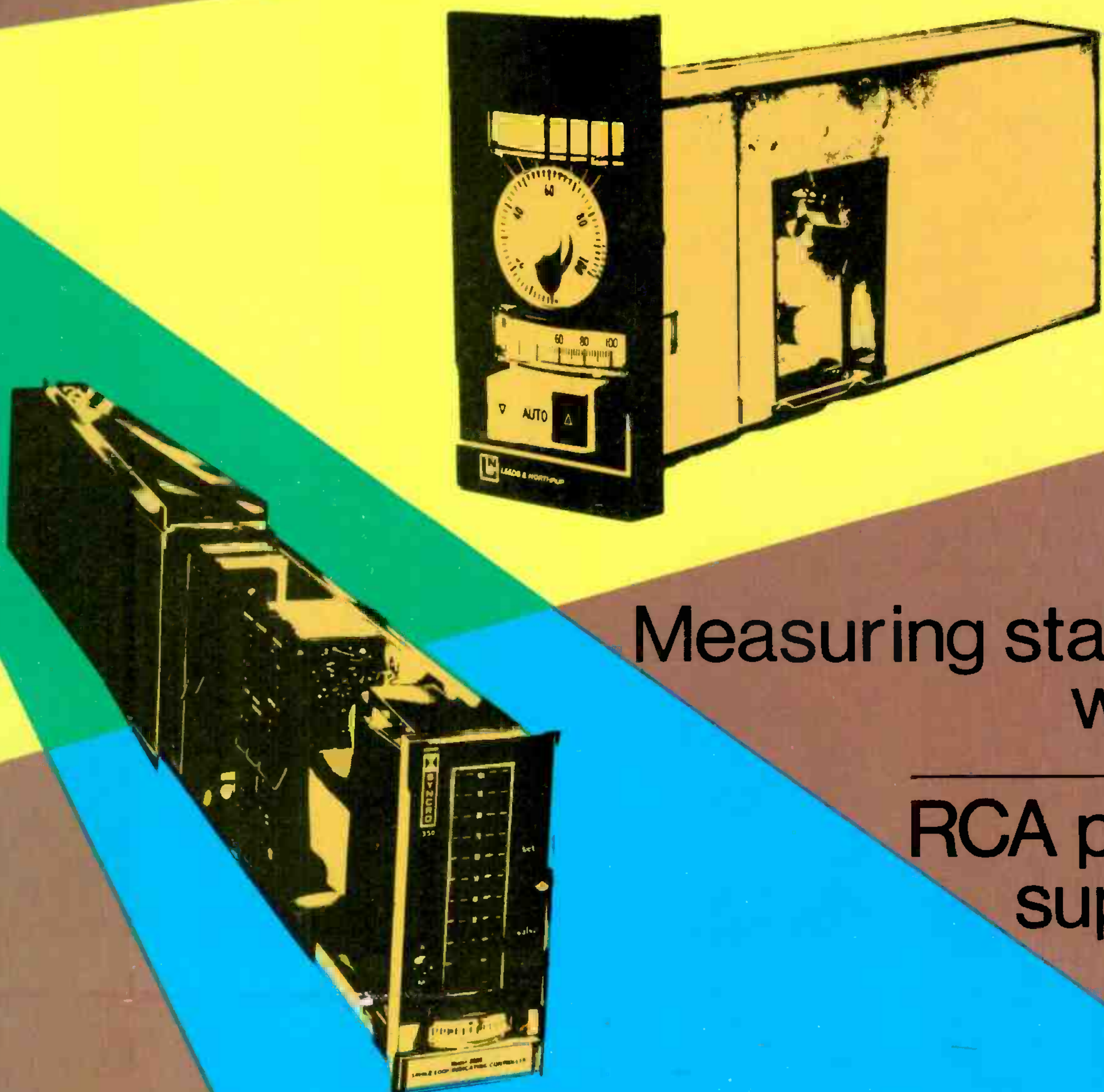
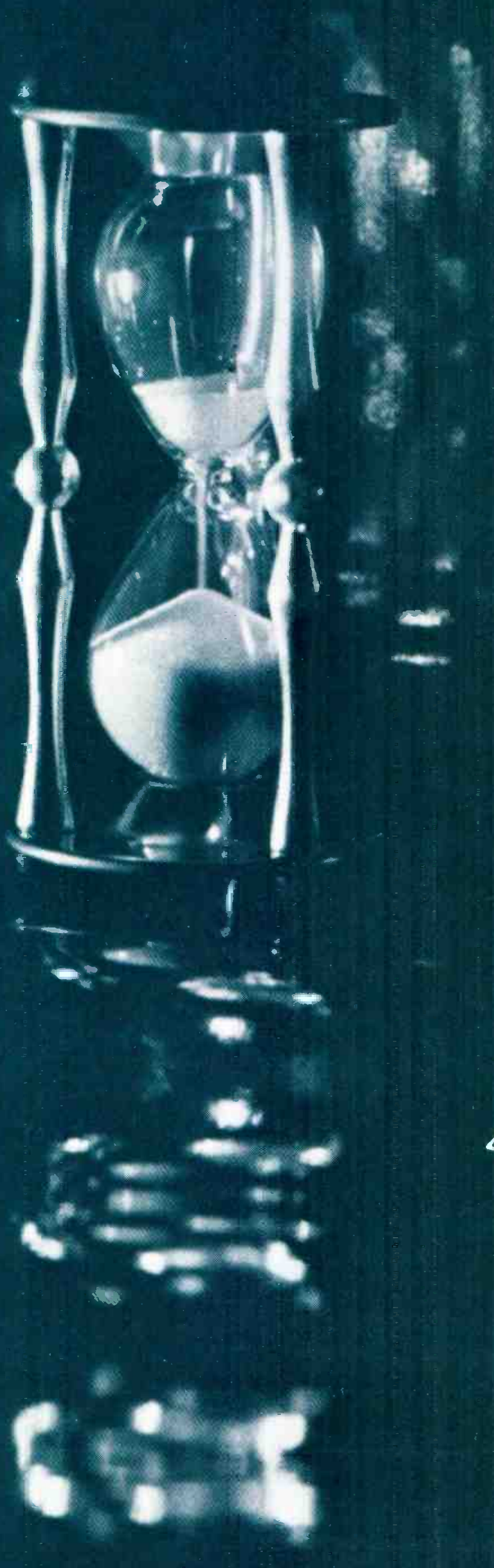


Measuring standing waves

RCA power supplies



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December, 1979 □
Volume 29, No. 12

Electronic Servicing®

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About the cover

Graphic design by Linda Franzblau

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news of the industry

Stereo sound for television will receive a theoretical analysis in January, with field testing of four different systems expected to begin in the spring. The analysis and field tests are arranged by the Broadcast Television System Committee of the EIA. Several 1980 model color TVs have more powerful speakers and amplifiers, and some include *simulated* stereo. Japan now has a choice of bilingual or true stereo sound with TV broadcasts, and interest in similar systems is growing rapidly in the United States.

PTS Electronics has moved its Memphis branch to 1289 Madison Avenue, P.O. Box 41043, Memphis, TN 38104. The move provides space for a larger inventory and improved service along with sufficient off-street parking.

The Institute of High Fidelity (IHF) has been merged into the EIA, becoming an operating subdivision of the Audio Division of the Consumer Electronics Group of EIA.

Maurice R. Valente becomes president and chief operating officer of RCA on January 1, 1980. Edgar Griffiths formerly was president. He will continue as chief executive officer and alos assume the chairmanship. Herbert S. Schlosser, executive vice-president of RCA, has predicted that between 25 and 40 million videodisc players will be sold during the first 10 years. About 300 titles for the RCA SelectaVision videodiscs should be available when RCA introduces its players. License to use 75 Paramount Pictures feature films was obtained recently, and RCA also has agreements with MGM, 20th Century Fox, ITC Entertainment and United Features Syndicate.

No license now is required for receive-only satellite TV terminals. Previously, before licensing a terminal, the FCC asked for a local survey to prove that the new system could have good reception without interference from other microwave signals. Nothing now prevents anyone owning a direct satellite terminal except the high cost of special antenna, down converter and amplifiers.

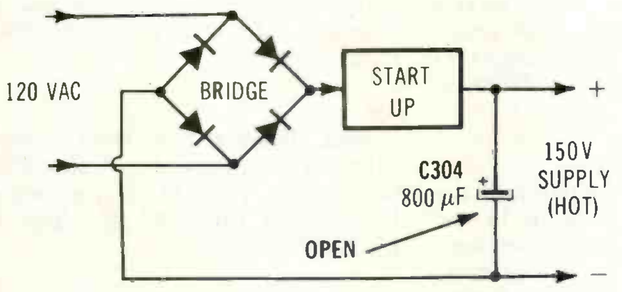
John J. Nevin resigned recently as chairman of Zenith, and Joseph S. Wright was appointed as interim chairman and chief executive officer. Zenith also has announced a new five-hour microprocessor-controlled videocassette recorder that can be programmed to record up to four TV channels at four different times during a 14-day period. Other features include automatic indexing, triple-speed play and remote control.

A new lie detector is said to identify deception by analzying inaudible microtremors in the human voice. It is the Telestar Voice Stress Analyzer which is small and sells for $149.

symcure

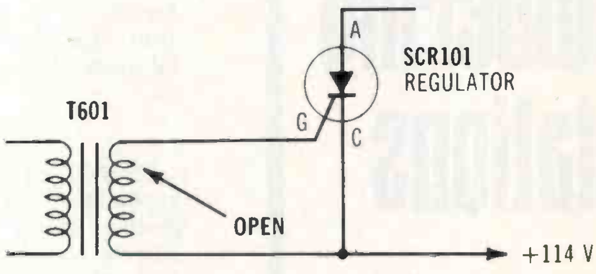
Symptoms and cures compiled from field reports of recurring troubles

Chassis—RCA CTC85
PHOTOFACT—1800-1



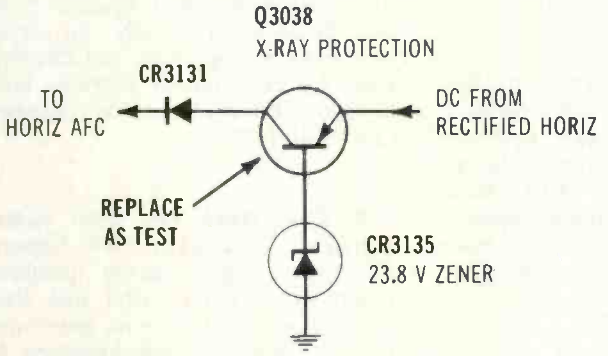
Symptom—No sound, no picture, no start-up
Cure—Check filter capacitor C304, and replace it if open

Chassis—RCA CTC88
PHOTOFACT—1787-1



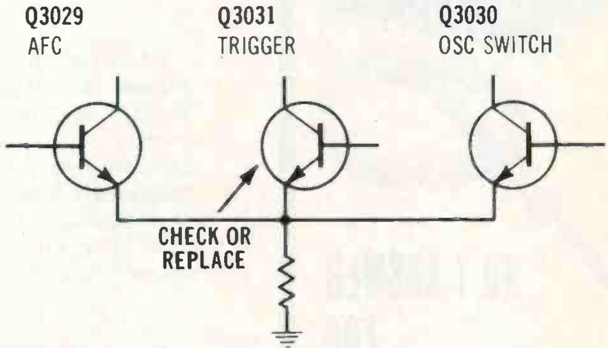
Symptom—No sound, no picture, and no start-up
Cure—Check triggering transformer T601, and replace it if open

Chassis—RCA CTC88
PHOTOFACT—1787-1



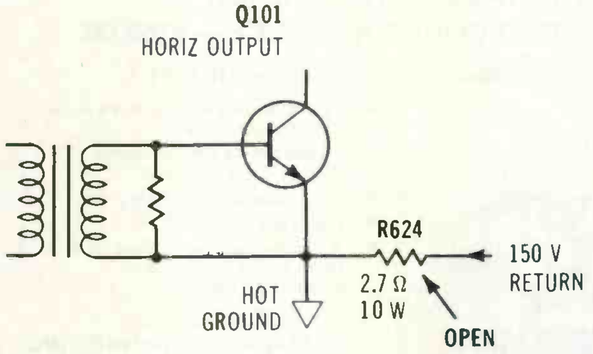
Symptom—No sound, no raster, and horiz osc is dead
Cure—Check shut-down transistor Q3038, and replace it if bad

Chassis—RCA CTC87
PHOTOFACT—1778-2



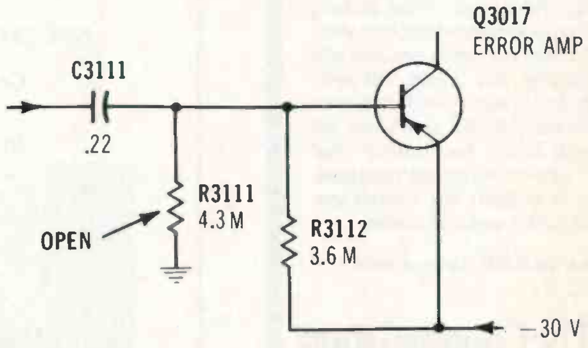
Symptom—Erratic start-up or intermittent raster
Cure—Check or replace trigger transistor Q3031, and replace if bad

Chassis—RCA CTC97
PHOTOFACT—No Photofact



Symptom—No picture, no sound and no start-up
Cure—Check R624, and replace it if open

Chassis—RCA CTC97
PHOTOFACT—No Photofact



Symptom—No height, or insufficient height
Cure—Check R3111, and replace it if open

people in the news

The Electronics Industries Association recently awarded **William E. Boss** the 1979 Distinguished Service Award. Boss is division vice president, distributor and commercial relations, RCA Consumer Electronics.

US JVC recently announced the appointment of **N. Sakoda** to the position of director and president. Sakoda was formerly general manager of the export administrative division of Victor Company of Japan.

The appointment of **Seth M. Willenson** as staff vice president of SelectaVision videodisc programs was announced by RCA. Willenson joined RCA in April. Previously, he was vice president, feature distribution, with Films Incorporated.

GC Electronics has appointed **Wayne G. Timpe** vice president-general manager. Timpe was previously vice president-manufacturing and research. Also at GC, **James Heighway**, former national manager of distributor and consumer sales, has been promoted to director, special marketing.

Terry McCarthy, former Western region manager of marketing communications for the electronic components group, TRW, has been named manager, advertising, ITT Cannon Electronic. McCarthy is a director and past president of the Los Angeles chapter, Business/Professional Advertising Association. Previously, he was advertising manager, Turco products division, Purex.

Ellen Beebee has been named sales representative for Alpha Wire Corporation. Prior to her promotion, Beebee was employed at Alpha in technical service.

ITT Blackburn has elected **Peter E. Fuerst** president. Fuerst succeeds **William E. Wilton**, who has been named chairman of ITT Blackburn's executive committee.

Richard C. Tyrrell has been named director of AutoSound sales, RCA distributor and special products division. Previously, he served as manager, planning and development for government services marketing, in the RCA service company, Cherry Hill, NJ.

R. Fred Webb has been named manager, marketing, for General Electric's semiconductor products department. Webb, who has been with GE since 1960, was previously regional manager, Southeastern region, for the electronic component sales department. Webb replaces **John C. Garrett**, who was named president and managing director of ECCO Ltd., GE's semiconductor manufacturing subsidiary in Dundalk, Ireland.

reader's exchange

There is no charge for a listing in *Reader's Exchange*, but we reserve the right to edit all copy. Due to the limited amount of space for this department, ads must show no more than *five* items. If you can help with a request, write directly to the reader, not to **Electronic Servicing**.

For Sale: 100 octal tubes (mostly unboxed) with 1V, 7V, 14V, 35V and 50V heaters, $35 plus shipping, or trade for test equipment; Millivac model MV-27 micro-millivoltmeter (250µV to 1000V in 14 ranges), with manual, in good condition and calibration, $45; McMurdo-Silver model 900 Vomax VTVM, with manual but needs selector switch rewired, $25 or trade. *Howard Adams, 209 West Shadywood Drive, Midwest City, OK 73110.*

Needed: Magnavox volumes 5-12 service manuals. Will buy complete set or single volumes. *Gerwig's TV, Rt 1, Box 194, Round Hill, VA 22141.*

For Sale: Complete set of Rider's TV manuals with indexes; Rider's radio manuals 6 and 8-to-22 inclusive; Rider's PA manual 1. $15 each in sets, or $25 singly. *R. N. Douglas, 1020 Fitzallen Road, Glen Burnie, MD 21061.*

For Sale: Overstock of transistor, tubes and other TV and stereo parts and merchandise. *A. Tucker, P.O. Box 2636, Macon, GA 31203.*

For Sale: EICO 495 voltage calibrator, $10; Sprague TO-6 capacitor tester, $100: Hickok 470 VTVM with probes, $50; B&K-Precision 970 radio Analyst, $100; also, 5AXP4 and 8YP4 test tubes, $15 each. *L. E. Stokes, 2316 Fontaine Drive, Alton, IL 62002.*

For Sale: Leader model LS-5 electronic switch, never used, $65; Rider's volume 12 Perpetual Troubleshooter's manual, $15; Photofacts 330 to 800, $2.75 each. *Richard Sanderford, 6400 Andy Drive, Raleigh, NC 27610.*

For Sale: Precision E-200 RF generator, $15; Heathkit LG-1 RF generator, $15; Heathkit IO-30 5-inch scope, $30; Kirby 98 flyback tester, $10; Simpson 479 FM/TV signal generator, $30; Supreme 589A tube tester, $10. *Paul Ellis, 419 Bellevue, Santa Cruz, CA 95060.*

For Sale: Antenna lead wire and installation materials, tubes, speakers and many other components at below cost. Send for list. *H. C. L., 20 Etna Lane, Dix Hills, NY 11746.*

For Sale: Army BC-221-T frequency meter with ac supply, $20; Navy LM-14 frequency meter, $10; Hickok 203 VTVM, $15; B&K-Precision 350 CRT tester, $10; and Supreme servicing data, volumes TV-8 to TV-29, $30. *Paul Ellis, 419 Bellevue, Santa Cruz, CA 95060.*

Needed: Convergence assembly for Sylvania D12 or D13 chassis. State price and condition. *John DeLuco, 435 Ocean Boulevard, Cliffwood Beach, NJ 07735.* □

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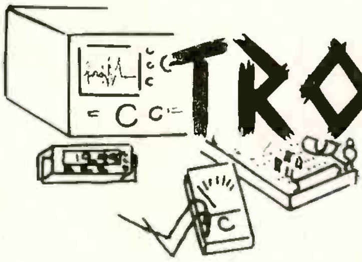

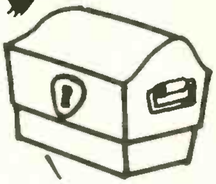

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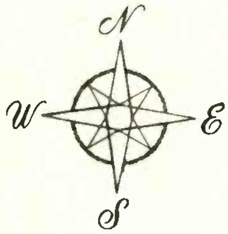

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Electronic controllers in industry

By Dale R. Patrick, Professor
Eastern Kentucky University

Automation in industrial systems is possible principally because of *electronic controllers.* Typical applications of controllers range from simple on/off operations to huge totally automated systems that respond to signals from a digital computer. Control might be applied to only one variable (such as temperature, pressure, fluid flow or electrical conductivity), or controls might correct hundreds of variables simultaneously in a large process.

Functions and circuitry of several representative electronic controllers will be analyzed in this article. These controllers have gone through several generations. When first introduced in the early 1940s, they were equipped with vacuum tubes and mounted in large metal cabinets. With the development of solid-state devices in the late 1950s, the outward appearance of controllers was significantly changed.

The transition to all-solid-state controllers, however, has been rather slow. Initially, most companies were reluctant to give up their popular-selling vacuum-tube controllers. There was then a period when controllers employed both vacuum tubes and solid-state devices. These "hybrid" controllers and many of the vacuum-tube devices are still in operation today. Some manufacturers still have vacuum-tube controllers available because the demand for them continues to be surprisingly good.

All major controller manufacturers today produce a wide variety of solid-state instruments. These units, in general, are small in size and usually employ hundreds of discrete components. Figure 1 shows a typical solid-state controller of this type. It has unusually precise control capabilities with exceptional stability.

The advent of solid-state controllers has brought about some innovative design features that have had a decided impact on controller maintenance. Components, for example, are mounted on removable printed-circuit cards or boards for easy replacement. Figure 2 shows an example of an indicating controller that has been partially removed from its metal housing. The printed-circuit modules of this controller can be easily removed by pulling the wire rings near the center of the controller. This controller has a great deal of versatility through this type of construction. Figure 3 shows a functional diagram of the potential location of alternate modules that can be utilized in this unit.

