Poor Ham's Dynamic Component Analyzer

Build your own circuit detective.

by T. S. Rowinski KA1MDA

As technology becomes more complex, the test equipment needed to troubleshoot problems becomes more complicated as well. Twenty years ago, the only test gear required to repair virtually any consumer electronics product was a VOM, and an oscilloscope was a luxury many had to do without. Today, an oscilloscope is a must!

One of the newer diagnostic trends involves the use of active component analyzers. Part oscilloscope, part curve tracer, and part signal injector, these units typically fall into two categories: self-contained portables with built-in CRT, and accessory units (usually part of a test jig) designed to be used with an outboard oscilloscope. Both types are priced beyond the reach of the average ham or electronics hobbyist, with prices ranging from $400 to $1,000!

After a bit of research, it became apparent that all these units functioned on the same principle. The analyzer supplies a current-limited AC sine wave to the device being tested, and displays the resulting current and voltage relationships on an X-Y display CRT. This creates a "signature," a unique pattern which identifies the characteristics of the device being tested. The commercially available units also feature a myriad of bells and whistles, such as automatic signature comparison, various test frequencies, waveform storage, etc.

Since I already owned an oscilloscope, all I needed was an accessory-type analyzer. I sat down at the drawing board and came up with the Poor Ham's Component Analyzer. Although this unit lacks the bells and whistles of the big bucks analyzers, its basic effectiveness and operation are identical. The project itself is very easy to assemble, and requires only a handful of common junk box or hamfest parts. All components also have a high "fudge factor" and can be substituted for almost anything the builder has on hand. For those without a junk box, a parts list of Radio Shack equivalent part numbers is included. The best news, though, is that total cost of construction, if all parts are purchased new, is less than $25!

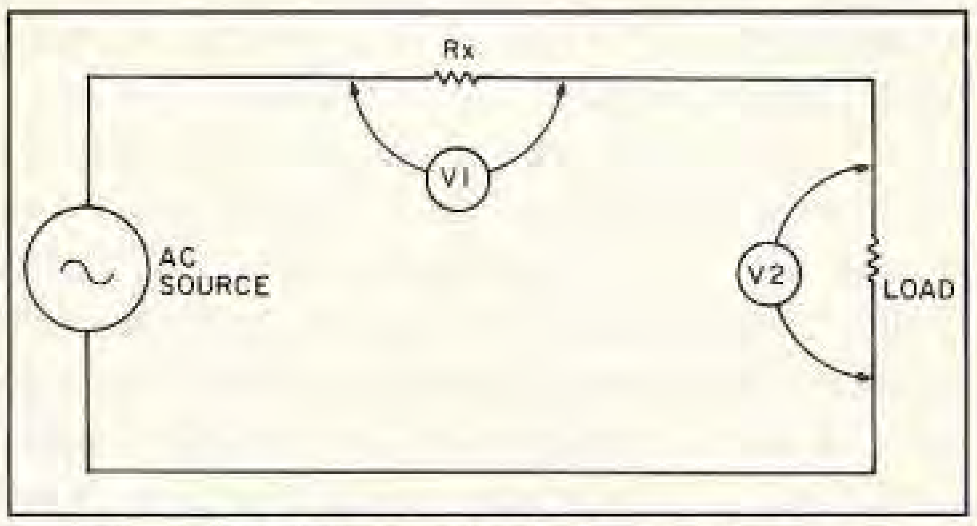

Figure 1. Theoretical circuit diagram.

How it Works

The basic circuit theory is quite simple (see Figure 1). A load is fed by an AC source through a current-limiting resistor. A voltage reading at point V2 indicates voltage across the load. According to Ohm's law (E = I/R), resistor Rx will develop a voltage drop proportional to the current passing through it. The higher the current drawn by the load, the higher the voltage drop across Rx. A voltage reading taken at point V1 is directly proportional to the current drawn by the load. If the load is purely resistive, both V1 and V2 would rise and fall together as the source voltage increased and decreased through each cycle. If we replace the load with a non-linear device such as a diode, V1 and V2 would no longer read in unison. During the first half-cycle the diode might be reverse biased, giving a high voltage and low current reading. During some point of the next half cycle, the diode would become forward biased and conduct, producing a high current and low voltage reading. If an X-Y oscilloscope were connected across points V1 and V2, the scope would display the diode's switching signature and become a dynamic component analyzer!