The next trend in controller technology found large numbers of discrete solid-state components replaced by integrated circuits. These controllers are somewhat smaller than their discrete component solid-state counterparts. Maintenance, in this case, is based on faulty IC determination and PC board replacement.

Microprocessors are now finding

Figure 1. A typical solid-state controller. Photograph courtesy Lees & Northrup Company.

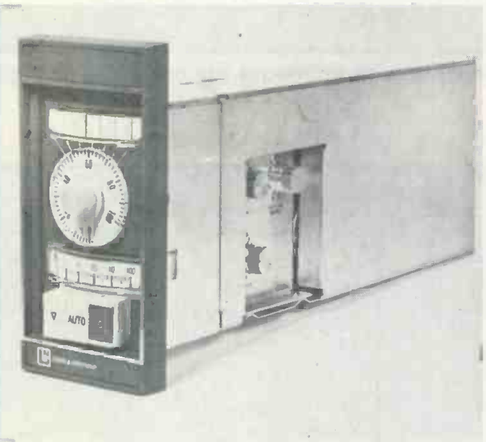
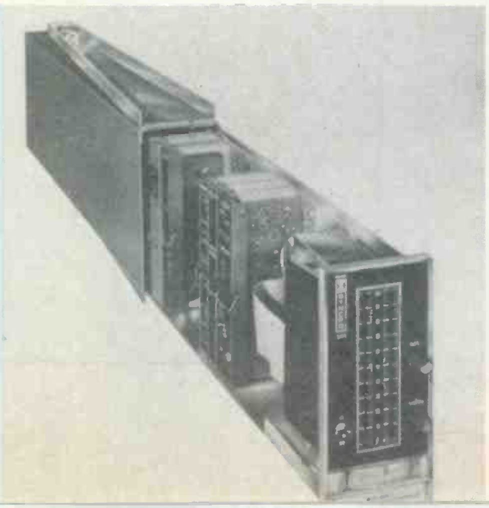


Figure 2. An indicating controller partially removed from its housing showing plug-in modules. Photograph courtesy Moore Products Company.



Material in this article has been adapted from Chapter 12 of Instrumentation Training Course, Volume 2, which is book number 21580 by Howard W. Sams [$11.95].

Circle (15) on Reply Card

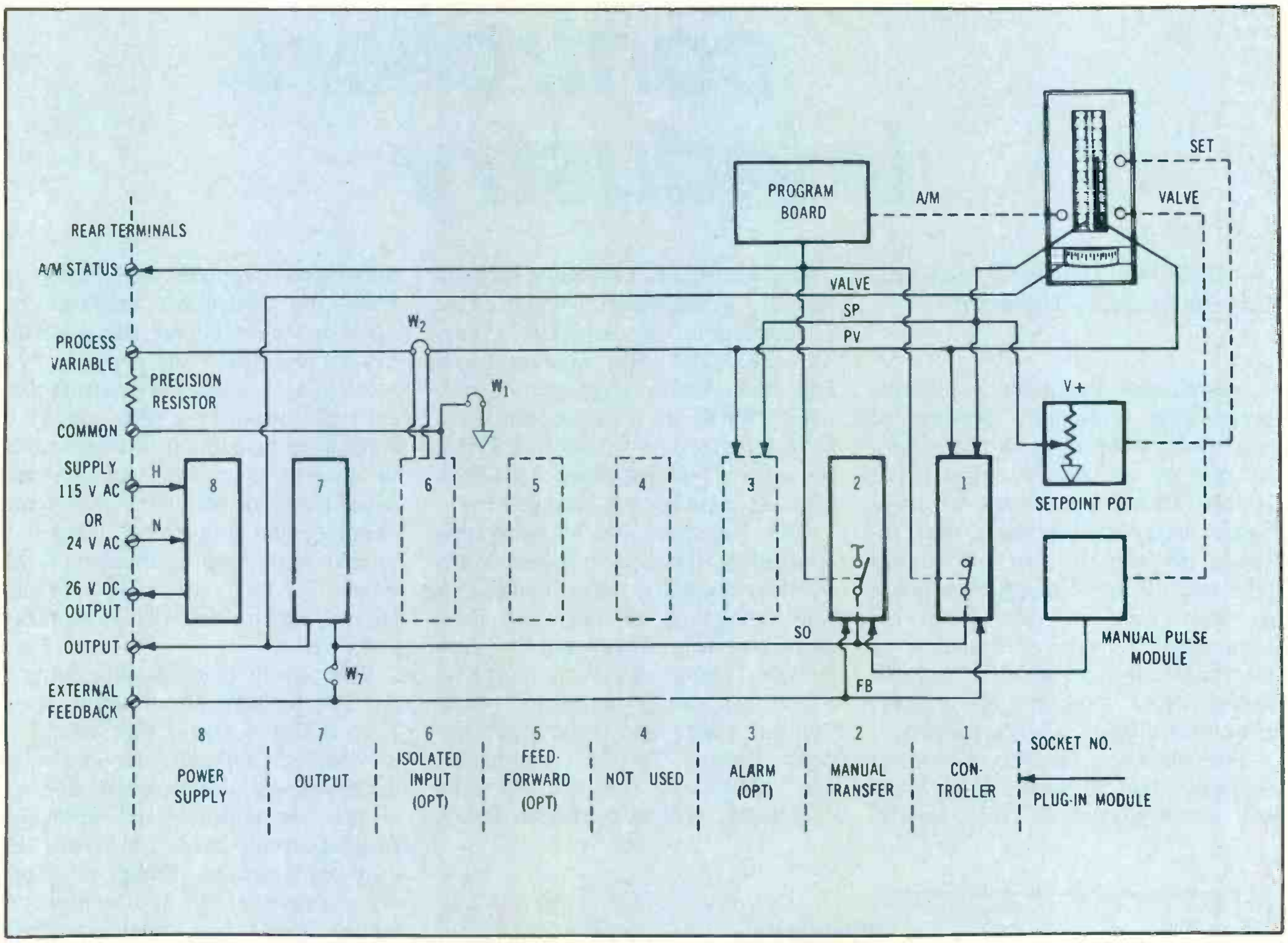


Figure 3. Functional diagram of alternate module locations for the controller of Figure 2.

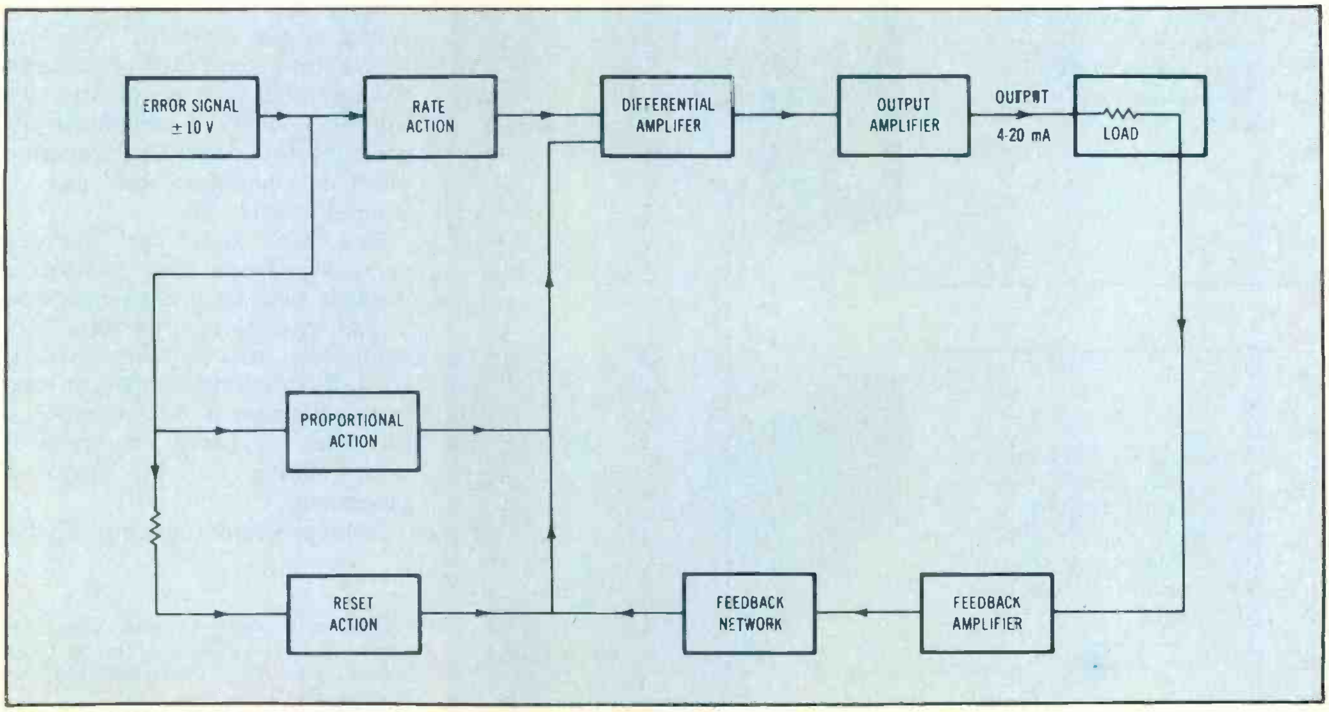


Figure 4. Block diagram of a typical controller.

their way into the process controller field. A microprocessor has a large number of discrete ICs on a single chip. In many situations the entire controller may be built on a single chip. This will obviously change the controller size again, and in many cases eliminate most maintenance problems.

With the wide range of diversity that exists today in controller technology, it is difficult to single out a particular controller that is representative of the field. In this regard, we will first discuss some common solid-state controller circuitry, then show some typical IC applications using op amps. Through this approach you will be able to pick out the information that is particularly applicable to your controller needs.

Controller functions

General information

Figure 4 is a block diagram of a typical controller. Three modes of operation are incorporated in this instrument: (1) proportional action, (2) reset action, and (3) rate action. They will be discussed in connection with the input circuits of the controller.

Sections will be devoted to the rate action, differential, output, and feedback amplifiers. The controller power supply will not be covered separately because it is so similar to power supplies previously discussed.

Controller input circuits

Figure 5 is a simplified schematic diagram of the controller input circuits. Each of the three previously mentioned modes of controller operation are described here.

1. **Proportional action.** This action determines the ratio between the controller output signal and the input signal. If the proportional-band control is set at 100%, the controller output will result in a change that is directly proportional to the error signal. For insensitive transmitters, the proportional-band control will be set for less than 100%. The error signal will, therefore, produce an output that is proportionally greater. This is called narrow-band control. A narrow range in error signal can produce a full range of controller outputs. For settings of the proportional-band control of greater than 100%, the error signal range will be greater than the controller output. This is called wide-band operation.
2. **Reset action.** This action is constantly driving the final control mechanisms to zero-out any error signal. Any time the controller position differs from the set point, reset action moves the controlling device in such a direction as to agree with the set point. The amount of action depends on the amount and the length of time of the deviation.
3. **Rate (derivative) action.** This action determines the rate of controller action. Its effect on controller output is twofold: If the controller output rate were dependent on proportional-band control only, it is possible for the error signal to become so great that the controller could not possibly zero itself. On the other hand, if the rate action were too fast, the controller would oscillate or hunt. The error signal input to the controller is differentiated so that its rate of change can be detected and the proper rate action provided.

Figure 5 shows that the error signal is applied to a voltage divider made of R_{25} and R_{26}. This signal is a dc voltage with a magnitude of 10V or less. The plug into the controller can be positioned in either the direct or reverse position. In the direct position, a positive input produces an increase in controller current. In the reverse position, a positive input produces a decrease in controller current. This input is fed directly to the rate-action amplifier, which will be discussed later. Its output is one of the inputs to the differential amplifier.

The first input to the differential amplifier is a signal that combines reset and proportional action. One-half of the error signal is developed across R_{20}. This voltage is fed to the reset control circuit. The reset control circuit is made up primarily of R_{28} and C_{12}, R_{27}, R_{39}, and a portion of R_{31} are also in the circuit. Since R_{28}, calibrated in repeats per minute, is so much larger than the others combined, it largely determines the time constant of the circuit. This time constant determines how often the proportional response is repeated. In other words, C_{12} charges to the change in the error-signal voltage; R_{28} determines the length of time it takes C_{12} to charge. The voltage across C_{12} is the second input to the differential amplifier. The amplifier is stabilized by a feedback voltage that is equal and opposite to the

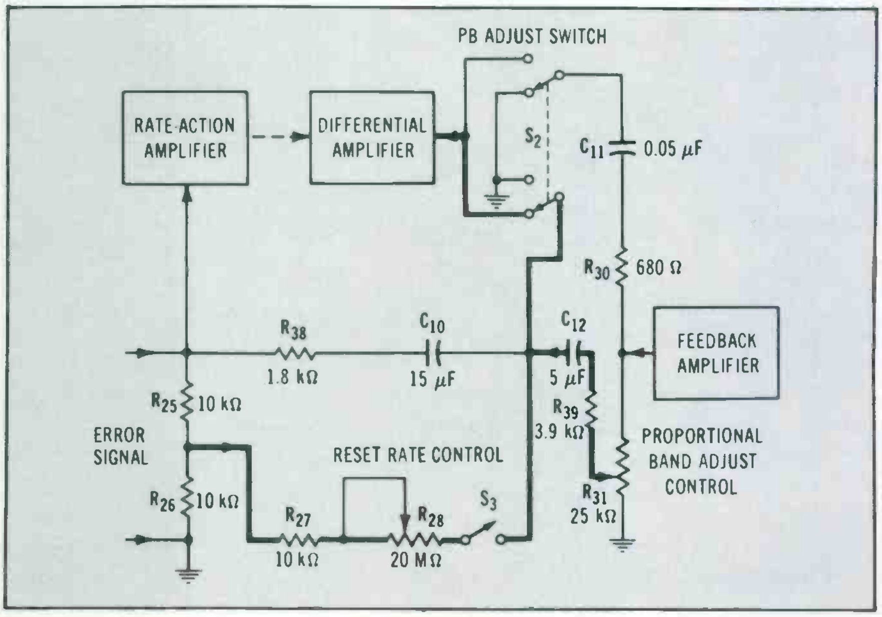


Figure 5. Simplified schematic diagram of controller input circuits.

input. How this signal is produced will be discussed in the section covering the feedback amplifier.

Proportional action is determined by the percentage of feedback-amplifier output that is applied to the differential-amplifier input. The percentage of feedback is determined by the setting of the proportional-band control, R_{31}. The voltage at the wiper arm of R_{31} determines proportional action as well as a reference voltage for C_{12}. The reset action voltage, the charge across C_{12}, adds to this voltage. The sum of these two voltages makes up the input to the differential amplifier. A few words need to be said about the proportional-band adjust switch, S. This switch is incorporated in the proportional-band adjust (R_{31}) procedure by being a push-and-turn type of adjustment. When the switch is pushed, the normal differential-amplifier input is grounded. The other pole of S_2 feeds an input into the amplifier that is the charge across C_{11}. During normal operation, C_{11} maintains a charge that is equal to the voltage across R_{31}. When S_2 is thrown, the ground is removed from one side of C_{11} and applied to the input of the amplifier. Since this voltage is the same as that maintained previously, no change in output is assumed until after the adjustment has been made. The result is a smooth transfer from one proportional band setting to another.

Solid-state controllers

Discrete component solid-state controllers have obviously not been around as long as their older vacuum-tube counterparts. Nearly all controllers sold in recent years are, however, predominantly solid-state. Figure 6 shows a representative schematic diagram of a discrete component solid-state controller.

As can be seen in Figure 6, the power supply provides two dc outputs. They are +36V and +46V, respectively. Each power supply uses silicon diodes to provide full-wave rectification.

Filtering of the power supply voltage is not quite as obvious in this circuit as is generally displayed in other schematics. The +36V source, for example, is filtered by a pi-section filter near the center of the diagram. (See printed-circuit points 32, 33 and 10.) The +46V supply, by comparison, employs an LCR filter composed of L_2, C_{12} and R_{31}. These components are located

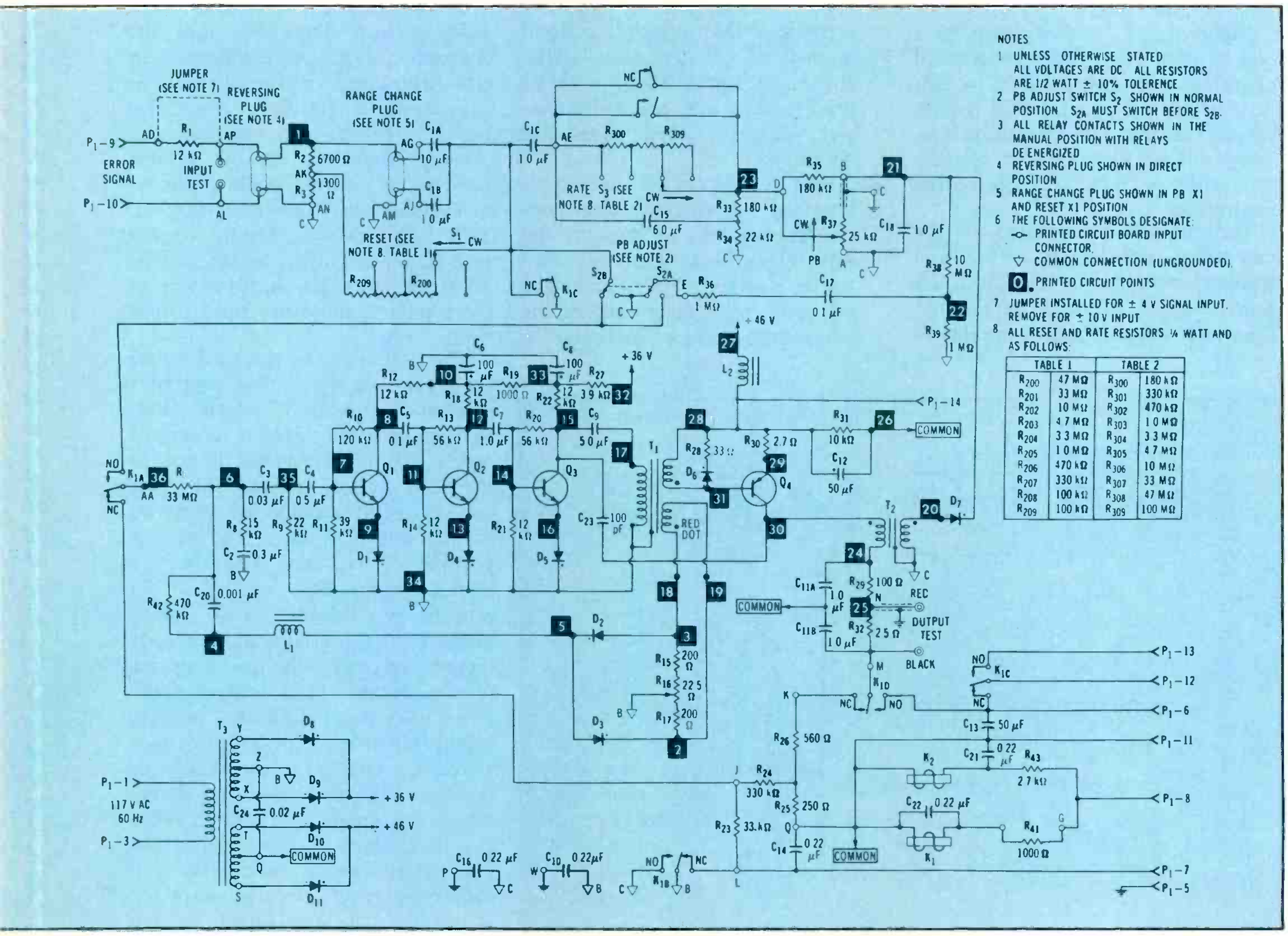


Figure 6. Schematic diagram of a typical discrete component solid-state controller.

between printed-circuit points 27 and 26.

In the discussion that follows, we will single out specific solid-state controller circuits for explanation. In some cases operational amplifiers will be used in circuits where this type of component finds acceptance today. Through this approach you will see how the IC simplifies the circuit and the explanation of its operation.

The controller input is the error voltage developed by the recorder. This input signal is negative or positive, depending on whether the process variable signal is above or below the set point. When the process variable signal is the same as the set point, the input to the controller is zero. The operational amplifier circuit shown in Figure 7 is the basis for amplifier action. It consists of an input network and a feedback network in which the current is equalized by an amplifier. If the input current is constant, C_{in} charges to that voltage. The feedback current, produced by this input voltage, charges the feedback capacitor, C_f. Once the two capacitors are equally charged, no current will conduct. The slight excess of input current necessary to sustain amplifier output is insignificant.

An input signal causes an input current to conduct, charging C_{in}. This amplifier input immediately produces an output, or feedback current. Feedback current charges C_f to a value that equals the charge on C_{in}. Since the reaction of the amplifier is practically instantaneous, the feedback current is constantly tracking or following the input signal. As these two equal currents vary, adding to and subtracting from the charge of the capacitors, these charges always remain the same. As a result of this action, the junction of the two capacitors (summing junction) is always essentially at a ground potential.

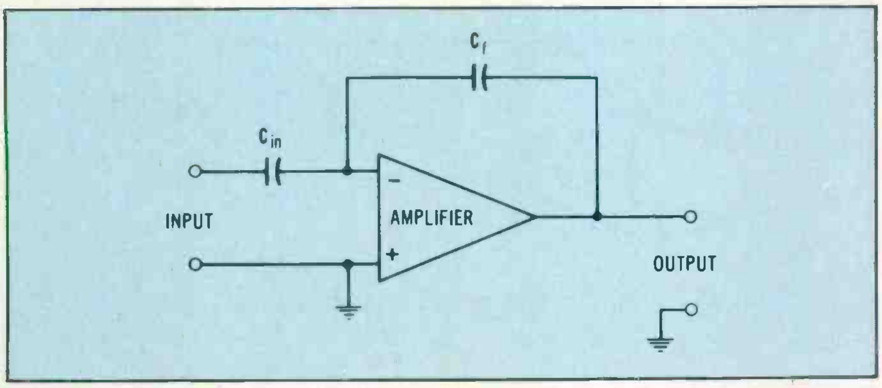


Figure 7. Operational-amplifier equivalent of transistorized controller.

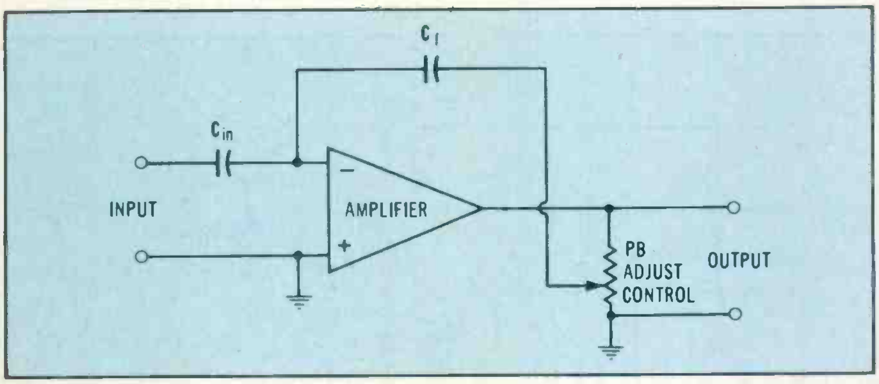


Figure 8. Proportional-band circuit.

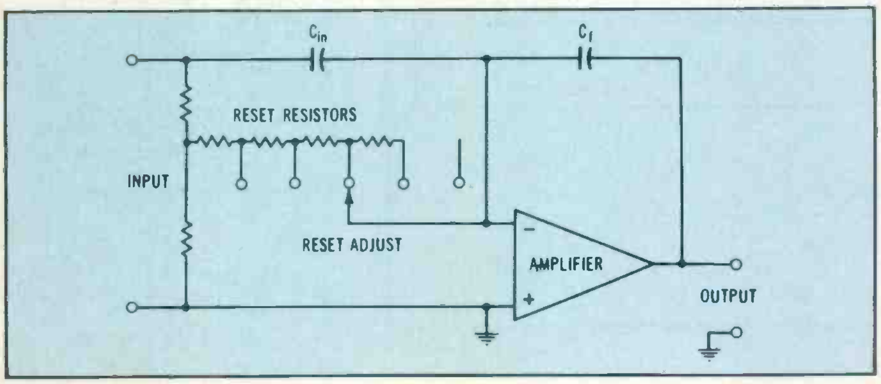


Figure 9. Reset circuit.

Proportional action

The effective ratio of the value of the input capacitance and the feedback capacitance determines the proportional band. The effective value depends not only on capacitor size, but on the voltage gain of the amplifier. If the effective ratio is 1:1, then the proportional band is 100%. Under these conditions, a full-scale input change produces a full-scale output change. A change in the ratio of the capacitances changes the proportional band. A range of proportional bands can be provided by 1—100% or 10—1000% by changing the ratio. In addition to a variation in range of the proportional band, a change within the range is provided by a potentiometer. The potentiometer is the proportional-band adjust control shown in Figure 8. By adjusting this control, the amount of the output that is used in the feedback circuit can be varied. With a decreasing feedback signal, a larger output must be produced to fully charge C_f. An increased output for a given input is merely a narrowing of the proportional band. A full range of output signals can, therefore, be produced by small input signals. The range of input in percent that produces a full range of output signals is the proportional band.

Reset action

A voltage divider is placed across the controller input and a variable resistor is placed in parallel with C_{in} for reset action (Figure 9). The voltage divider and variable resistor provide a path for current whenever an error signal exists. This current provides a continuous amplifier input whenever the process variable signal differs from the set point. Feedback current, therefore, continues to charge, or discharge, the feedback capacitor as long as there is an input. The amplifier then produces a continuous change in output as long as an input signal exists. This, by definition, is reset action, since the controlled device is seeking the null position. In discussing the proportional circuit, it was evident that there was current only when there was a change in the input signal. In the reset circuit, the only time that input current stops is when the error voltage is zero. By decreasing the value of the reset resistors, input current is increased for a given input signal. The output current must increase at a faster rate in order to produce a matching charge across the feedback capacitor. The result is a faster reset rate. Increasing the size of the reset resistors results in a slower reset rate. To produce a very low reset rate, the voltage divider has been incorporated in the input circuits. The voltage divider causes the reset resistors and the amplifier to see a smaller portion of the input signal, resulting in a smaller charging current. The input capacitor, however, still sees the full input voltage. The value of the reset resistor determines the number of times that proportional action is repeated per minute.

Rate action

Rate (derivative) action is accomplished by the addition of a voltage divider, a variable resistor, and a capacitor in the feedback circuit (Figure 10).

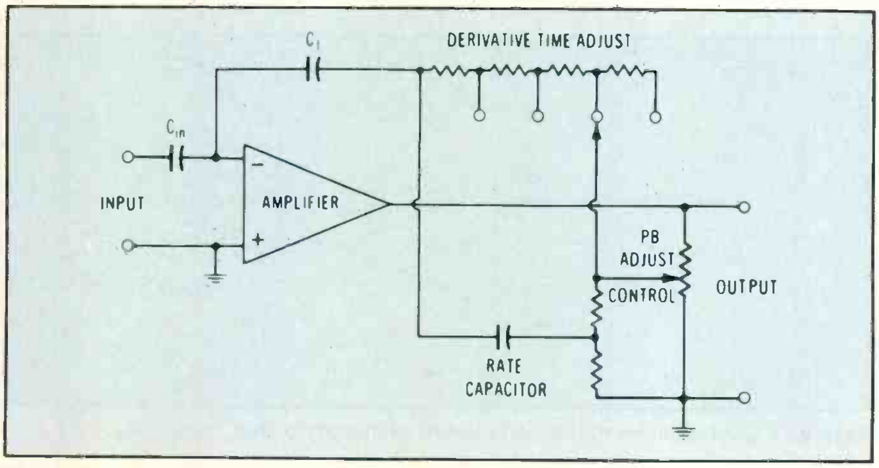


Figure 10. Derivative (rate) circuit.

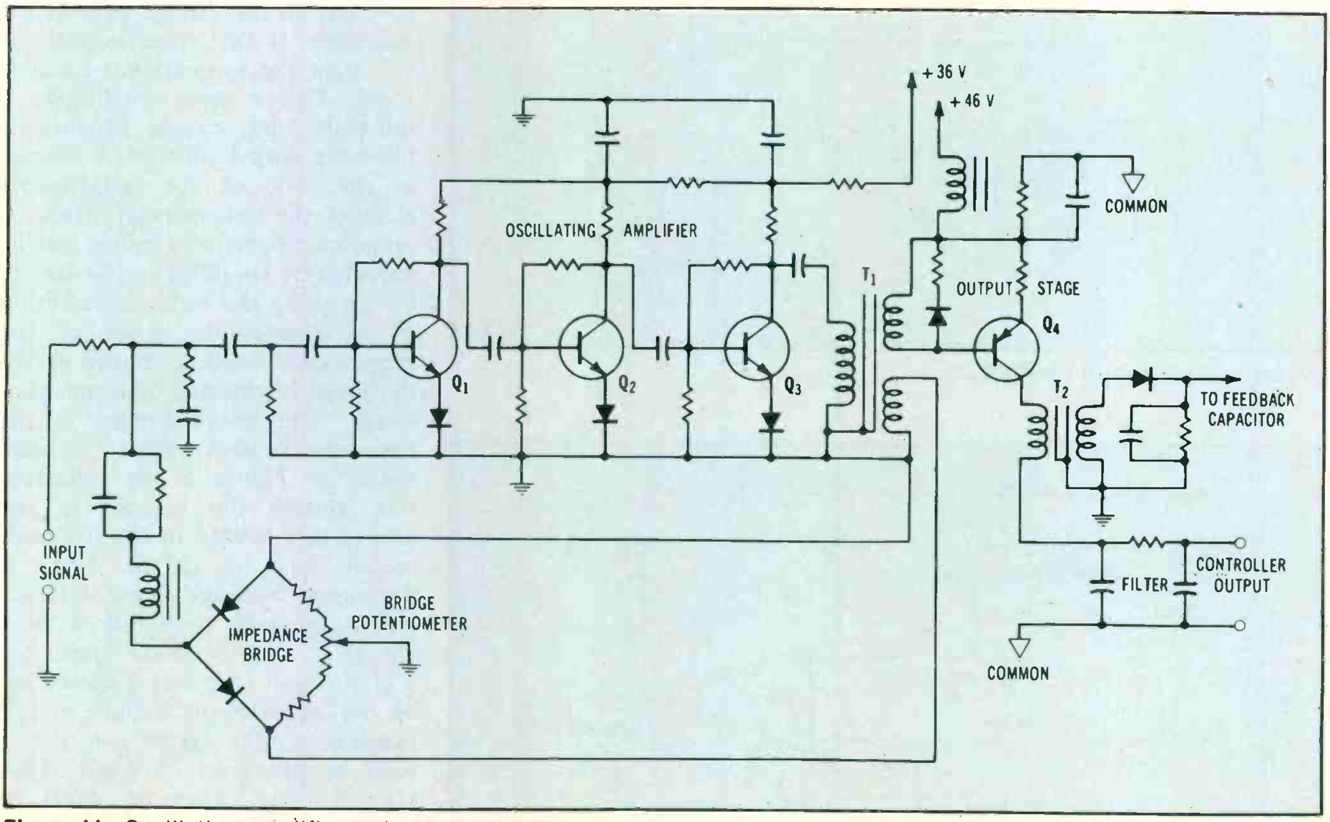


Figure 11. Oscillating amplifier and output circuit.

An input signal change produces an output change that is easily passed by the rate capacitor. Since this change is taken from across the voltage divider, the result is that the feedback capacitor sees only a portion of the output. The effect is the same as a decrease in the proportional-band control. That is, the instantaneous effect is a narrowing of the proportional band. This results in a greater output change for a given input until the rate capacitor charges. The time it takes the rate capacitor to charge depends on its time constant. This can be changed by the variable resistor, the rate time adjustment. As soon as the rate capacitor charges, the effect of the voltage divider disappears. The proportional band is then restored to its original value. Rate amplitude will be determined by the voltage divider. This, of course, determines the amount of the instantaneous change in signal fed through the rate capacitor.

Rate action has an anticipatory function that acts only when the output is changing. It then provides a braking or damping action. In general, rate action is used to reduce cycling and overshoot and to permit the use of narrower proportional bands.

Amplifier

The amplifier used in the transistorized controller can be divided into three basic sections: the impedance bridge and internal feedback loop, the three-stage oscillating amplifier, and the output stage. The schematic for the amplifier is shown in Figure 11.

A Wheatstone or impedance bridge forms an important part of the feedback loop that makes oscillation within the amplifier possible. This bridge is made up of two fixed resistors, a potentiometer, and two diodes. Two legs of the bridge are resistive, while the two remaining legs are formed by the diodes. The diodes provide rectifying action and also function as variable resistances. The amplifier output is applied across the bridge. A portion of this voltage developed across the bridge is fed to the amplifier input. The amount of feedback is determined by the position of the bridge potentiometer. The polarity of output coupled to the feedback loop is determined by the feedback winding of the output transformer. The polarity is such as to provide positive feedback (regeneration) at the operating frequency. The amount of feedback is determined by the bridge as mentioned previously. The frequency of oscillation, about 20kHz, is determined by the coil and capacitors located in the amplifier input circuit.

The input signal comes from the recorder. This voltage is fed to the base of Q_1 along with the feedback signal. If this error signal has the same polarity as the feedback signal, the output of the three-stage amplifier will increase. On the other hand, if the polarity is reversed, the output voltage across transformer T_1 will decrease. The amplitude of the signal across the primary of T_1 depends on the error signal. The three-stage amplifier is composed of three npn transistors connected as common-emitter amplifiers. The three stages are RC-coupled, and a voltage divider determines the forward bias of each.

The base signal is taken from a secondary winding of T_2, which is associated with Q_4, a pnp transistor that is the output amplifier. Transistor collector current passes through the load for controller output. Since this current is a changing or pulsating dc, it must be filtered to give a dc current range of 4 to 20mA. Collector current also passes through the primary of transformer T_2. The secondary voltage, rectified and filtered, charges the feedback capacitor as discussed in the preliminary paragraphs of this section.

Vacuum-tube controllers

Using the previous controller block diagram (Figure 4) as a general reference, vacuum tubes can be used to achieve the same basic modes of controller operation as those of the transistor circuits. In general, these circuits are considered obsolete today. A large number of vacuum-tube controllers are, however, still being used in many applications.

Rate-action amplifier

Figure 12 is a simplified schematic of a vacuum-tube rate-action amplifier. This is a two-stage dc amplifier. The first stage is a normal voltage amplifier and the second stage is a cathode follower. A dc plate voltage for both stages is provided by 100V ac, which is

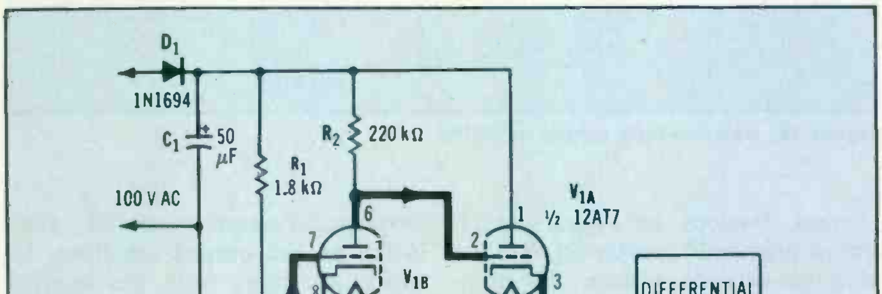


Figure 12. Vacuum-tube rate-action amplifier.

rectified by D_1 and filtered by C_1. A negative voltage is developed across R_3 by rectifier action and is maintained at the cathode of V_{1B} by the action of C_3 and D_2. This develops the proper plate voltage so that direct coupling can be used with the proper bias on V_{1A}. V_{1B} amplifies and inverts the input error signal. The error signal input is integrated by the aciton of R_{24} and C_2. By integration, we mean that the rate of change in error signal voltage is averaged out by the rate of charge (time constant) of the input circuit. If the position of C_2 and R_{24} were reversed, the input signal would be differentiated. In both cases, the amount of integration, or differentiation, is dependent on the size of the resistor or capacitor involved.

This changing signal is fed to the grid of V_{1A}. Static tube current maintains a constant positive voltage at the cathode of V_{1A}. C_4 assumes a charge equal to the voltage drop across R_4 (the cathode voltage). During static operation (no signal input) there is no current through R_5. The input to the differential amplifier is then zero volts during this period of time. When a change of voltage occurs at the grid of this cathode follower, the cathode voltage changes. Since the charge across C_4 does not change immediately (notice the long time constant of C_4 and R_5), the change appears across R_5. Notice that only the change, or rate of variation in voltage, appears as an output of the rate amplifier. R_5 and C_4 make up a differentiating circuit.

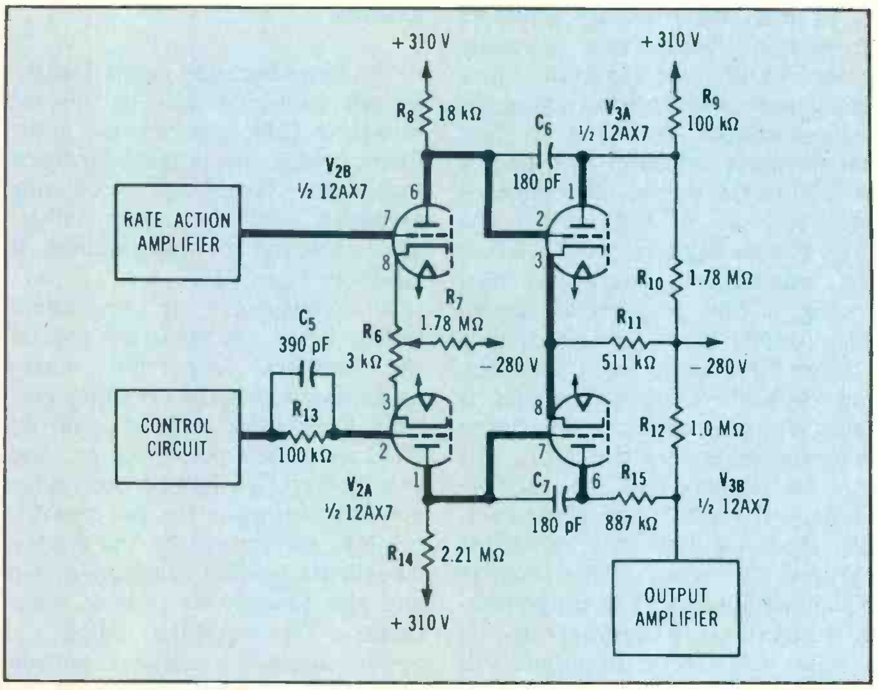


Figure 13. Vacuum-tube differential amplifier.

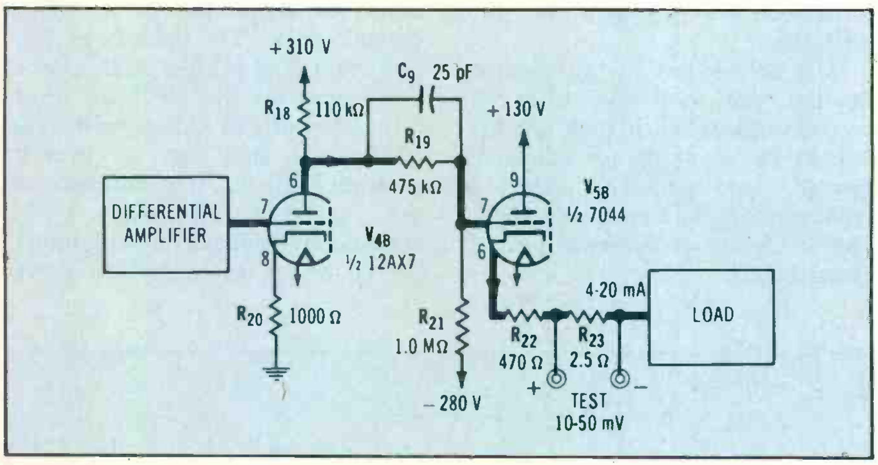


Figure 14. Vacuum-tube output amplifier.

Differential amplifier

Figure 13 is a simplified schematic diagram of a vacuum-tube differential amplifier circuit. Two stages of amplification are provided for the rate-action signal. Two stages also amplify the combined proportional-band and reset-action signal. These two outputs are mixed by common cathode coupling; a single output is developed that is the difference of these two input signals.