The actual circuit is not much more complicated than that! (Refer to the schematic in Figure 2.) Transformer T1 converts the 120 volt AC current to 12 volts across the full secondary winding, or 6 volts across the center tap to either end. Resistors R1 (50 ohm, 1 watt) and R2 (10k ohm, 1/4 watt) limit the maximum current which can be obtained from T1 on the low and high range respectively, and create the voltage drop which is fed to the scope vertical amplifier via J1 to display current. Note that the parts list shows two 100 ohm resistors for R1—this is because Radio Shack doesn't stock a 50 ohm, 1 watt resistor, so we make our own by connecting two 100 ohm resistors in parallel. If a 1 watt resistor between 47 and 56 ohms is available, it can be substituted for the resistors shown for R1 in the parts list. Switch S2 is a DPDT type and acts as a range selector. Section S2B switches between the 6.3 and 12.6 volt windings of T1, while section S2A connects the scope vertical input via J1 to the appropriate current-limiting resistor. The test leads are connected to J3, and the oscilloscope horizontal amplifier measures voltage at J2. I1 is a neon lamp assembly with built-in dropping resistor and acts as a power-on indicator. Switch S1 serves as the main power switch, and fuse F1 provides over-current protection in the event of shorted wiring or transformer windings.

Construction

Before beginning construction of this project, please remember that this circuit is powered by 120 volt AC current. The voltages present on the primary side of T1 can be LETHAL! ALWAYS UNPLUG THE UNIT FROM THE ELECTRICAL OUTLET BEFORE OPENING THE CASE! Likewise, never attempt to troubleshoot or modify the dynamic component analyzer while the circuit is live. When working on the unit, do not rely on the front panel power switch to remove power—always unplug the power cord! For additional safety, I recommend that the unit be assembled in a plastic case—do not use a metal chassis! If using a polarized power cord, connect the wider blade to one end of T1's primary and the narrower blade to fuse F1.

Component location and layout is non-critical, and virtually any form of construc-