The output of the rate-action amplifier is directly coupled to the grid of V_{2B}. Any change in tube current develops an output signal across plate-load resistor R_8. R_7 is a common-cathode resistor for both V_{2A} and V_{2B}. A change in tube current of V_{2B} changes the cathode voltage of V_{2A}. A cathode variation provides a signal input equal in amplitude, but opposite in polarity to a grid signal. A plate-voltage change of V_{2A} results in a rate-action input. R_6 is a balance control that eliminates the need for perfectly balanced tubes. The output is V_{2B} is directly coupled to the grid of V_{3A}. The unbypassed cathode again feeds a signal to the common cathode of V_{3B}. This cathode signal develops an output across R_{15} that is fed to the output amplifier, to which an input from the control circuit is fed directly through two stages of amplification. When two inputs occur simultaneously, the output of V_3 is a combination of the two inputs and is proportional to the difference in the two.

Output amplifier

The vacuum-tube output amplifier (Figure 14) consists of two stages of amplification involving tube V_{4B}, a voltage amplifier, and tube V_{5B}, a cathode follower. The input signal from the differential amplifier is

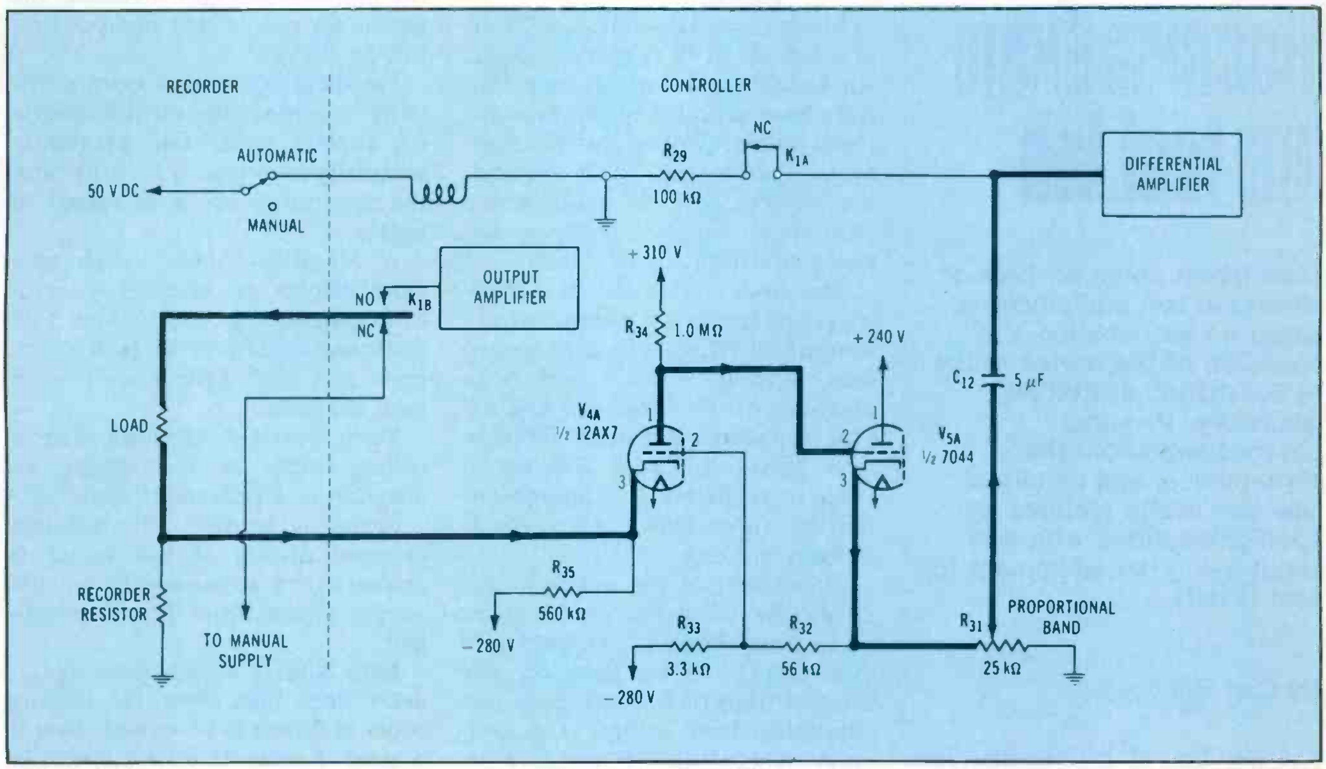


Figure 15. Vacuum-tube feedback amplifier.

fed to the grid of V_{4B}, which amplifies and inverts it. The output of V_{4B} is dc-coupled to the grid of the cathode-follower stage. Capacitor C_9, by shunting R_{19}, helps prevent parasitic oscillation.

The cathode-foller stage takes the high-impedance voltage input from V_{4B} and changes it into a high-current, low-impedance output. The current output lies within the range of 4 to 20mA dc. A 2.5 resistor (R_{23}) is inserted in series with the current output to provide a convenient test point to measure the output current in equivalent millivolts.

Feedback amplifier

Figure 15 is a simplified schematic diagram of a vacuum-tube feedback amplifier. The output-amplifier current passes through the load (0.1150 Ω) and a recorder resistor. This recorder resistor ensures a constant current output from the controller, regardless of load impedance. It also develops the input voltage for the feedback amplifier. The feedback amplifier involves two stages of amplification. The first stage (V_{4A}) is a normal voltage amplifier that is dc-coupled to the second stage, cathode follower V_{5A}. The voltage developed across the recorder resistor is fed to the cathode of V_{4A}. A cathode input affects tube current in exactly the same manner as if fed to the grid with an opposite polarity. A change in cathode voltage produces a plate voltage change in phase with the input signal. The plate-load resistor, R_{34}, is connected to the +310V plate supply, while the cathode resistor is connected to the -280V is maintained at about 0V so that dc coupling can be used.

The output of V_{4A} is fed to the grid of V_{5A}. Any change of grid voltage produces an in-phase change in cathode voltage. Tube current develops this voltage across R_{31} (the proportional-band control) and the parallel voltage divider, R_{32} and R_{33}. The portion of the output voltage developed across R_{33} is fed back to the grid of V_{4A}. This voltage is out of phase with the input to V_{4A} and is, therefore, a negative feedback. The amount of negative feedback determines the gain of the feedback amplifier and stabilizes the dc amplifier. The amount of feedback at the input of the differential amplifier is determined by the setting of the proportional-band control. The less the feedback voltage, the greater the sensitivity of the entire system. This, of course, is the purpose of the proportional-band action.

As described previously, when the recorder is in the manual position, the load current is determined by the set position of the manual control. The controlled output is open-circuited. Manual load current is still detected by the voltage drop across the recorder resistor. This voltage is still fed to the input of the feedback amplifier. Feedback amplifier output maintains a charge across C_{12}. C_{12}, therefore, remembers the load current (the charge of C_{12} is proportional to load current) so that smooth, continuous operation can be maintained when switching to automatic operation.

Summary

Present-day electronic controllers usually employ discrete transistors and integrated circuits, while older models have vacuum tubes.

The three major modes of operation are proportional action, reset action and rate action. □

Reports from the test lab

Each report about an item of electronic test equipment is based on examination and operation of the device in the **ELECTRONIC SERVICING** laboratory. Personal observations about the performance, and details of new and useful features are spotlighted along with tips about using the equipment for best results.

By Carl Babcoke

A new line of four oscilloscopes has been released by Hitachi Denshi America. These models are virtually identical. Therefore, the top-of-the-line model V-302 is described here as typical of all four, except for the stated exceptions.

General features

Wide bandwidth, high sensitivity and several advanced features qualify these versatile scopes for adjustments and analysis of radios, audio systems, TVs, videocassette recorders, industrial systems, computers and other products.

One unusual feature is the choice of two bandwidths. When the 5MHz bandwidth is selected, the maximum vertical gain is 1mV.

Horizontal sweep

Sweep times extend from 0.2S/div to 0.2uS/div in 19 calibrated ranges. An uncalibrated variable-time control allows selection of slower-in-between values. Pulling out the horizontal positioning knob expands the sweep width to 10 times normal (X10 mag), which provides a fast sweep equivalent to 100nS/div.

The *mode* switch selects normal triggering (no sweep unless locked), automatic triggering (has sweep even without signal) and both polarities of TV sync. An internal sync separator provides TV-type sync pulses for solid locking of video waveforms (an important feature since video otherwise is difficult to lock).

Adjustment of the *source* switch allows the triggering signal to be taken from channel 1, channel 2 (if dual-tract), 60Hz line or the external-triggering input jack. An adjustable level control also provides triggering on positive or negative slopes.

Vertical channels

Vertical frequency response of model V-302 is rated within -3dB from dc to 30MHz. Sensitivity between 5mV/div and 5V/div is available in 10 fixed steps. Also, continuous height variation is possible by an uncalibrated control. The 0.005V (5mV/div) maximum sensitivity is higher than that of older models, and it can be increased at the expense of reduced bandwidth. With an X10 probe and the graticule of eight divisions, the maximum measurable input is limited to 400VPP.

For those times when extra sensitivity is needed, the vertical centering knob is pulled out. Maximum sensitivity increases to 1mV/div and the upper response is decreased to 5MHz.

A 5-position *mode* switch provides display of: channel 1 waveform; channel 2; both channels in dual-trace; addition of both channels; and the difference between both channels.

Each vertical channel has a sliding switch for ac coupling, dc coupling or a grounded input.

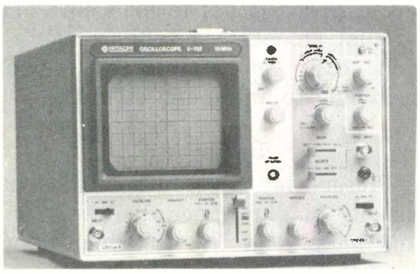
Switching between alternate and chopped display of two traces is accomplished automatically by the setting of the *time/div* sweep control.

Both 30MHz models have signal-delay lines that allow the leading edges of pulses to be viewed. This is a good feature that is imperative for digital waveforms.

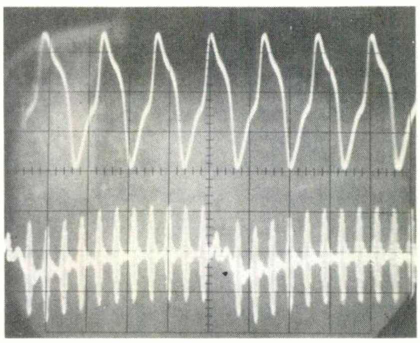
CRT and calibration

Each 5-inch CRT has blue traces, black lines for graticule calibration and no provision for illumination. Ordinary room light is usually adequate for taking readings from the screen.

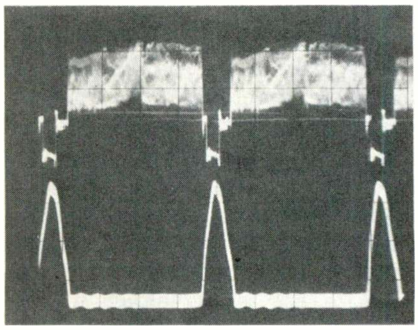
In addition to the customary *trace intensity* and *focus* controls, a screwdriver-adjustable *trace rotation* control is provided. This control can tilt the horizontal traces as needed. If a local magnetic field moves the traces so they no longer are parallel with the graticule lines, a simple adjustment will level the traces.



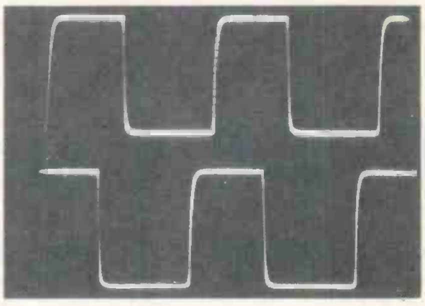
All four models of the new Hitachi line of scopes have similar appearance and features. This is the 15MHz model V-152.



Top trace shows a 3.58MHz color carrier at 0.2μS sweep on the Hitachi model V-302 30MHz scope. Bottom trace has two horizontal lines of color-bar chroma waveforms viewed at 10μS sweep.



Excellent detail without ringing or overshoot is shown by this dual-trace view of composite video and horizontal-sweep pulses.



These waveforms show the effect of signal delay lines in Hitachi scope models V-302 and V301. Top waveform shows a 200kHz series of square waves with the initial leading edge displayed. When the signal-delay line was bypassed by locking from the same signal applied to the external-trigger input jack, the leading edge and part of the first peak are missing.

Probes

Probes supplies with these Hitachi scopes provide only an X10 function that reduces the input amplitude by a factor of 10 while it provides low-capacitance operation. Elimination of the direct (or X1) function is not a disadvantage because it is offset by the high vertical sensitivity. And without the X1 function, the probes are smaller and less prone to problems. The cable has a small diameter and is very flexible.

For frequency compensation, the hook probe is attached to the calibration waveform terminal at the panel upper-right corner, then a trimmer (inside the cable's BNC plug) is adjusted for flat-top square waves.

Comments

Model V-151 is the single-trace 15MHz version. Model V-152 is similar except for the dual-trace feature. Both have about 2kV acceleration voltage.

Model V-301 is identical to the V-302 just described except it has one vertical channel for single-trace operation. Both are rated at 30MHz vertical response, have about 4kV acceleration voltage and feature a vertical-signal-delay line.

Each year the need increases for better scopes and other items of test equipment. Therefore, it is recommended for the purchase of any scope that the model selected have more features and better specifications than those required at the present time. This will prevent early obsolescence.

The sample model V-302 performed very well in the Test Lab where it produced sharp stable waveforms of color-TV signals. It is recommended for troubleshooting of home-entertainment, industrial, radio-communication and digital equipment. □

Circle (16) on Reply Card

RCAs unique scan rectification

CTC99 & CTC101

In an unusual upside-down circuit, two diodes are the Siamese-twin connection between the +23V and +10.5V power supplies. Regulation of the +123V supply is accomplished by switching-on an SCR for an adjustable period of time. These sweep-rectification and regulation circuits are more difficult to understand than most, so they should be studied carefully.

By Gill Grieshaber, CET

Although dc power supplies are essential, most are boring in their simplicity. That's not true of those in the RCA CTC99 chassis. Never before has one type of chassis had so many unusual circuit variations.

As stated last month, dc voltage from bridge rectification of line voltage is filtered and supplied only to the horizontal-output transistor and the regulator circuit. This is the **hot** power supply that is isolated from chassis ground for safety. A special dc supply (that operates only for a split second after the TV is turned on) starts the horizontal oscillator and driver stages. After start-up applies drive to the horizontal-output transistor, rectification of horizontal sweep from several flyback pulses provides all other dc power (including that for oscillator and driver after start-up). Isolation for these other voltage sources is furnished by the flyback and the start-up transformer.

An interesting mixture of unorthodox and conventional engineering is found in the power supplies that are described here.

210V supply

Most uncomplicated of all dc supplies is the 210V source shown in Figure 1. Positive-going 250VPP pulses (without any dc component) are rectified by CR403. Hash remaining after filtering by peak-reading capacitor C409 was only 1.5VPP, and the measured dc was +208V (which supplies the color output transistors). CR403 is the smallest diode of the three in Figure 2. (The others are CR401

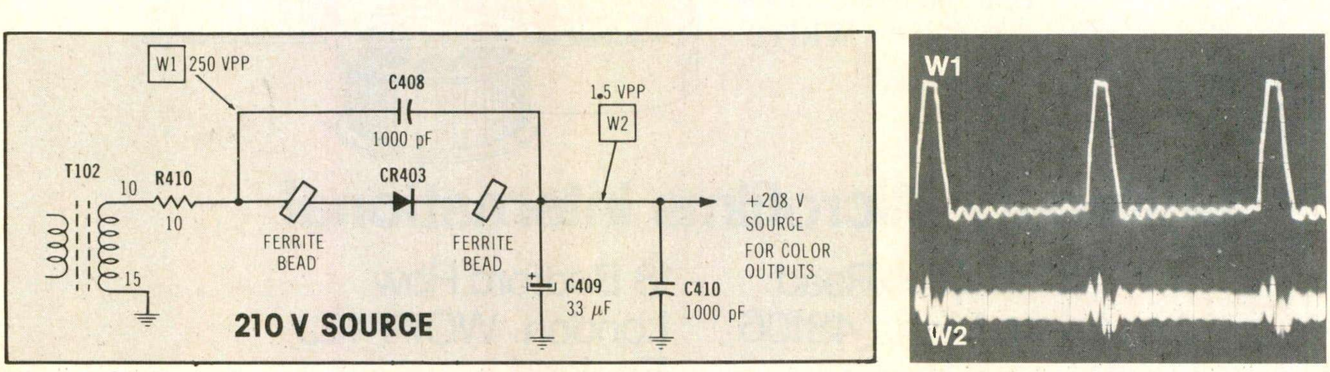


Figure 1 CR403 rectifies the positive-going horizontal-sweep pulses to produce a measured +208V for the color-output transistors. T102 is the flyback (HV transformer).

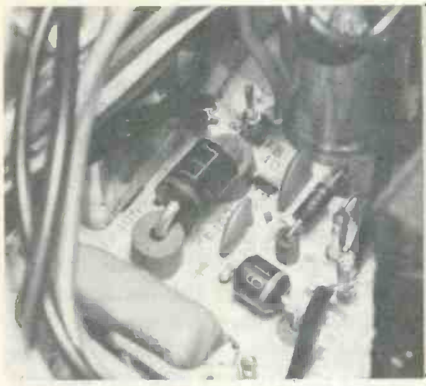


Figure 2 Three diodes of different sizes are almost hidden in the wires between the pincushion-transistor heat sink and the flyback (at right). The smallest diode is CR403 which rectifies the +210V supply. Below it is the medium-sized CR401, and the large CR402 is shown at the left.

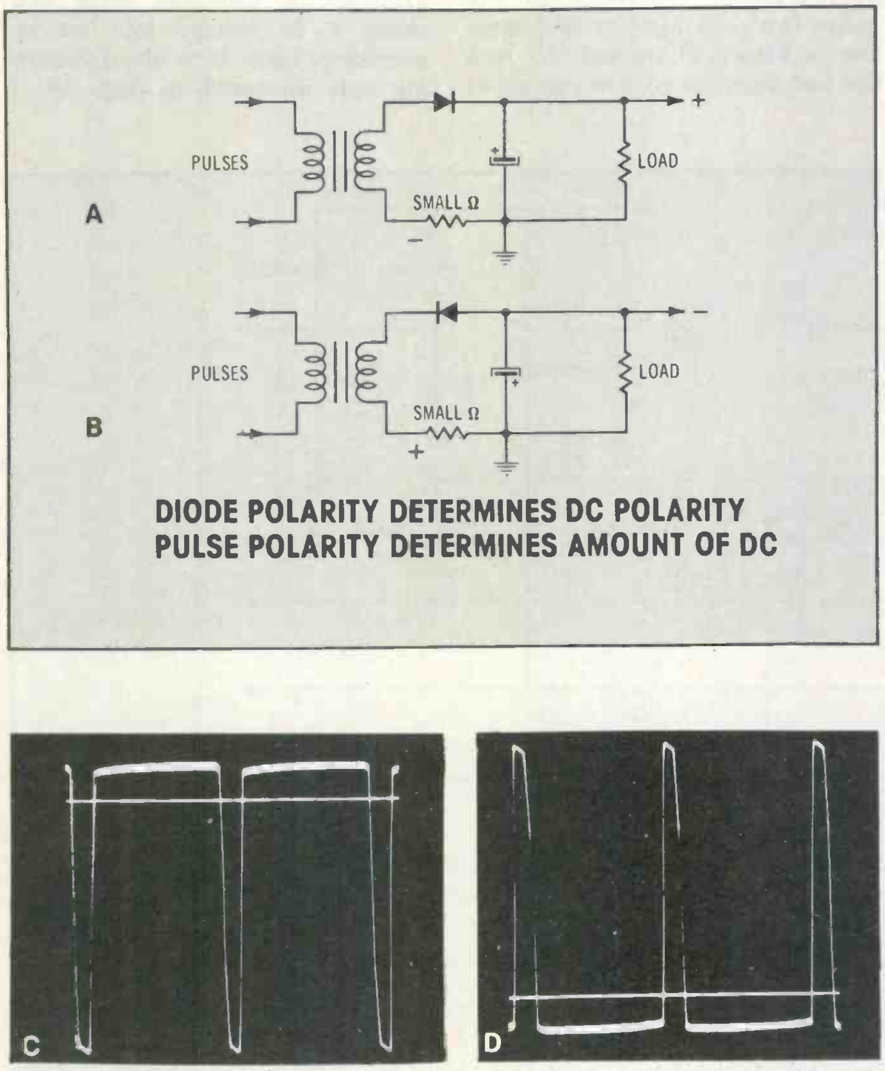


Figure 3 The amount of dc voltage obtained from series rectification depends on the voltage between the zero-voltage line and the tip of whichever peak is forward bias for the diode. Therefore, inverting the pulse polarity changes the dc voltage reading, since the zero line always is nearer the baseline of waveforms without dc. For example, the pulses of C applied to schematic A allow only a *low positive* voltage. If the C pulses are supplied to the B schematic, about six times as much *negative* voltage is produced. Also, the D pulses with the A schematic generates a high positive voltage, but the D pulses with the B schematic produces a low negative voltage (which is equal to the low positive voltage from C pulses and A schematic). As the caption says: The diode polarity alone determines the rectified dc polarity, but the pulse polarity determines the amount of rectified dc voltage.