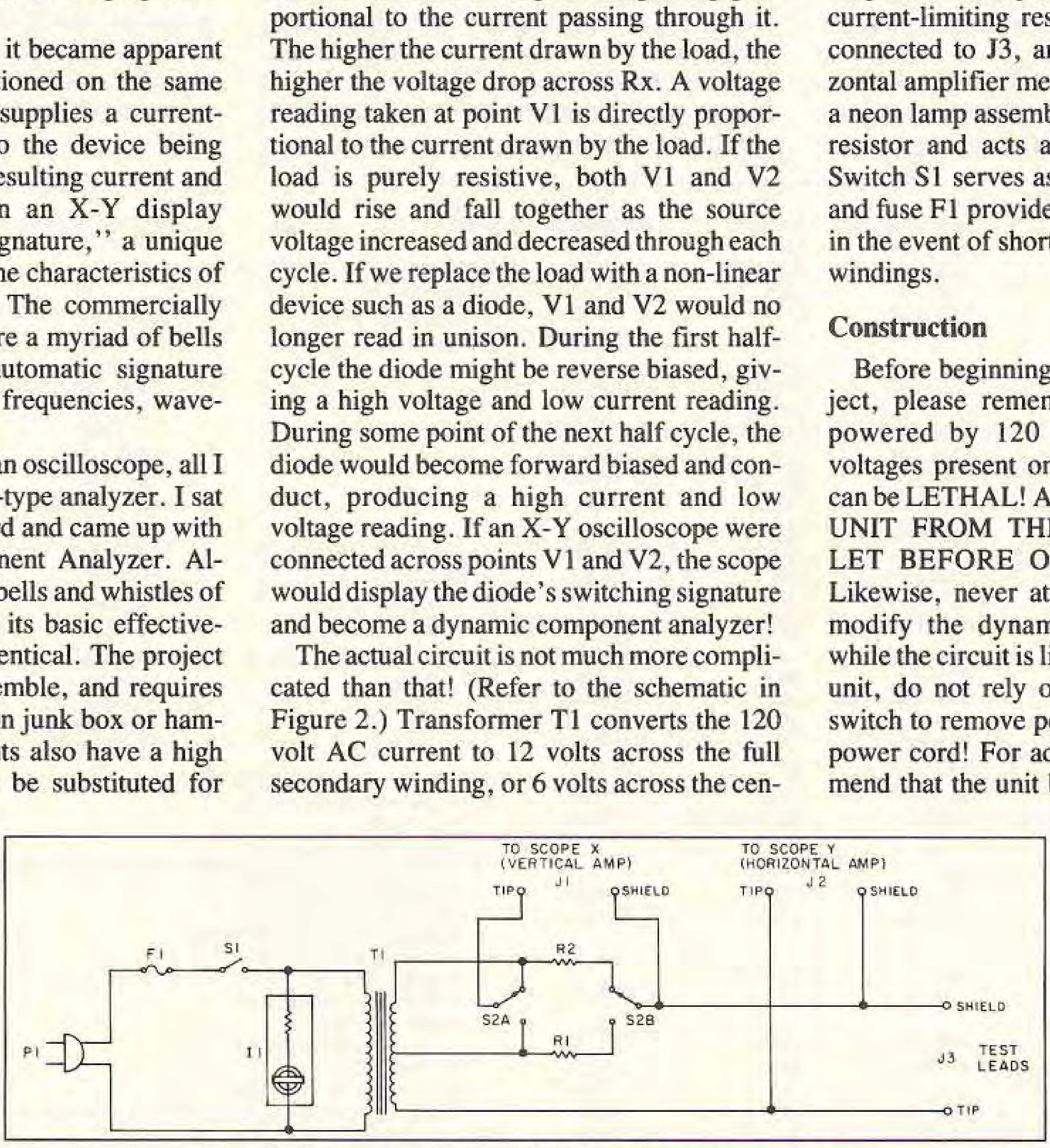

Figure 2. Schematic diagram for dynamic component tester.

tion can be employed, such as perf board, printed circuit board, or point-to point wiring. The prototype incorporated point-to-point wiring across a single, insulated solder-lug terminal strip. The unit can be housed in nearly any type of enclosure, as long as the material is non-conductive. The original unit was built into a 5-1/4" wide, 2-1/2" high, 5" deep plastic project case, which allowed for an open, uncluttered parts layout. If the selected enclosure has no provisions for air circulation, drill five or six 1/4" holes in an inconspicuous area to allow for the escape of heat generated by transformer T1. Although T1 operates at a relatively cool temperature, heat build-up could become a problem if the analyzer were housed in a small, non-vented enclosure and operated for extended periods of time. Although Radio Shack appears to have discontinued the enclosure used in this article, they offer a number of other suitable enclosures. Figure 3 shows the front panel layout used for the original. I used BNC jacks for J1/J2/J3, although banana jacks or five-way binding posts could have been used just as easily. When wiring the jacks, pay close attention to the polarity—all three jacks should have their negative (shielded) lead hooked to the same point. Reversing the connections on one jack will cause the analyzer to display erroneous patterns or not work at all!

For those who prefer to roll their own with whatever parts are on hand, only a few simple calculations are needed to design a functional unit. Transformer T1 is the heart of the project, and must have a center tap secondary with a terminal voltage between 9 and 20 volts AC. Let's assume the builder has an 18 volt transformer on hand. We need to calculate the ohmic value for R1 to limit current in the low range (R1) to no more than 125 mA. Our hypothetical transformer develops 9 volts across half the secondary, so we use Ohm's law (R = E/I) which gives us R = 9/.125 (remember to convert milliamps to amps), or 72 ohms. The next highest value commercially available resistor is 100 ohms. Using I = E/R, we can calculate the actual current as I = 9/100, which produces 0.09 amp, or 90 mA. To calculate power rating, we use the formula P = IE. Plugging in the numbers, P = 0.09 x 9, or 0.81 watts. Thus a 100 ohm, 1 watt resistor is required for R1. To calculate the value of R2, we use 18 volts, since the entire transformer winding is used in HIGH range, and we want to limit current to a maximum of 1 mA. Using R = E/I, we get R = 18/0.001, or 18,000 ohms. The next highest commercially available value is 22k ohms. Calculating for actual current using I = E/R produces I = 18/22,000, or 0.00081 amps (0.81 milliamps). Power rating (P = IE) calculates to P = 0.00081 x 18, or 0.0145 watts. So, for R2 we need a 22k ohm, 1/4 watt resistor. Using this example, it is possible to quickly calculate the proper component values and for virtually any transformer!