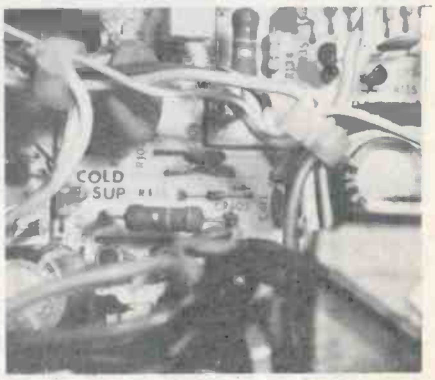
and CR402 that are discussed later.) These diodes are located to the left of the flyback.

The next "simple" voltage supply gave the first surprise.

60V supply

Both the -10V and the +60V sources appeared to be somewhat conventional. It certainly is *possible* to obtain a high B+ and a lower B- (or vice versa) by rectification of a pulse waveform's two peaks (see Figure 3). And it is unusual but not impossible for both polarities to come from two series rectifier circuits fed through a common coupling capacitor, as is true with CR405 and CR404 in Figure 4. A single series rectifier circuit fed through a coupling capacitor is not efficient because the capacitor side of the diode develops a reverse voltage that subtracts from the desired dc voltage at the other end of the diode. (This is compatible with a "law" proposed by **ES** editor Carl Babcoke which states: *A dc voltage produced by rectification will be positive at the cathode end of the diode or negative when at the cathode end.* So, a single diode can develop opposite polarities of dc voltage at cathode and anode in certain cases.)

When both positive and negative peaks of a sine wave are rectified by two circuits that have about the same load, and differ only in polarity, the undesired dc voltages at the coupling capacitor cancel each other. Those specific conditions allow two series rectifiers to be operated efficiently through a



Diode CR405 of the 60V supply and the -10V supply CR404 diode are located near the flyback and the 123V regulator circuit.

common coupling capacitor.

Therefore, your writer at first deceived himself by believing that CR405 (+60V supply) and CR404 (-10V supply) were operated within the limits given in the last paragraph. That delusion was dispelled when it was noticed *the pulse waveform was negative-going;* therefore, the positive dc voltage **should** have been smaller than the negative dc voltage (the positive peak has less amplitude than the negative peak). Perhaps the wrong point had been scoped, and the pulses actually were positive-going.

A quick recheck proved the 74VPP pulses were negative-going, as shown in the Figure 4 waveforms. Until a digital multimeter was used to check the dc voltages, it seemed the paradox had no logical explanation. The DMM measured +55.9Vdc at the anode of CR405 and the cathode of CR404. *This dc was aiding the pulses for the positive supply and subtracting from the negative supply.* But that did not explain where the positive voltage originated.

Additional dc tests answered some questions, but others appeared. A dc waveform of the pulses (with average-line and zero-line in Figure 5) showed the zero line had been moved down to about 10V above the negative tips. If the waveform had no dc, the zero line would have provided 8VPP or positive rectification and 66VPP for negative rectification. But with the zero line moved down because of the positive voltage present, the positive peak had 64VPP and the negative peak 10VPP. This corresponds closely with the measured dc voltages from rectification.

Unfortunately, the source of the positive voltage still was not known.

Two partial explanations are available. A clamping diode can insert a dc voltage into an ac waveform. Some facts about clamping were discussed on page 26 of

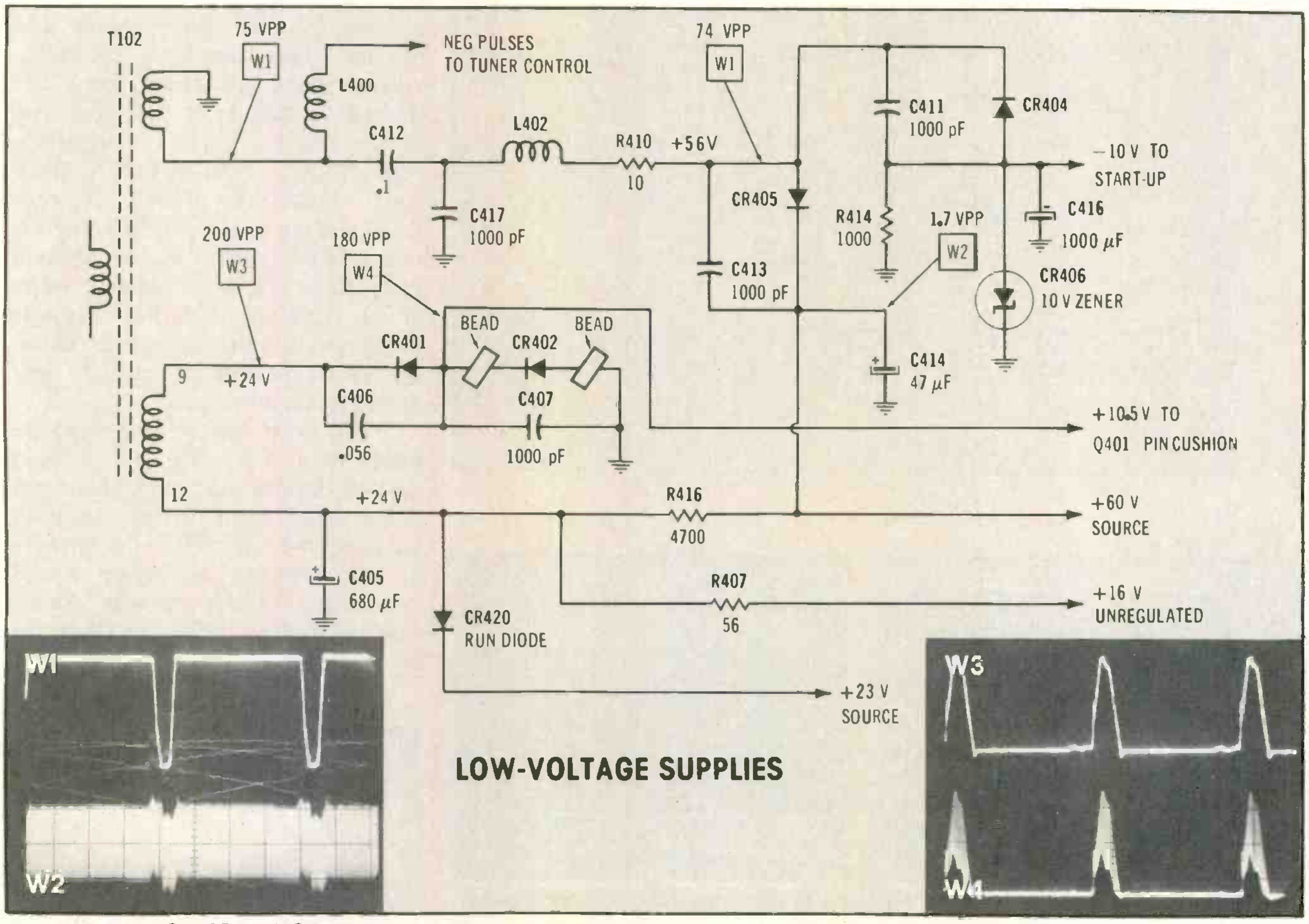


Figure 4 Both CR405 and CR404 receive input from C412. In the other Siamese-twin supply, CR405 rectifies the +23V source and CR402 rectifies +10.5V for the pincushion transistor. C406 eliminates vertical-rate variations of the flyback pulses.

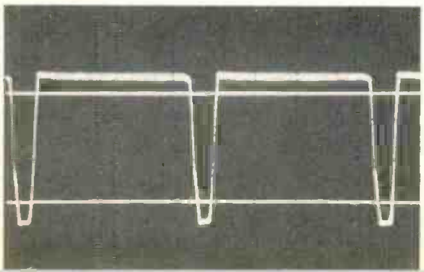


Figure 5 Clamping of CR404's anode voltage forces the remainder of the rectification dc to appear at the cathode (input) of CR404. This +55V remainder is added to the input waveform, moving the original zero line (near top of waveform) down near the pulse tips (bottom line). This has the effect of increasing the voltage of the positive peak. So, the CR405 output is +63V rather than the usual +8V.

Electronic Servicing, June 1979. Also, one type of voltage doubler operates by adding the dc from shunt rectification to the ac input of a series rectifier (Figure 6A). As shown in the simplified schematic in Figure 6B, the CR404 rectification of the pulse negative peaks **must** produce 66V. But, the -10V supply has heavy current plus a zener diode for regulation. Therefore, the -10V supply is dominant, and the remaining +55V must appear at the CR404 cathode where they add to the 10VPP waveform to produce +63V at the cathode output of CR405. (Voltage drops across the diodes and small errors between scope and voltmeter readings account for the minor discrepancies in the figures.)

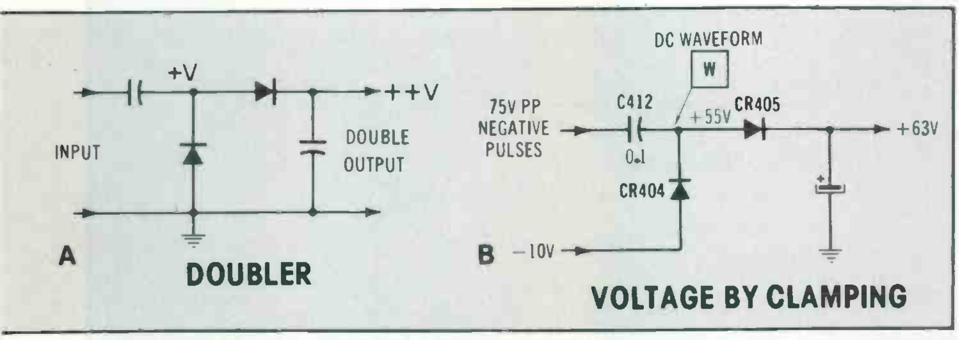


Figure 6 (A) The conventional voltage doubler has a peak-reading shunt rectifier feeding a series peak-reading rectifier. Thus, the output is twice the dc voltage of either. A more accurate explanation is that the shunt rectifier actually is a clamp which shorts the negative peak tip to ground leaving a positive waveform. Therefore, it is possible to control the dc voltage coming from clamping (shunt rectification) by applying a reverse (negative) voltage to the anode (-10V, in this case), as shown by the (B) schematic redrawn from the CTC99.

23V inverted circuit

Although the 23V supply is basically a series peak-reading rectifier circuit, it appears to be all wrong. The diode (CR401) is grounded through an extra CR402 diode, and the positive voltage is taken from the transformer winding. Figure 7 gives a progression from basic circuit to the same one with the flyback winding moved, and then to the same circuit redrawn as it is in Figure 4. So far, the conventional wiring has been juggled and drawn differently. But no reason for the CR402 diode has been given.

The pincushion connection

Diode CR402 produces a dc voltage that powers the pincushion output transistor (Q401), as shown in Figure 7D. Conventional schematics do not make clear that two "siamese" power supplies are at work here. *CR401 rectifies flyback*

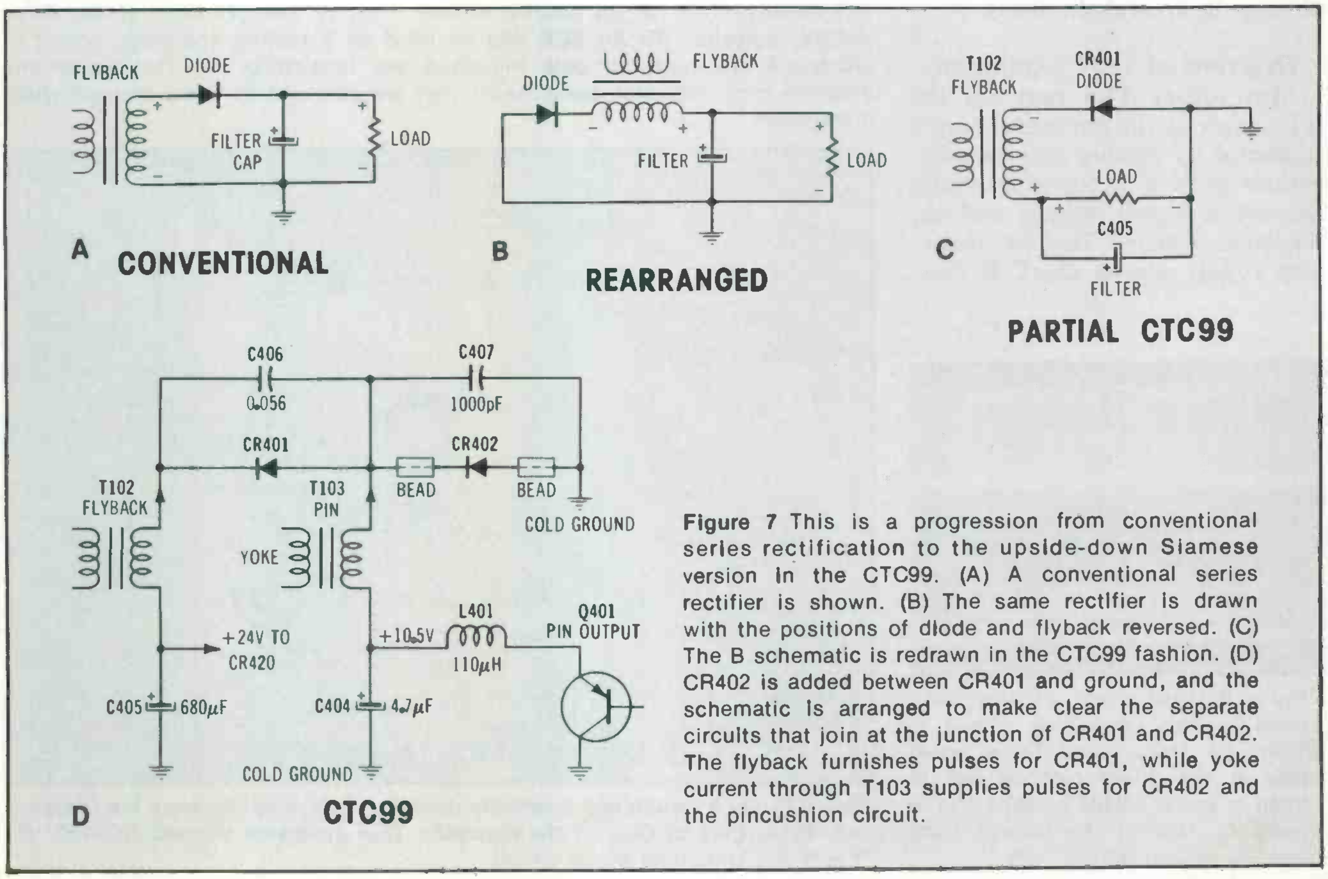


Figure 7 This is a progression from conventional series rectification to the upside-down Siamese version in the CTC99. (A) A conventional series rectifier is shown. (B) The same rectifier is drawn with the positions of diode and flyback reversed. (C) The B schematic is redrawn in the CTC99 fashion. (D) CR402 is added between CR401 and ground, and the schematic is arranged to make clear the separate circuits that join at the junction of CR401 and CR402. The flyback furnishes pulses for CR401, while yoke current through T103 supplies pulses for CR402 and the pincushion circuit.

power, while CR402 rectifies power developed from deflection yoke current. (The pincushion-correction operation will be explained more fully when the horizontal deflection is discussed.) In fact, to test the theory of operation, CR401 was disconnected from CR402 and grounded. The TV operated fairly well and developed nearly the right +24V and +10.5V levels, but picture bending or horizontal nonlinearity was seen according to where C406 was connected. However, the Q401 pin-output transistor ran too hot.

CR401 and CR402 are connected together so that C406 can feed some of the variable-amplitude yoke pincushion pulses back to the flyback. Without this crossconnection, the variation of yoke current during pincushion correction would change the flyback pulse amplitude at the vertical-scan rate. Connecting together these two circuits eliminates such variation. It should be clear now why the designer inverted the 24V supply circuit. Figure 8 shows the W3 and W4 waveforms of Figure 4 scoped at vertical-sweep rate. The W4 pulse amplitude changes in a parabolic shape.

Overview of 123V regulation

Most other TVs regulate the B+ supply of the horizontal-output transistor by placing the collector/emitter path of a power transistor between a higher voltage and the regulated supply. Then a closed-loop circuit adjusts the C/E resis-

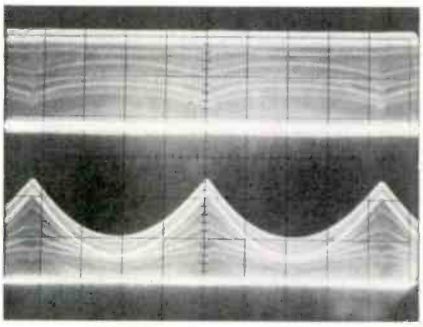


Figure 8 Modulation of the yoke pulses by the pincushion circuit is shown by these vertical-rate waveforms at the CR401 cathode (W3 in Figure 4) and at CR402 cathode (W4 in Figure 4). Tips of the bottom trace mark the vertical-retrace time.

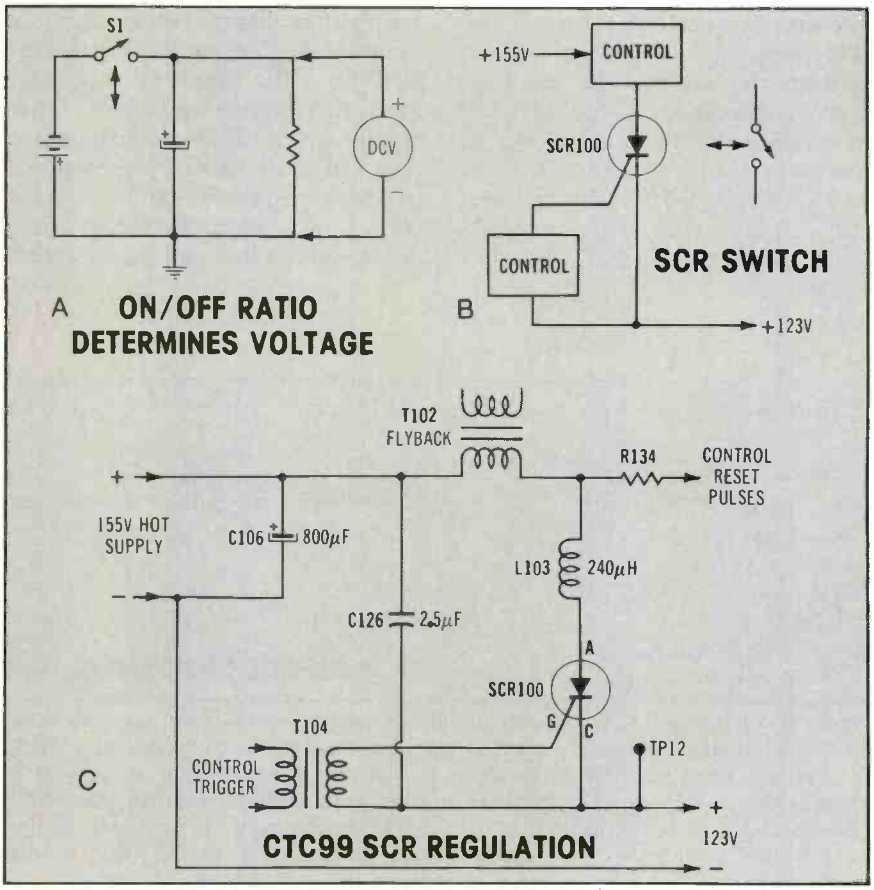


Figure 9 (A) If S1 switch is turned on constantly, the meter reading will equal the source voltage. If S1 is turned on for 10% of the time, the output dc voltage will measure 10% of the source voltage. That is one principle of the RCA +123V regulator. (B) An SCR can be used as a rapidly operating switch if provisions are made for gate triggering and unlatching. (C) This schematic includes most regulator components that are arranged to make the operation more clear.