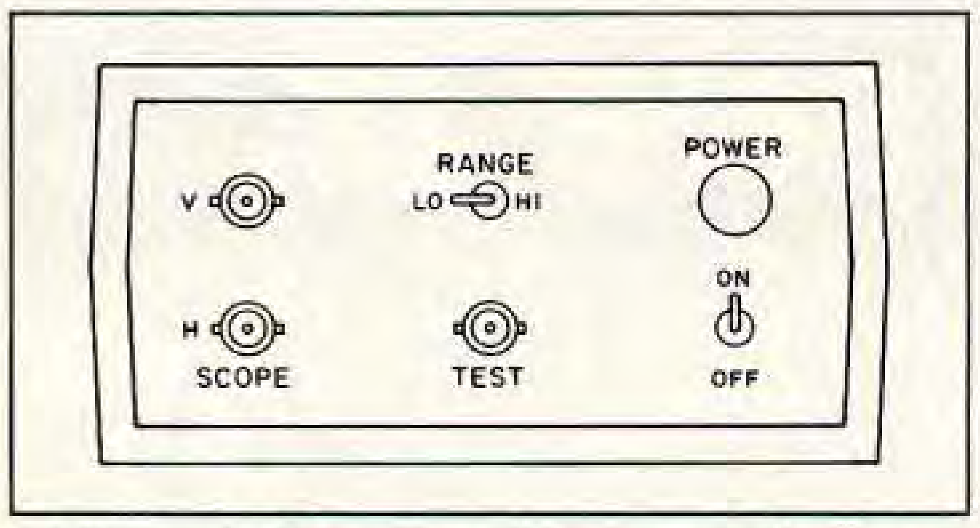

Figure 3. Front panel component layout.

Initial Check Out

Before plugging in the analyzer, a few safety checks must be made to insure proper wiring and operator safety. The values listed below are for units built with the parts specified in the parts list. Set a VOM or DMM to the OHMS x1 range, and connect it across the analyzer's power cord. The meter should measure infinite resistance with S1 set to OFF, and about 160 ohms with S1 in the ON position. Next, connect one lead of the meter to the negative (or shield) terminal of J3, and touch the other lead to the shield connection of J1 and J2. The meter should read 0 ohms (dead short). Connect the meter across J1 and read the resistance—it should be about 50 ohms with S2 in the LOW position and 10k ohms with S2 in the HIGH setting. Switch the meter to the highest resistance range available (Rx1M on a VOM, or Rx20M on a DMM). Connect one meter lead to a blade on the power cord, switch S1 to the ON position, and touch J1, J2, and J3 with the other lead (be sure to check both the shield and the center contact). If a metal case was used, touch the case as well. The meter should read infinite resistance. Move the meter lead on the power cord to the other lug and repeat the above tests. Again, the meter should read infinite resistance. If the meter reads any resistance at all, stop and check the wiring. Do not proceed to the next step unless all the above tests check out correctly!

Plug the analyzer into a 120 volt outlet, and turn switch S1 on. Indicator lamp I1 should glow. Switch the VOM or DMM to read AC volts, and hook the leads across J3. About 6.5 volts should be present with S2 in the LOW position. Switching S2 to HIGH should cause the voltage to increase to approximately 13 volts. Connect the meter across J2—the same readings should be observed. Connect the meter across J1—it should read 0 volts. Now short the terminals at J3. The meter should indicate around 6.5 volts with S2 in LOW and around 13 volts with S2 set to HIGH range. If all readings were correct, the analyzer is working properly.

Analyze Any Situation

Now we're ready to put the component analyzer to work. Set up the oscilloscope for X-Y operation, and connect J1 to the scope's vertical input and J2 to the horizontal input, making sure the scope inputs are set to DC coupling. Do not use AC coupling, as the low frequency reactance of the scope's internal DC blocking capacitors may distort the wave form. Turn the analyzer on, set range switch