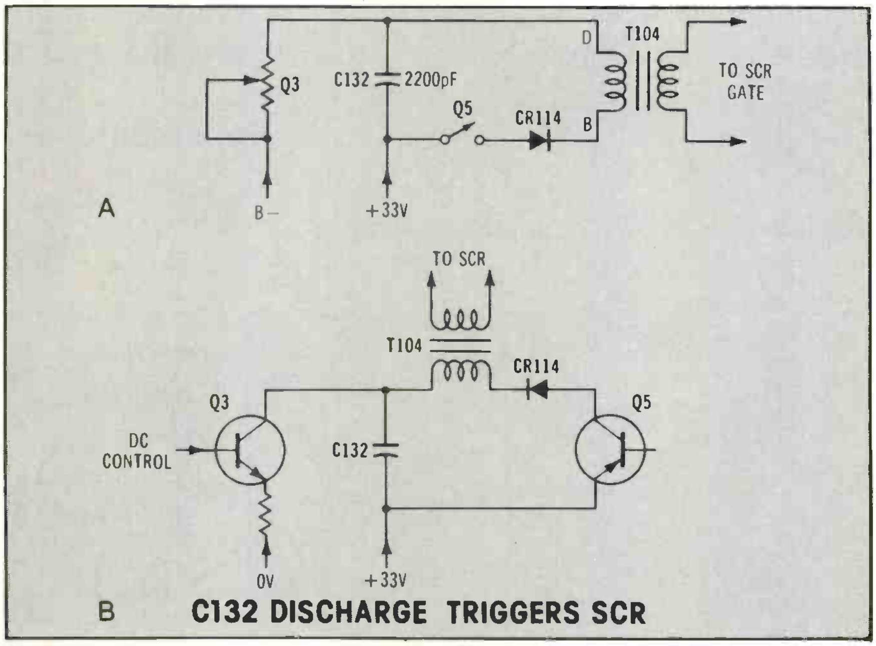


Figure 10 (A) A switch and a variable control are used to illustrate the charging and discharging of C132 in the regulator. This discharge triggers SCR100. (B) This is the simplified actual circuit.

tance (and voltage drop) to whatever value is required to maintain the regulated supply at the desired voltage. This resistance variation is gradual and stepless. It seldom approaches either an open circuit or zero ohms. Therefore, the power transistor dissipates considerable wasted heat.

Although the RCA SCR system obtains an input dc voltage from a higher (+155V) source, the power to maintain the regulated voltage comes in on-or-off pulses, not continuously.

As shown in Figure 9A, these dc pulses are averaged by the filter capacitor. The filtered output voltage varies directly with the S1 **on** duty cycle. In other words, if S1 is on for 90% of the time and off for 10%, the output voltage will be 90% of the battery voltage. If the switch is turned on for 20% of the time, the voltage at the load will be 20% of the battery voltage. The RCA system operates this way, but an electronic switch replaces the mechanical switch.

SCR switching—An SCR has many desirable qualities of a good switch. Because of internal regenerative action, both switching on and turning off occur very rapidly. Such fast switching minimizes the heat that is dissipated, and allows a high repetitive frequency to be used.

But SCRs have a peculiarity. When the anode has positive voltage, and the gate is made positive, conduction occurs. After conduction starts, removal of the base voltage (or applying negative) does not stop the A/C conduction. Nothing except reduction of the anode current below the latching point will stop the conduction. Usually, the unlatching is accomplished by reducing the anode voltage to zero or reversing it to negative.

In Figure 9B, the control circuit between gate and cathode produces a positive-going pulse at the gate to start anode/cathode conduction *sometime* during each horizontal scanning line. SCR current continues until another part of the control circuit applies a large negative-going flyback pulse to the anode, thus stopping all SCR conduction. Those components are shown in Figure 9C.

The control circuit (covered next month) senses how much the +123V has dropped during each horizontal scan. If more than average power is needed to restore the supply, the circuit triggers-on the SCR earlier in the horizontal scanning time. During darker scenes when less replenishing voltage is needed, the SCR is triggered later in each horizontal scan. Thus the SCR is forced to conduct for longer or shorter periods of time as required to maintain the regulated voltage near the designated +123V. In all cases, SCR current is stopped during horizontal-retrace time and is not resumed until the SCR is triggered later.

SCR pulse rectification—An important action not mentioned in any RCA books or service data is that a portion of the +123V supply comes from rectification of the negative pulses that are applied to the SCR anode to unlatch it. This operation was discovered first in the anode current-versus-voltage waveforms, and then proved by more tests.

Voltage from rectification of the unlatching pulses greatly helps the voltage regulation at low line voltage. Otherwise, the regulation would cease when the +155V hot supply dropped to less than +123V.

Regulator oscillator and control

Remember that the so-called multivibrator oscillator (including Q104 and Q105) must reset C132 to a discharged condition during each horizontal pulse from the flyback. That allows good accuracy when Q102 and Q103 charge C132 at a rate that varies in step with the precise voltage of the +123V regulated supply. Then when the C132 voltage reaches a certain level, the oscillator fires, triggering the SCR (Figure 10). Any voltage above +123 in the regulated supply causes C132 to be charged at a slower rate. Therefore, the SCR is triggered later and contributes less voltage to the regulated supply.

A lower regulated voltage reverses that action. C132 is charged more rapidly, thus reaching the oscillation point (and triggering the SCR) earlier in the horizontal scanning time. Then the SCR conducts for a longer time, which restores the regulated supply to the required +123V.

Q104 and Q105 are opposite-polarity transistors. Therefore, both conduct at the same time, not alternately. Q105 collector current discharges C132 through the primary winding of transformer T104, and the secondary pulse triggers SCR100 into full conduction. It latches there until turned off by the next negative anode pulse.

Actually, Q105 conducts twice during each horizontal scan. The first is when the C132 voltage charge starts an oscillation. However, C132 is not discharged completely this time. In addition, it begins to charge again following the oscillation. The second discharge conduction is produced by a retrace flyback pulse at the Q105 base, and C132 is discharged totally (as required for accurate SCR firing).

Not a multivibrator—Although the collectors of Q104 and Q105 are connected through resistors to the other's bases, the oscillator is **not** a multivibrator. A multivibrator must have one or both bases fed through a coupling capacitor that sets the repetition rate according to the time required for the capacitor charge to leak away. None of these bases or collectors has a coupling capacitor.

Actually, C132 is the time-constant capacitor which is connected through diode CR113 to the Q104 emitter. Even so, this oscillator is not an upside-down multivibrator, for the Q104 emitter current plays no part in the C132 charging or discharging. Instead, the C132 voltage controls the Q104 bias through this emitter connection.

Next month

Detailed circuit operation of the regulator system will be discussed first next month. This includes the oscillator, control circuit, SCR regulator and an explanation about how the regulated voltage can be higher than the source voltage at low line voltages.

Troubleshooting methods for the various power supplies and the +123V regulator will be presented after coverage of the horizontal-sweep circuit, which begins next month. □

Sam Wilson's Technical Notebook

This is Sam's last Technical Notebook because he is not writing articles at present. Sam regrets that his time did not permit him to answer all of the letters. However, he read (and appreciated) them and thanks you for your interest.

By J.A. "Sam" Wilson, CET

Contest winner

Several months ago, I offered a copy of my industrial electronics book as a prize to the first reader who submitted a practical counting circuit that skipped number six each time it counted from zero to nine and repeated.

Many schematics and suggestions were sent in. Several readers mailed materials taken from books or magazines. These could not be printed without permission from the author or publications, but they were interesting.

A surprising number of circuits skipped both six *and* seven. However, the object was to include all numbers from zero through nine except for number six.

Several readers invented complicated stories about how to use such a counter, but no one suggested a practical application.

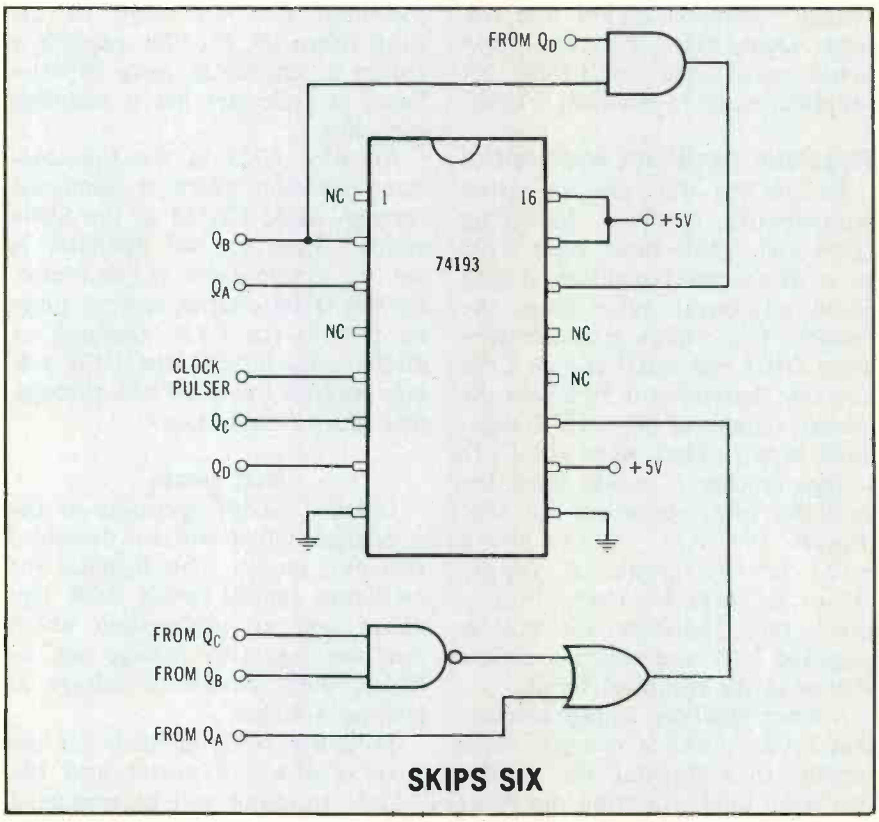


Figure 1 John Jones sent in this winning design for a zero-through-nine counter that skips six. QA, QB, QC and QD of the 74193 IC are outputs to a 7-segment decoder that drives an LED display.

A few sophisticated circuits used a read-only memory (ROM) or read-write memory IC, but the winning entry arrived earlier.

The winning schematic was sent by John Jones of Albany, GA, and his circuit is shown in Figure 1.

Imaginary number

High school algebra books refer to $\sqrt{-1}$ as an "imaginary number." According to the usual explanation, there is no number that can be multipled by itself to give -1 as a product. Then a chapter full of problems is given.

The term "imaginary" is an inappropriate descriptive word for the square root of minus one. It seems to imply that the term is worthless for practical uses and can be discarded or ignored. That is not true. It is very valuable in the study and mathematics of ac networks, where the term is called the *j operator.*

An *operator* is a mathematical symbol that describes the procedure to be followed. For example, the math problem 4+6 uses the operator +. Other popular operators are -, x and ÷.

Incidentally, an operational amplifier (op-amp) first was designed to perform addition, subtraction, multiplication and division as well as other basic math operations, and it was used extensively in analog computers. Op-amps became even more versatile and valuable when packaged in integrated-circuit form.

Refer to the vector in Figure 2. Its value is +1 and it lies in the zero-degree or standard position.

In Figure 3, the vector has been rotated 180°. Its value now is equal to -1. Of course, purists will argue that the value of this vector never can equal -1, because it's impossible to have a negative length. However, the *point* of the vector is at -1, so it can be said to be in the -1 position.

To rotate the vector from its Figure 2 position to the position in Figure 3, the vector is multiplied by -1.

Therefore, if multiplication by -1 rotates a vector 180°, by what must it be multipled to rotate the vector only 90°? Answer: multiplication by $\sqrt{-1}$ rotates it 90°. This must be correct, for when it is multiplied again by $\sqrt{-1}$ it moves to the -1 position.

$$\sqrt{-1} \times \sqrt{-1} = -1$$

In this case, the operator j commands you to rotate the designated vector by 90°.

Relating operator j to electricity

Ac current in a purely inductive circuit lags behind the voltage by 90°. It would be proper to say the current vector is operated on by a j.

Ac current in a purely capacitive circuit leads the voltage by 90°. If j rotates a vector 90° for a lag, then -j should operate on it for a 90° lead.

The expression $R+jX_L$ means that X_L is at an angle of 90° relative to R. A +j causes a counterclockwise rotation. So the expression $R-jX_C$ indicates that X_C is clockwide by 90° from R.

To summarize, j simply is an operator that rotates a vector away from the standard position. A +j rotates it 90° counterclockwise, while a -j rotates it 90° clockwise.

The term *vector* indicates a magnitude and a direction. In electrical circuits, the arrows of vectors represent magnitude and phase *differences*. Therefore, they properly should be called *phasors* rather than vectors.

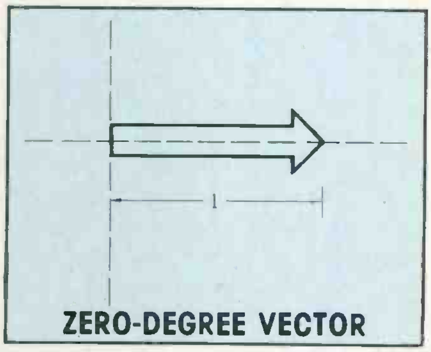


Figure 2 The value of this vector is +1. It lies in the standard or zero-degree position.

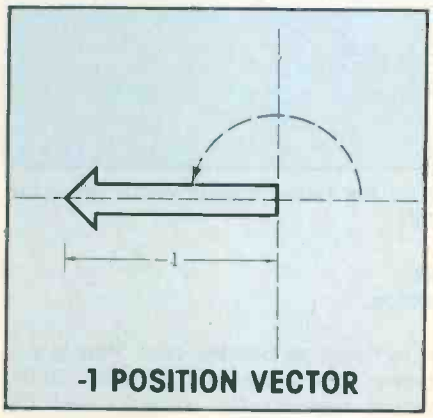


Figure 3 Rotation of the vector by 180° brings it to the -1 position.

Repetition makes it true

Lewis Carroll said in *The Hunting of the Snark*, "What I tell you three times is true." Repetition does enhance credibility.

I have heard the following story more than three times. Therefore, it *must* be true There was an intense but friendly rivalry between engineers of Swiss and American watch factories. Finally, the Swiss engineers made a spring so delicate that observation of it required a microscope. They sent it to the American engineers with the challenge, "Match this." Before the Americans sent the spring back, they drilled a tiny hole in the end of it.

The story took on special significance for me last spring when one of my brighter students placed a circuit board on my desk. It was a breadboarded digital counter that first counted all odd numbers between zero and 20, then the even numbers were counted, and finally it counted zero to 20 by ones. "Match this," he said in an arrogant manner. I drilled a hole in the counter.

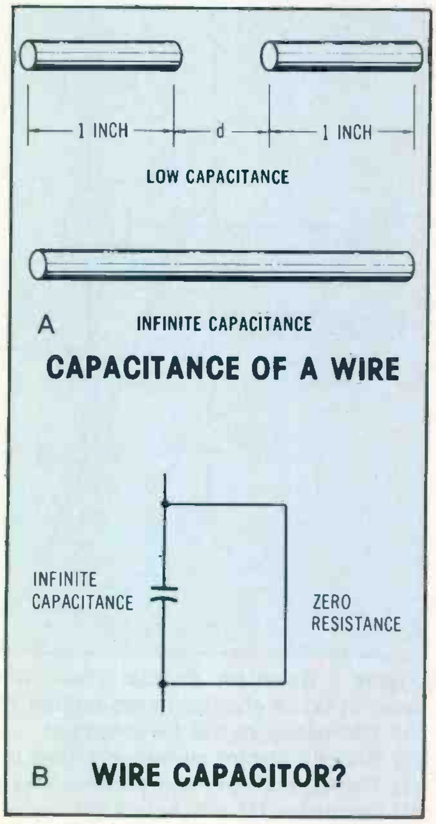


Figure 4 (A) This is the original drawing of the wire capacitance. (B) Some readers believe the wire has infinite capacitance but is paralleled by zero resistance.

Last charge for the wire capacitor

Letters came in for several months following previous descriptions of the marvelous infinite capacitance made from a short length of solid wire.

A few readers suggested that the wire really was made up of an infinite number of capacitors in series, thus making the final value equal to zero. Others said the circuit equivalent is an infinite capacitance paralleled by a zero-resistance leakage path, as shown in Figure 4. However, no one has argued successfully against the wire capacitor having a very thin air space for a dielectric.

Two correct answers

Richard Colby of Honolulu, HI, doubts the completness of my answer to a question from Allen Daubendiek (Beatrice, NE) about a question in one of my CET Practice Tests. The schematic and original question are printed in Figure 5.

The corrected answer given on page 42 of the September 1978 issue of **Electronic Servicing** was number four. Colby replied that although answer four is correct, answer three is also equally correct. In fact, answer four precedes answer three in the circuit analysis.

Good tests should not have two correct answers to any question. So, Colby wondered if the jumper could be moved to other points that would make answer two the correct condition.

Quoting from his letter: "If the short is changed to the Q1 collector and the Q2 emitter, the situation is

Technical notebook

similar to Q1 saturation. The emitter is made more positive by voltage from R3. This is lower forward bias for Q2, so its reduced conduction increases the collector voltage. This increases the forward bias at the Q3 base and causes heavy current to flow through Q3."

The corrector is corrected—One of the difficulties faced by those who make up tests is that a lack of vigilance and crosschecking can allow several answers to be correct rather than just one. It is interesting to note that Colby also fell into the same trap he tried to correct.

His suggestion of moving the jumper *does* make answer two correct. Unfortunately, it also makes answer four correct. (Answer four stated: Transistor Q1 would be cut off.) Perhaps one could argue that the new short does not affect the R1/R2 base voltage divider, so it could not have decreased the base voltage. That's true. (In fact, the reversed bias increases the base-to-ground voltage.) However, the emitter voltage rises *above* the base voltage because of voltage from R3 (usually a low-value resistor). Remember, the emitters of Q1 and Q2 are connected together; therefore, Q1 is biased to cut off, and answer four is correct.

Because the Q1 and Q2 emitters are connected together, the new jumper position gives the same symptoms and voltage readings as a collector-to-emitter short in Q1. Check for such a short immediately after a voltage reading shows the transistor bias is reversed but collector-emitter current is flowing. □

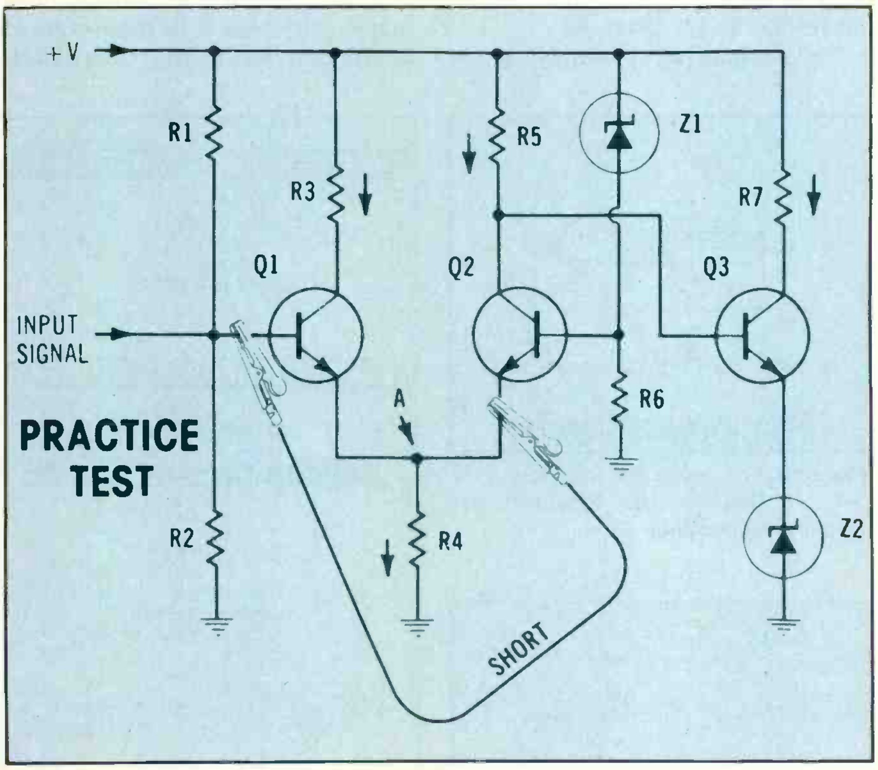


Figure 5 Question: In this circuit, which of the following will occur when the base of Q1 is shorted to the emitter of Q2?