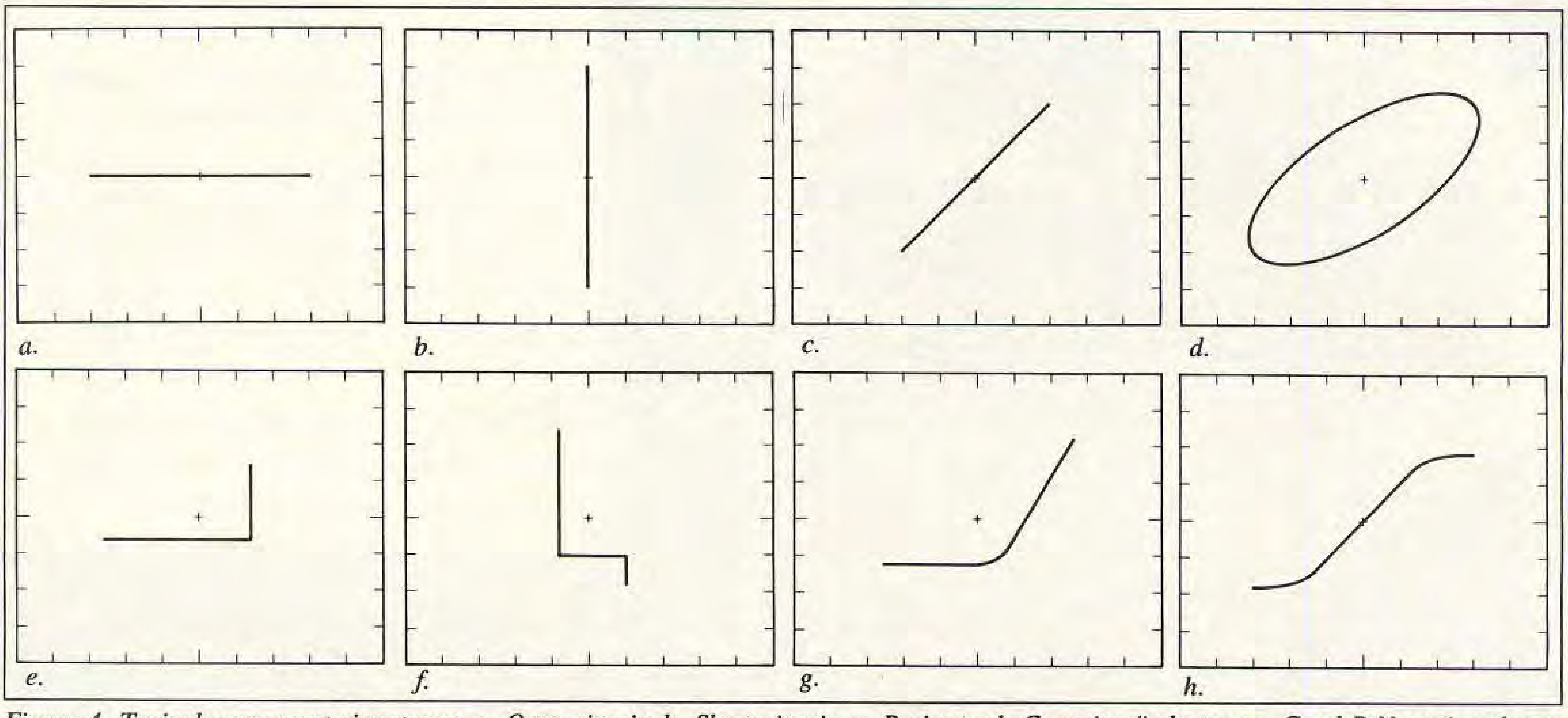

Figure 4. Typical component signatures: a. Open circuit; b. Short circuit; c. Resistor; d. Capacitor/inductor; e. Good P-N semiconductor junction; f. Zener diode; g. Leaky semiconductor junction; h. Non-linear resistance.

S2 to HIGH, and then switch the scope on. A horizontal line should appear on the CRT. Now short the test leads at J3, and the trace should become a vertical line (if these displays are reversed, swap the connection to the scope). Never turn the analyzer off with the scope on, as this will stop all trace sweep on the oscilloscope, and the resulting stationary spot could burn the CRT if left in place too long! Adjust the scope's input attenuators to obtain a nearly full-scale deflection on the CRT in both axes (about 5 volts per division). The actual attenuator setting or scope calibration is unimportant, since we are not interested in measuring absolute voltage or current values. The trace shape is the important thing.

The dynamic component analyzer can be used to test discrete components in or out of circuit, and can also be used to isolate defective stages in complicated circuits. To test components out of circuit, clip the component across the test leads at J3, and observe the waveform displayed on the oscilloscope. Small signal diodes, transistors, and IC chips are tested in LOW range, while power transistors and rectifiers should be tested using the HIGH range. Resistors, capacitors, and inductors can be tested on either range—simply select the range which gives the most detailed display. When testing capacitors, pay attention to the voltage rating, especially on electrolytics!