(1) Transistor Q2 will be destroyed.
(2) Heavy collector current will flow in Q3.
(3) The Q2 collector will become less positive.
(4) Transistor Q1 will be cut off.

In the practice test, the correct answer is listed as number two. That is not true. Instead, both answer three and answer four are correct. Reader Colby suggested the jumper should be connected between Q1 collector and Q2 emitter, which would make answer two correct. Is anything wrong with such reasoning?

Measuring standing-wave ratio

By Joseph J. Carr, CET

The terms *standing waves, standing wave ratio* (SWR) and *voltage standing-wave ratio* (VSWR) are used constantly regarding antennas, coaxial cable and radio/TV transmitters. Unfortunately, there is much confusion about the importance and measurement of standing waves. Even the name is not informative. Does it imply that other waves sit, lie down or run?

A lack of basic understanding about standing waves can lead to misuse of excellent VSWR meters so they might produce wrong readings under some conditions. The material in this article is intended to help technicians avoid such pitfalls.

Standing-wave model

Complex subjects can be understood more rapidly when they are compared to other already-known concepts. Hydraulic water flow is used often to illustrate electron current in basic circuits.

A model of standing waves can be the undulations in a length of rope. The rope is fastened at one end to a solid wall while the other end is moved up and down in various ways. It's easy to see the waves travel smoothly down the

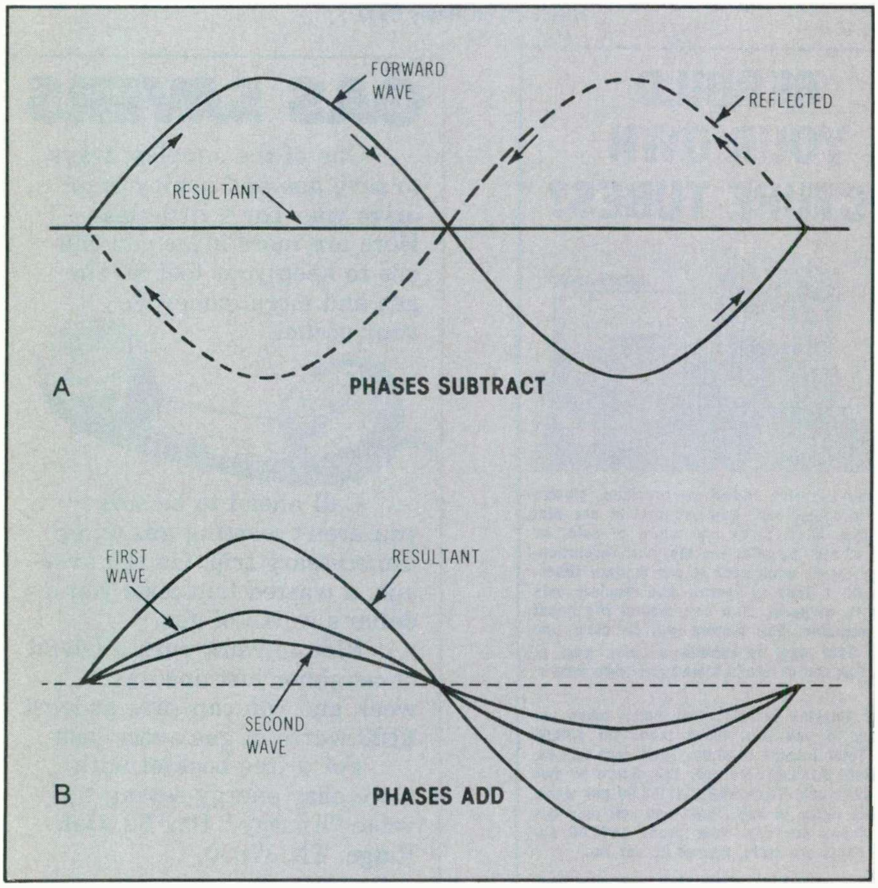


Figure 1 (A) When the forward wave and the reflected wave happen to be at 180° relative phase, subtraction occurs. If both have the same amplitude, cancellation takes place. (B) At antinodal points, both signals have the same phase, so the amplitudes add.

Standing waves

rope to the wall, apparently strike the wall and rebound at **reduced amplitude** and **opposite phase** back to the source. This is essentially the same as applying pulses or continuous waves to a section of radio transmission line or cable.

A continuous radio carrier moves downstream along a length of coaxial cable while any of the same carrier that is reflected from the load moves in the opposite direction upstream. Therefore, the relative phase between them changes constantly.

At some points, the two signals are 180° out of phase, so cancellation takes place (Figure 1A). When the amplitudes are equal, total cancellation occurs, leaving zero voltage. Unequal amplitudes produce an intermediate signal amplitude by partial cancellation.

Amplitudes of in-phase signals add, thus making a resultant amplitude equal to the sum of both.

These alternate additions and subtractions produce stationary points of maximum and minimum amplitude (or nodes and antinodes) that are called *standing waves.*

Matching versus standing waves

Figure 2A shows perfect matching of 50 Ω source, 50 Ω coaxial signal-transmission line and 50 Ω noninductive load. All of the forward signal is absorbed by the load; none is reflected back towards the source. A graph of the nodes and antinodes for this one example shows only a straight line. Without a reflected signal, no standing waves are formed. The SWR then is a perfect 1:1 reading.

Any deviation from the ideal matching of source, transmission line, and load allows reflected signal, which produces the peaks and nulls of standing waves. A graph of these standing waves (Figure 2B) shows the nodes are separated by a half wavelength of the signal. (This is true also of the antinodes.)

A shorted or open load is the worst possible example of mismatching. As illustrated in Figure 2C and Figure 2D, the SWR has the same high ratio with either a short or an open load. However, the phase is different by a quarter wavelength for the two conditions.

Measuring SWR

SWR can be measured with different degrees of accuracy at some point in the transmission line by comparing one of these conditions: forward versus reflected **voltage;** forward versus reflected **current;** or forward versus reflected **power.**

VSWR tests by RMS power provide consistently accurate readings, but they are not fast or convenient. For example, if a Bird model 43 Thruline RF wattmeter is used to measure the forward and reversed powers, the VSWR must be calculated from the following formula:

$$VSWR = \frac{1 + \sqrt{\frac{P_r}{P_f}}}{1 - \sqrt{\frac{P_r}{P_f}}}$$

Of course, radio technicians soon learn the **range** of forward versus reversed power readings that indicate *acceptable* VSWR ratios, and therefore do not calculate each one.

The advantage of power SWR measurements is that testing at the transmitter, the antenna base or any other point in the coaxial cable gives the same dependable reading.

Most service-shop SWR meters compare forward and reversed **voltage** or **current.** However, these tests are sensitive to the location of the measuring equipment. In fact, they might mislead a technician into believing erroneously that VSWR can be reduced to 1:1 by trimming the length of the coaxial cable.

These voltage or current VSWR meters do indicate *relative* VSWR, and so are useful for trimming the antenna length or tuning the matching circuit for minimum VSWR reading. But the 1.3:1 or 2.2:1 VSWR numbers obtained are not valid unless the measurement is made either at the base of the antenna or through a section of coaxial cable that is a multiple of the signal half wavelength.

For 27MHz, a half-wavelength

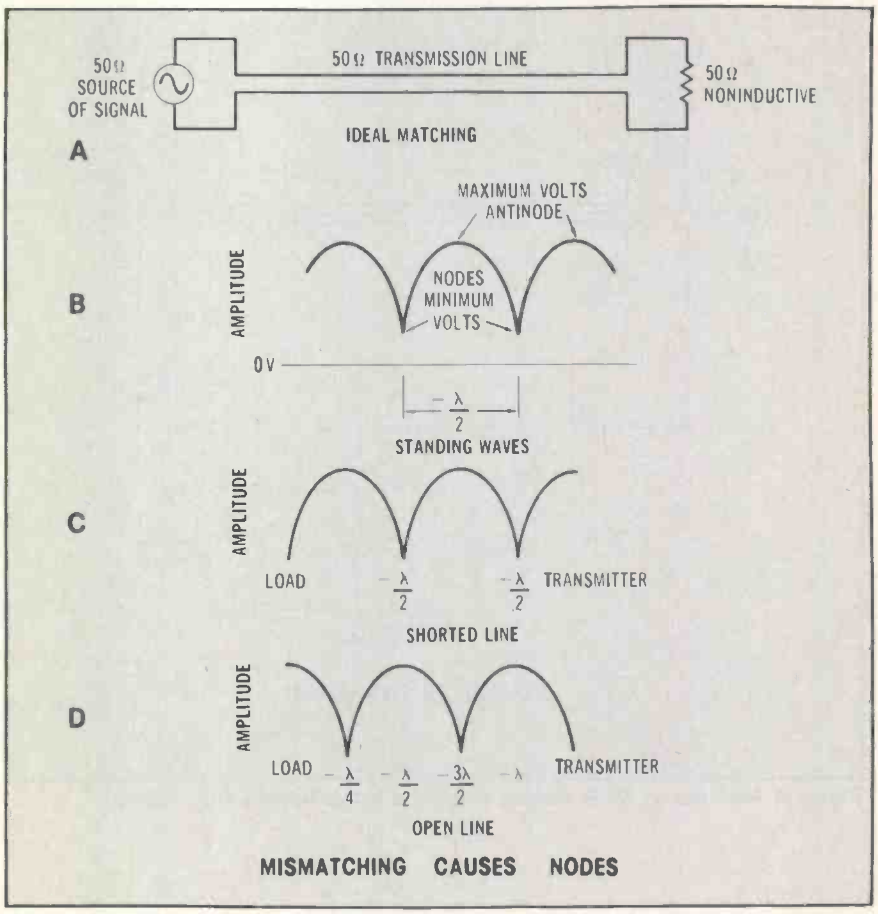


Figure 2 Mismatching of impedances produces the nodes and antinodes of standing waves. (A) Perfect impedance matching eliminates all standing waves. (B) The nodes are a half wavelength (of signal) apart. (C) and (D) Although the standing waves have identical high amplitudes, a short or an open at the antenna end of coax changes only the relative phase of the antinodes (or nodes).

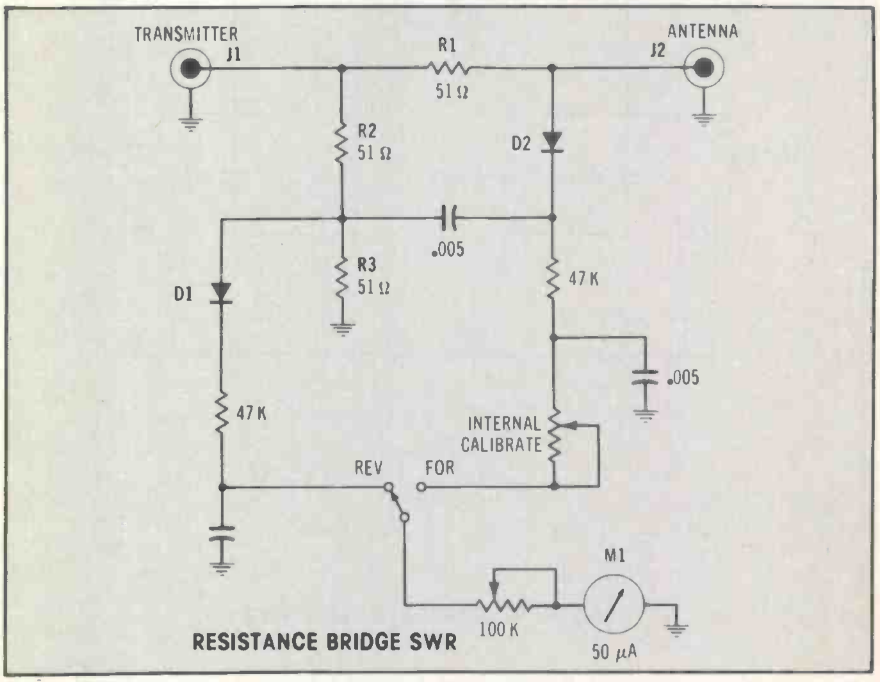


Figure 3 The voltage drops of forward and reversed signals are measured in a resistance-bridge SWR tester.

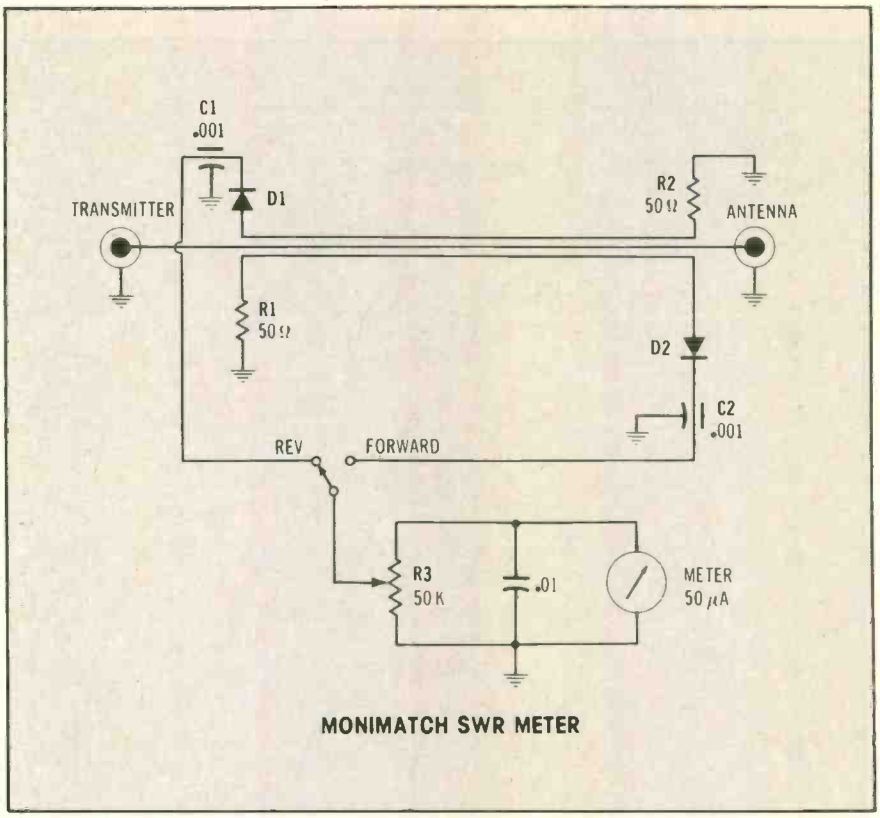


Figure 4 Monimatch SWR meters employ a transmission-line bridge.

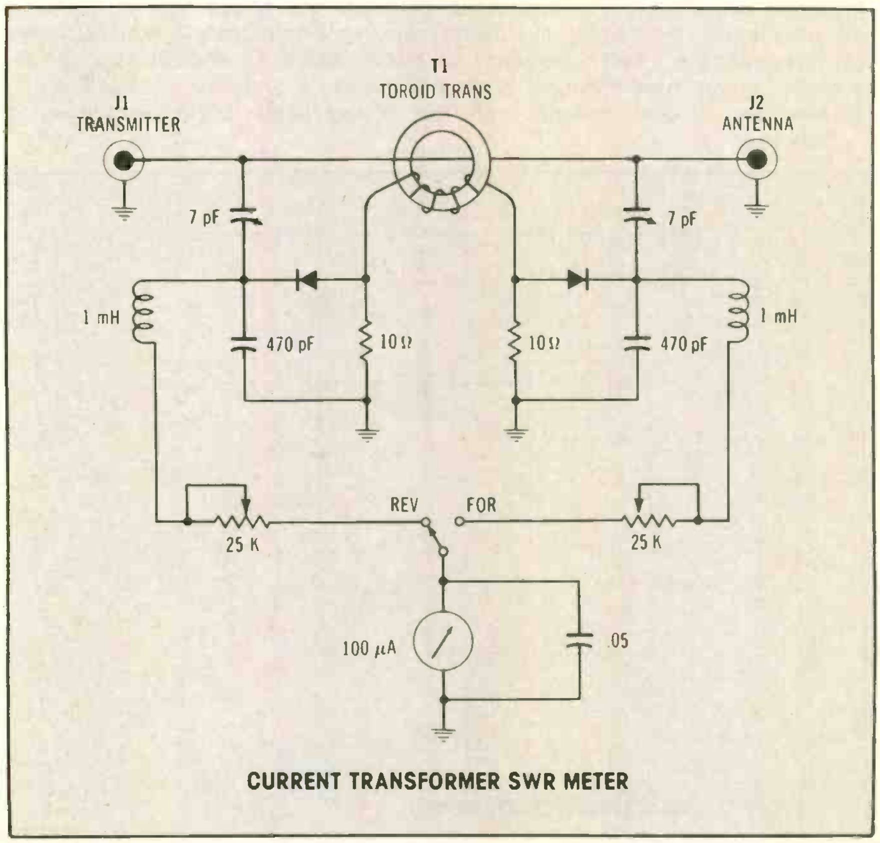


Figure 5 A toroid-type current transformer tests forward and reversed *current* to measure the SWR.

cable should be 14.6 feet long for foam type or 12 feet for regular.

Bridge VSWR meter

Figure 3 shows the schematic of a typical resistance-bridge type of VSWR meter. Two of the bridge arms are R1 and R3, and the bridge is balanced when the antenna impedance is exactly 51 Ω.

The switch is set to forward, the meter control is adjusted for full-scale reading, then the switch is turned to reverse for the SWR reading from a special meter scale.

Monimatch meter

Two identical pick-up conductors are spaced the same distance from the center conductor of the internal transmission line in the monimatch type of SWR meter (Figure 4). RF current in the center conductor induces current in the pick-up wires and the signals are rectified by matched diodes to form dc voltages which are in proportion to the amplitudes of forward and reflected signals. With the switch set for forward, the calibrate control is adjusted for a full-scale reading. After the switch is turned to reverse, the SWR is read from the calibrated meter scale.

Toroidal type

Basically, a toroidal-transformer VSWR indicator (Figure 5) operates similarly to the previous monimatch type. However, the doughnut-shaped current transformer is used instead of a pickup assembly.

RF wattmeters often employ a toroidal transformer, using the Ohms Law formula of wattage equals current squared divided by resistance. Capacitor values are chosen to provide accurate readings between 3MHz and 30MHz. This frequency compensation is not required for SWR readings because the meter is calibrated before each measurement.

Other antenna instruments

Although many CB-radio technicians use only a SWR meter and perhaps an RF wattmeter, there are other antenna-testing instruments that can provide valuable information.

An antenna-impedance meter measures the resistive component of

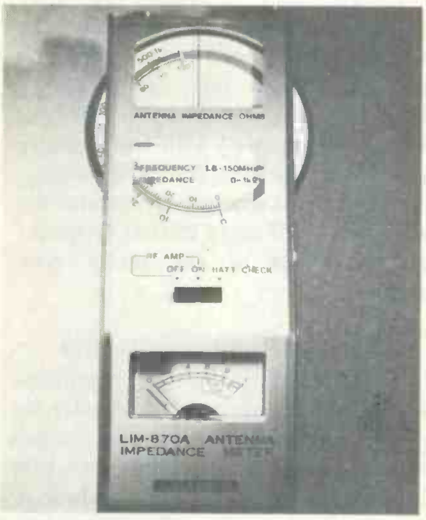


Figure 6 Leader model LIM-870A tests antenna impedances between zero and 1000 Ω.

the antenna-feedpoint impedance. One commercial model (Leader LIM-870A) is pictured in Figure 6. It employs a variation of the standard ac Wheatstone bridge to measure between zero and 1000 Ω.

Another method of measuring antenna impedance is found in noise bridges of several brands (pictures and schematic in Figure 7). A noise bridge also is a type of Wheatstone bridge, but a wide-bandwidth noise signal is used instead of a sine wave. The noise is produced by a reverse-biased diode inside the meter, and is amplified before it is fed to the bridge. This is *white* noise, containing all frequencies (theoretically).

Operation of the noise bridge is simple, although it requires a receiver (preferably with an "S" meter) for the test-frequency band. First, the bridge control is set for the coaxial-cable impedance (50 Ω in most cases), and then the receiver is tuned slowly around the desired frequency until a dip or null of the noise level is noticed. This is the resonant frequency of the antenna.

Some models have an additional control to show whether the resonant frequency is upband (X_L) or downband (X_C) from the desired one.

Approximate measurements of resonant frequency can be made with a dip meter (formerly a grid-dip meter, when tubes were

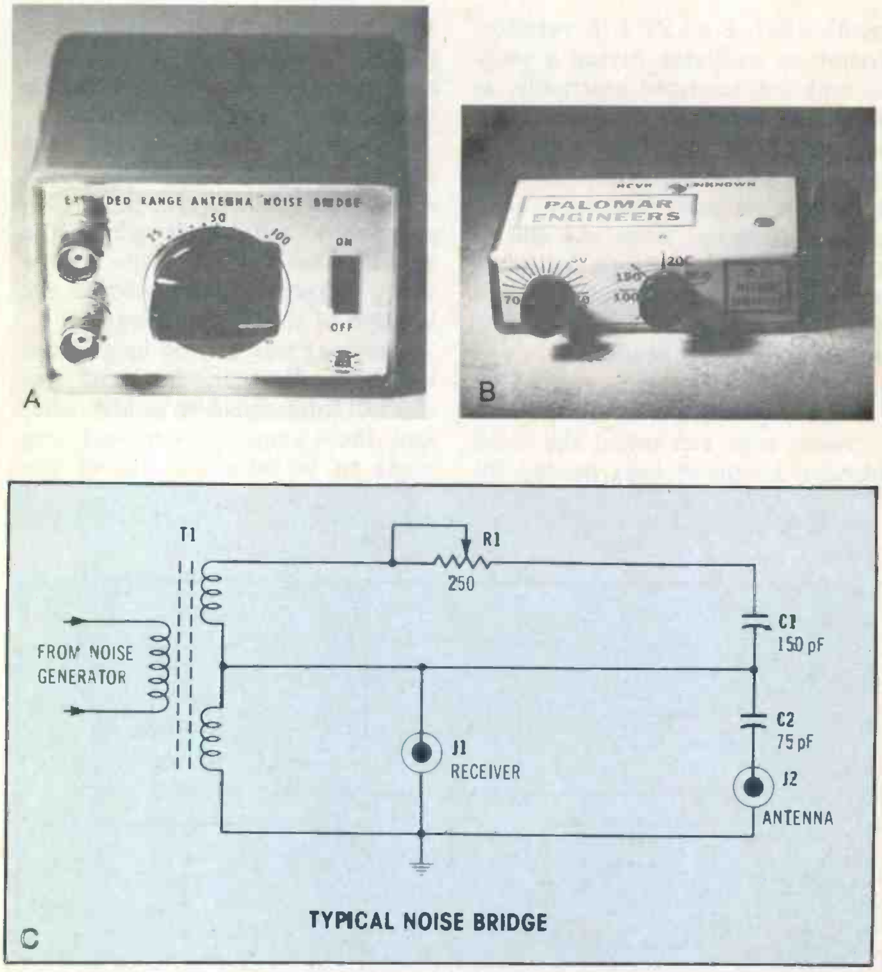


Figure 7 (A) The Omega-T noise bridge tests antenna resonance. (B) Palomar also markets a noise bridge with an extra control that can indicate whether the antenna has a high or low resonant frequency. (C) This is a typical noise-bridge circuit.

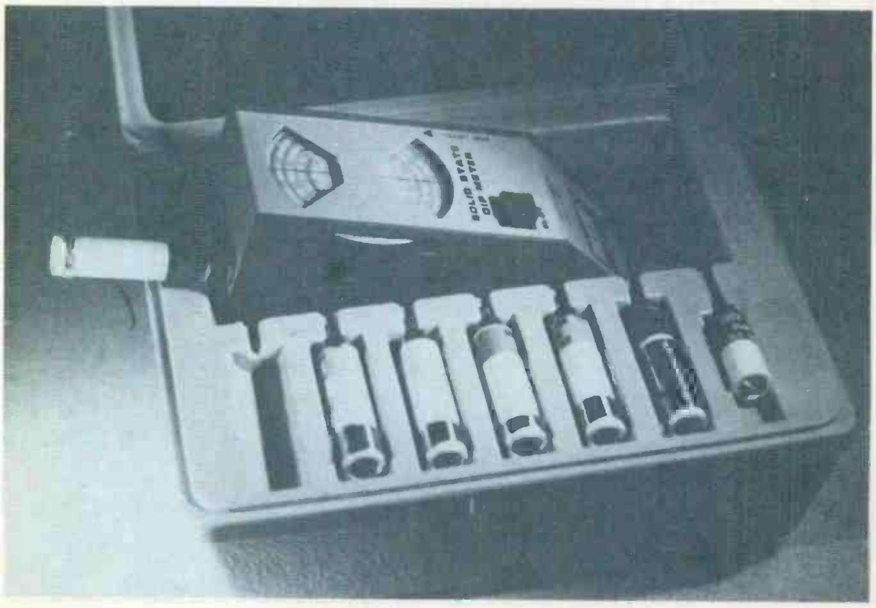


Figure 8 The Heath Solid-State Dip Meter can measure the approximate tuned frequency of coils.

used), which is an RF L/C variable-frequency oscillator having a plug-in tank coil mounted externally, as shown in Figure 8. When the dip meter coil is placed near (and in line with) the coil that is being tested for resonant frequency, energy is transferred from one coil to the other. If both coils have the same resonant frequency, the test coil loads down the dip signal and reduces the meter reading.

Sweep tests with scope

Sweep tests can reveal the exact physical length of coax needed for any specific frequency. For example, the author used the equipment of Figure 9 to cut a coaxial cable for a certain 27MHz frequency.

A short at the load end of coax reflects a similar short to the input end when the cable length is precisely a half wavelength of the signal. Therefore, a dip in the sweep response curve shows the location of the half wavelength.

The coax was cut too long in the beginning. Next, the load end was shorted from shield to center wire, and the sweep/marker test was made to be sure the dip of the response curve was beyond the marker. One inch was clipped off and the sweep test made again. This was continued until the response dip merged with the marker. Therefore, the coaxial cable electrical length was correct for producing accurate SWR tests at that frequency, regardless of the meter type used.

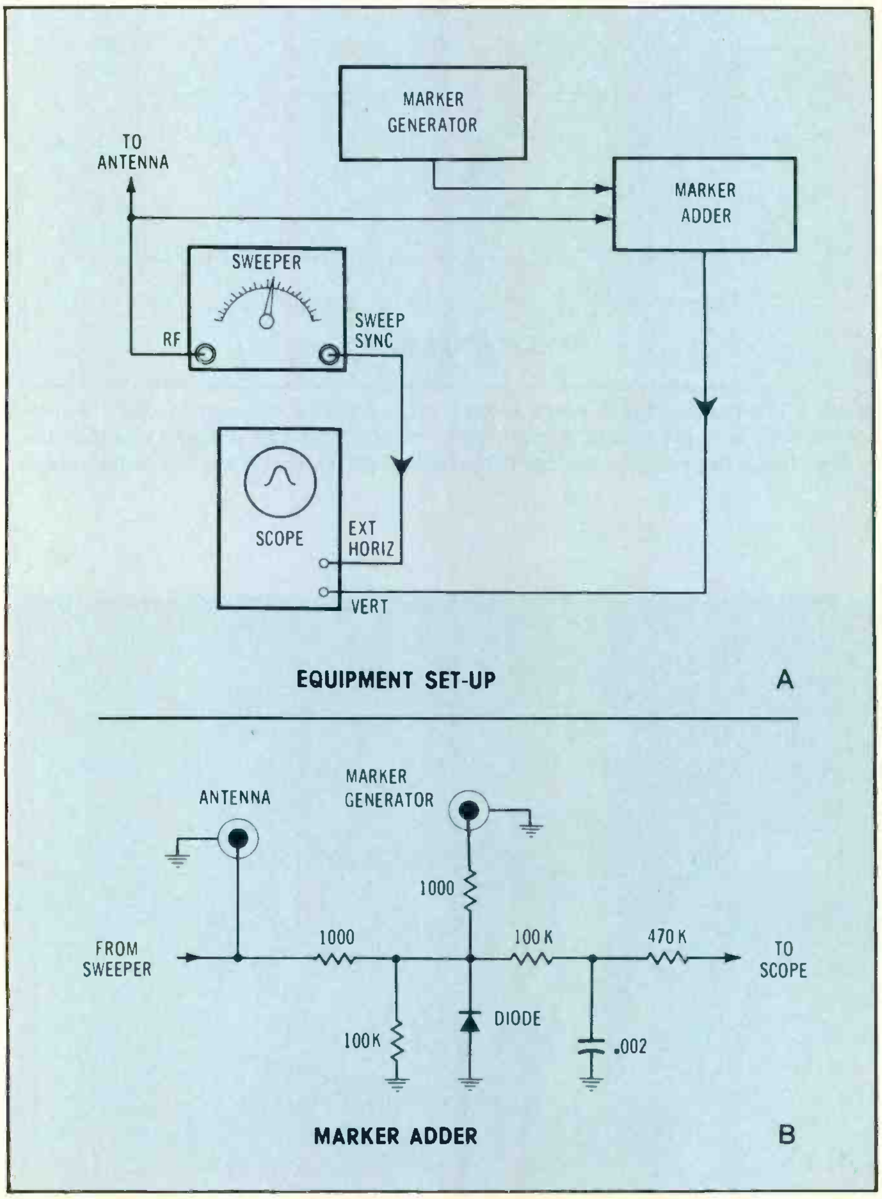


Figure 9 (A) This interconnection of equipment can show when coax is a half wavelength. (B) A marker adder for post-injected markers is easy to construct.

Summary and comments

Total elimination of standing waves can be accomplished only by perfect matching of source impedance, cable or transmission line impedance, and the non-inductive load impedance. Any less-than-perfect matching allows the signal to bounce from the load (or the source) and travel back through the cable in the wrong direction.

Relative phase between these forward and reversed signals produces stationary points of maximum amplitude (nodes from addition) and minimum amplitude (anti-nodes from subtraction). These maximum and minimum areas are called standing waves.

Notice that standing waves do *not* cause any reverse signal; instead, the direct and reversed signals produce standing waves. However, standing waves in SWR units can be measured either directly according to the node and anti-node amplitudes or indirectly by the amount of forward and reversed signals. Measurements by RMS power are accurate when made *anywhere* in the coaxial/antenna system, while SWR measurements by voltage or current vary according to where the meter is connected.

TV ghosts—Excessive reversed signals (high VSWR ratio) reduce the total power radiated by the antenna in radio systems. Also, the reverse signal might be absorbed partially by the output stage, thus increasing the dissipation. But the bouncing signals cause other problems.

At the frequencies used by MATV and CATV systems, these reversed signals can cause an effect similar to location ghosts. So, correct matching of all such systems is much more important for obtaining sharp video pictures than for reducing transmission losses. □

catalogs literature

A six page brochure illustrating the Intervox line of custom auto speaker products is available from **International Components.** The brochure contains sections describing speakers, acoustically transparent wire mesh grilles, custom metal and plastic grilles, speaker controls and accessories.

Circle (17) on Reply Card

The **Sprague** short-form catalog WR-167B lists the complete line of Sprague semiconductor products. The catalog contains 65 pages of intergrated circuits, transistors and diodes, with new products listed in every category.

Circle (18) on Reply Card

The **ETCO Electronics** catalog, issue H, contains 80 pages of unusual and hard-to-find parts, factory termination material and hundreds of bargain-priced items.

Circle (19) on Reply Card

A 60-page catalog from **Sprague** contains information on capacitors, resistors, interference filters, switches and optoelectronic devices. Also included are pulse transformers, miniature lamps, wiring components, both entertainment and MRO, as well as for electronic experimenters, schools and laboratories.

Circle (20) on Reply Card

A handbook called Mold Design Guide for the designer discussing injection molding of Noryl thermoplastic resins is available from **General Electric Company's Plastics Division.** The pocket-sized pamphlet is designed for on-the-job use.

Circle (21) on Reply Card

A short form catalog is available from **Ailtech Division Cutler-Hammer.** Photographs and specifications of such items as frequency synthesizers, spectrum analyzers and EM/RFI test instrumentation are included.

Circle (22) on Reply Card

Radio Shack has issued a 24-page catalog, *The Expanding World of TRS-80.* It includes information on the model I and model II TRS-80 microcomputer systems. Also listed are peripherals and accessories such as five line printers, disc expansion units, a voice synthesizer, system desk, dust covers, carrying cases and software including more than 50 ready-to-run programs. ☐

Circle (38) on Reply Card

Circle (8) on Reply Card

product report

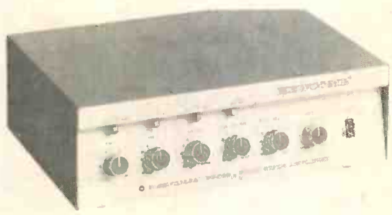
800MHz mobile antenna

An 800MHz low-silhouette radome-enclosed antenna, model ASP-930, has been designed by **The Antenna Specialists.** The unit has a maximum power rating of 100W and a VSWR of less than 1.5:1 over a 60MHz bandwidth. Frequency range is 806-866MHz.

Circle (23) on Reply Card

P. A. amplifier

The new Pathfinder line of all-solid-state public address amplifiers is being manufactured by **Newcomb Audio Products.** Six models in the line range from 25 to 100 watts. Most of the amplifiers have microphone-precedence music muting,

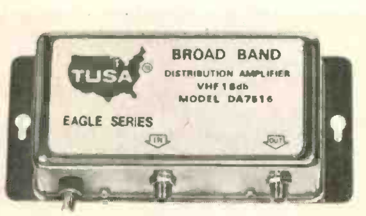


separate and independent response control for each microphone channel, and bridging jacks for joining two amplifiers together. Most inputs give a choice of low- or high-impedence microphones without the need of transformers where balanced line is necessary. The Pathfinder line includes two column loudspeakers and a 4-speed phono top.

Circle (24) on Reply Card

Distribution amplifiers

Three Eagle series MATV distribution amplifiers are available from



Trans USA. All models are 75 Ω units with gains of 8dB (DA-7508), 16dB (DA-7516) and 24dB (DA-7524). Maximum output is 52dBmV and noise figure is 7dB on all models.

Circle (25) on Reply Card

Power inverters

Two Micronta power inverters for converting 12Vdc/120Vac to power ac appliances from a car, boat or recreational vehicle battery are new from **Radio Shack.** The 300W (25 amps) and 100W (12 amps) inverters

feature a normal/boost switch and automatic overload protection.

The 300W inverter is priced at $79.95. The 100W unit, with cigarette lighter plug, is $39.95.

Circle (26) on Reply Card

Industrial sound transducer

The MS-1 electronic sound transducer, by **Floyd Bell Associates,** is a piezoelectric audio warning device that provides size and current

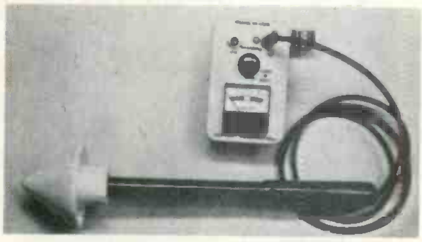
advantages over buzzers or speakers. The unit is a medium impedance device of a few thousand ohms. Operating voltage for the MS-1 ranges up to 150VPP maximum.

Circle (27) on Reply Card

Microwave survey meter

Holaday Industries has developed a microwave survey meter, the HI-1800. It has a single range of 0-10 mw/cm^2, push-to-use switch and low-battery indicator. Two 9V batteries are included.

The HI-1800 comes complete with carrying case, beaker and operating instructions for $169.



Circle (28) on Reply Card

Industrial electrical tapes

Tesa offers 16 different electrical tapes in a range of base materials, dielectric strengths and insulation class ratings. The line features tesafilm tapes which are either polyester or kapton film tapes with dielectric strengths ranging from 2100 to 4200 V/mil.

Circle (29) on Reply Card

Receiving tubes

Sylvania has added nine receiving tubes to their electronic tube line. The new line includes: Tube EY500A16E4, designed primarily for damper service in color television receivers; PCL805/18GV8 contains a double triode/pentode for

vertical multivibrators; PCL86/14GW8 and ECL86/6GW8 contain high amplification triodes and pentodes for audio power applications; PL504/27GB5 and EL504/6GB5, beamed pentodes with Magnaval construction and a special anode for better dissipation. ☐

Circle (30) on Reply Card

Circle (11) on Reply Card

Circle (12) on Reply Card

test equipment report

Digital multimeter

Weston has designed the model 6100 3½-digit LCD display audio response digital multimeter. The unit features a five range audio response function which allows go-

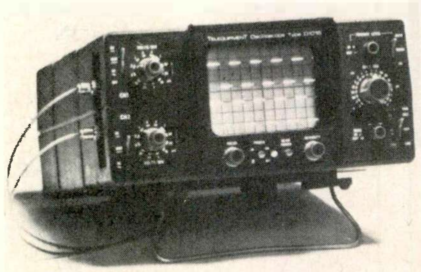
no-go testing to be performed without paying attention to the display and has instantaneous response. The unit also features five functions: ac/dc volts, ac/dc current and resistance.

The 1600 is priced at $139.

Circle (31) on Reply Card

15MHz dual-trace scopes

Telequipment's two new 15MHz scopes, the D1015 and D1016, feature 8 x 10 cm CRTs and color-coded front panels, 5mV to 20V/div vertical sensitivity, and triggering capa-

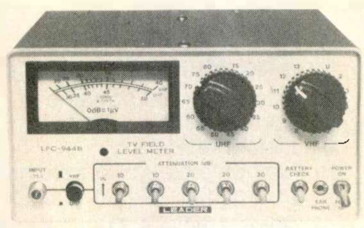


bilities including TV mode. The D1016 also features full sensitivity X-Y, differential, X5 vertical magnification and a variable time base.

Circle (32) on Reply Card

Strength meter

The model LFC-944B VHF/UHF field strength meter from **Leader** measures levels of 20 to 120dBμV on VHF channels. A built-in attenuator up to 80dB of attenuation in 10dB steps. The unit features VHF channel selection with accurate detented



The unit features VHF channel selection with accurate detented tuning and continuous UHF tuning, and is battery powered.

The suggested price is $512 complete.

Circle (33) on Reply Card

Scope probes

Model SP100, replacement 1X/10X scope probe, is available now from **Test Probes**. A ground reference switch position enables the scope input to be grounded at the probe tip. This feature serves as a positive means of trace identification, and allows a zero voltage to be selected from the probe. The cable has a flexible and rugged center conductor, strain relief at connector and probe head fittings, and a BNC-pin-diameter tip. For the 10X function, a 10-60pF trimmer range is provided.

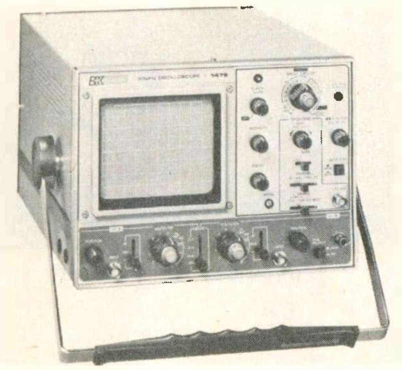
The SP100 comes complete with sprung hook, trimmer tool, BNC adaptor, IC tip, and insulating tip for $36.

Circle (34) on Reply Card

30MHz scope

The **B&K-Precision** model 1479 features an internal 160nS signal-delay line, minimum visible delay of 12nS. Rise time is 11.7nS or less. Other features include a 10-position vertical attenuator which covers 5mV to 5V per cm at an accuracy of +3%, 20 calibrated sweep positions from 0.2μsec/cm to 0.5 sec/cm (X5 magnification increases sweep speed to 40 ns/cm), and TTL-compatible intensity modulation. The 1479 has fully regulated power supplies and is designed to maintain accuracy over a 105-130VAC range. Optional accessories include a rack mounting kit and protective cover.

The unit lists at $1099.



Circle (35) on Reply Card

Microprocessor-controlled DVM

Sencore is now marketing a microprocessor-controlled auto-ranged DVM. Basically a 4½-digit instrument, the DVM-56 Microranger can be changed to a 3½ or 2½-digit DVM with the push of a button. The DVM-56 features a dc voltage accuracy of .075%, plus or

minus five counts, with 15M Ω input impedance. Three automatic peak-to-peak ac voltage ranges to 2KV at 100KHz, also are featured. Three automatic dB ranges to 1KV at 20KHz from -43 to +62dB, 1mV into 600 Ω, extends the use of the DVM to audio frequencies.

The DVM-56 is priced at $695.

Circle (36) on Reply Card

VHF signal generator

The **Leader** LCG-138 VHF signal generator is a calibrated source of test signals for CATV and MATV systems. The unit provides calibrated outputs on two high and two low VHF channels at accurate levels from 60 to 10dBμV in 10dB steps. It is battery powered.

The LCG-138 sells for $244. □

Circle (37) on Reply Card

photofact bulletin

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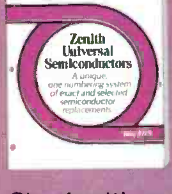

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