Testing components in circuit, or attempting to isolate a defective stage, requires a slightly different procedure. First and most important, do not attempt to use the analyzer on powered circuits! Always make sure the device under test is disconnected from its power source, or severe damage could occur to the analyzer, scope, or unit under test. This warning holds true for the commercial units as well. Dynamic component analyzers are not meant to be used on live circuits!

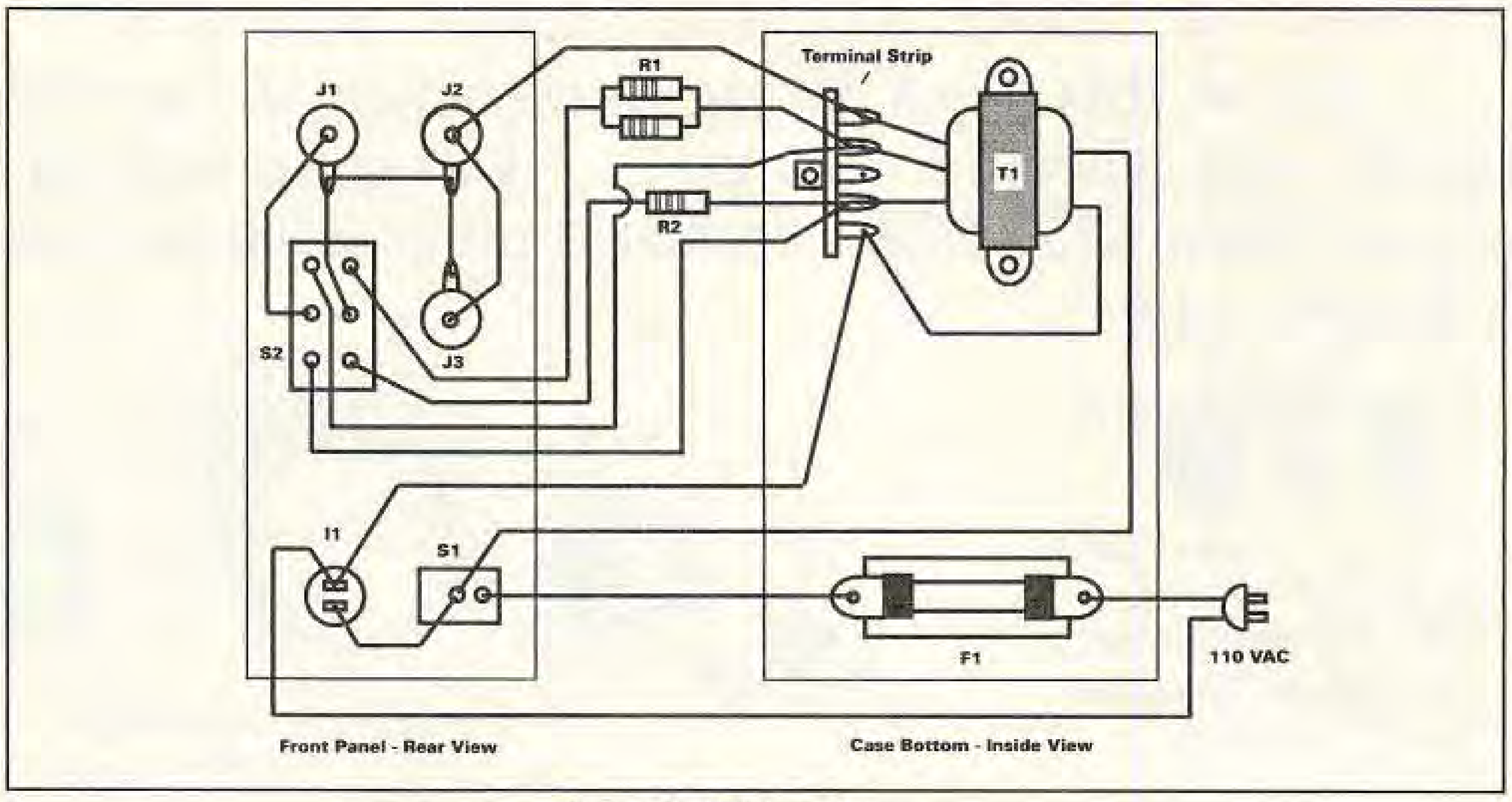

Figure 5. Wiring diagram.

To properly test a component in circuit, a known-good "reference" circuit is required, since multiple current paths will tend to distort the analyzer signature. The test leads are alternately placed across identical points on the good and bad boards. Although the resulting pattern may not look anything like it should, the scope traces should be identical between the two boards. When identical test points produce different signatures, the technician has found the defective stage, and further comparison on a part-by-part basis should quickly weed out the defect. Although most readers don't have a spare TS-440S or IC-735 lying around, this is still a viable troubleshooting technique for audio equipment. Most faults with stereo components typically involve only one channel. Thus, the functional channel can be used as the reference for the bad channel!

Component Signatures

Most components under test will produce one of eight main types of traces, or signatures. An open circuit (Figure 4a) produces a horizontal line, while a dead short will produce a vertical trace (Figure 4b). A resistor will produce a diagonal line (Figure 4c), the angle of which will depend on the value of the resistor. Very low resistances will produce an almost vertical trace, while very high resistances will tilt the trace just slightly off the horizontal baseline. Capacitors and inductors cause the trace to appear as an oval (Figure 4d). The shape and angle will vary from a very narrow ellipse to a large, broad circle, depending on the actual value of the component under test. A good P-N semiconductor junction should appear as a right angle (Figure 4e)—a vertical line meeting a horizontal line at a very sharp, well defined 90 degree angle. A skewed vertical line, or a rounded, poorly defined intersection between the two lines (Figure 4g) indicates a leaky semiconductor junction. If the pattern appears reversed, or upside-down, don't worry, as it is a function of test lead polarity. A zener diode should produce a stair-step type pattern (Figure 4f). Again, it doesn't matter if the pattern appears upside-down from the example—the overall shape and definition of the right angles are the important things. Finally, a non-linear resistance will produce the trace shown in Figure 4h. Non-linear inductance and capacitance will produce a similar trace, except that it will appear as an ellipse instead of a line. Three terminal devices such as transistors are tested as three discreet P-N junctions. Hooking the test leads across the emitter and base, the base and collector, and finally the emitter and collector, should produce traces for a good P-N junction, a good P-N junction, and an open circuit, respectively. Although it may seem a bit complicated, the basic patterns are easily learned within a few hours. The quickest way to learn is to grab a handful of junk-box parts and observe the signatures each produces!

The prototype unit described in this article has been in use for a little over six months now, and has proven itself extremely useful, especially in testing semiconductors. I previously tested transistors with an industrial digital multimeter with a built-in diode test function. I was literally shocked to discover how many of my surplus junk box power transistors were actually bad! Although the DMM indicated all the devices were good, the component analyzer showed over 40% of the devices suffered from excessive emitter-collector leakage, poor junction performance, and gross non-linearities! And checking junctions with the analyzer is twice as fast as using the DMM, since there is no need to reverse the test leads for front-to-back comparisons! The tester has also weeded out a number of capacitors which were either leaky or exhibited excessive amounts of series resistance. All in all, the unit has easily paid for itself many times over. The prototype was so successful in the shack that I'm building a second unit for the work QTH!

Dynamic Component Analyzer Specifications

Maximum open-circuit test voltage:
- Low Range : 9.3 VAC peak (6.5 V RMS)
- High Range: 18.8 VAC peak (13 V RMS)

Maximum short-circuit current:
- Low Range : 123 mA rms
- High Range: 1.2 mA rms

Test Frequency: 60 Hz
Input voltage: 120 volts AC
Maximum input power consumption:
- Low Range : 1.8 watts
- High Range: 1 watt

Parts List for Active Component Tester

Qty.	Description	SymbolRS#Price
1	12.6V CT transformer	T1273-1365$4.29
1	6-foot AC power cord	P1278-1255$1.19
1	5-point lug strip	274-6884/$1.29
1	SPST toggle switch	S1275-624$2.29
1	DPDT toggle switch	S2275-626$2.59
1	neon lamp assembly	I1272-7052/$1.79
1	fuse holder	270-7392/$.99
1	120V, 1/4A fuse	F1270-12713/$.79
2	100 ohm, 1W resistor	R1*271-1522/$.29
1	10 k ohm, 1/2W resistor	R2271-0312/$.25
3	BNC chassis mount jack	J1-3278-105$1.39/ea.
1	plastic case	270-250$3.99

Total cost of project: $23.92
*Connect the two 100 ohm, 1 watt resistors in parallel to create the 50 ohm resistor needed for R1.