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JANUARY-FEBRUARY 1975

ALL ABOUT POWER SUPPLIES

by Dick Gasperini, Editor

Virtually every piece of electronic gear has a power supply so the probability of having to repair a failure is rather high. Therefore, knowledge of power supply operation is essential for repair personnel.

A power supply that may look familiar is in Figure 1. It will convert the AC line voltage to a DC voltage, say 175 volts, for our load, lumped here as a single resistor R_L.

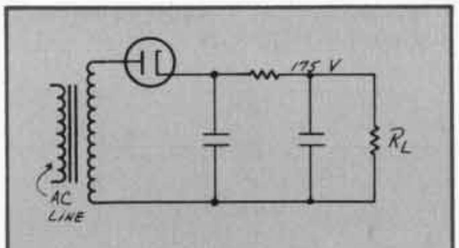


FIGURE 1.

This type of power supply has several shortcomings. Since this supply can be looked upon as an ideal battery with a resistor in series, it becomes clear that the output voltage will change if the load changes. See Figure 2.

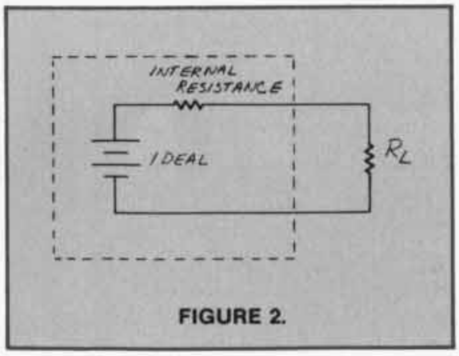


FIGURE 2.

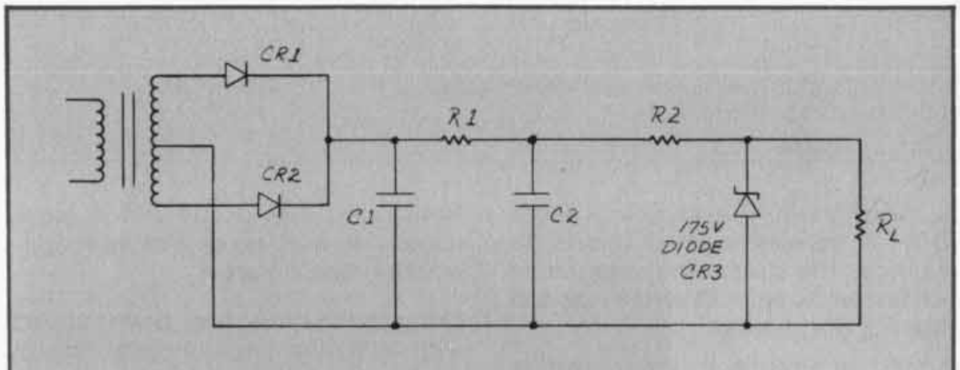


FIGURE 3.

This change of output voltage with a change in load ("load regulation") would not be a problem if we always had a fixed load that demanded a constant amount of current. Most times, though, a load is not constant. Therefore, the power supply voltage will change and this may be undesirable.

Also, what happens if the line voltage varies by 20%? In this supply the output voltage will again vary. This supply lacks "line regulation".

To obtain a more stable voltage we will want an improved supply.

One improvement is to change to solid state and to a full wave circuit. This gives a lower internal impedance and therefore better load regulation. (This also has other benefits, like reduced ripple.) A bigger improvement, though, will result from using a breakdown diode. See Figure 3.

The breakdown diode will start drawing current when its breakdown voltage is reached. Thus, as the output voltage starts to rise above 175V, the breakdown diode will conduct heavily, causing more voltage to be dropped across R2. If the output voltage were to start to drop below 175V, the diode would conduct less, dropping less voltage across R2. Thus, the diode helps to stabilize the output voltage.

This technique does have its limitations. Assume that CR3 is rated at 20 mA. We would select the value of R2 so that 10 mA of current flowed thru CR3. If the load were reduced by 10 mA, the voltage would tend to rise and CR3 would conduct more current, keeping the voltage at 175V. Similarly, if the load were to draw more current, less current would be drawn by CR3, again stabilizing the voltage. But we are very limited in the load variation that can be compensated with a breakdown diode.

The output voltage is also changing somewhat during this process.

IN THIS ISSUE

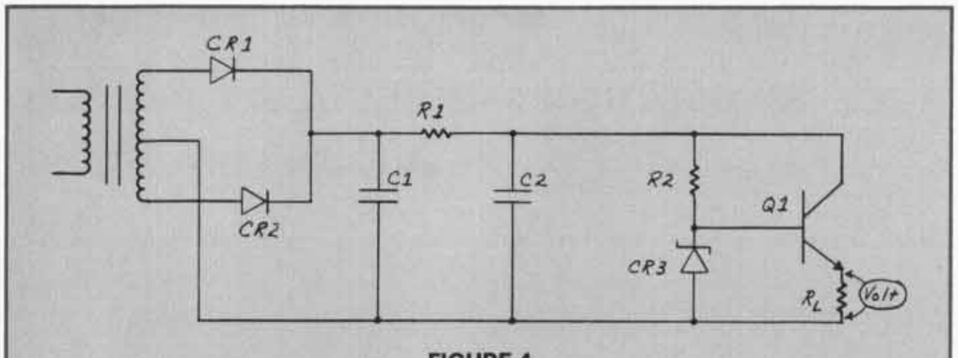


FIGURE 4.

A breakdown diode has about 10Ω of resistance, and this is, in essence, the output impedance of our power supply. This may be too high for our needs.

Putting an emitter follower on this circuit will reduce the impedance by about the gain (β) of the transistor. See Figure 4.

This circuit operation can be understood easily by recognizing that the base of Q1 will have a fairly constant voltage on it (developed across CR3). If the output voltage (emitter of Q1) drops more than one diode drop (0.6V for silicon, 0.2V for germanium) below the base, Q1 will tend to turn on harder, raising the output voltage. If the output voltage were to rise, Q1 will be biased off. Thus, the output voltage is fixed at the breakdown voltage of CR1 minus one diode drop (B-E drop of Q1).

If this power transistor has a gain of 10, the output impedance is now about 1 ohm (that is, 1 mA change in load current will cause a 1 mV change in output voltage). This is still too high for many circuits, so we can add another emitter follower. See Figure 5.

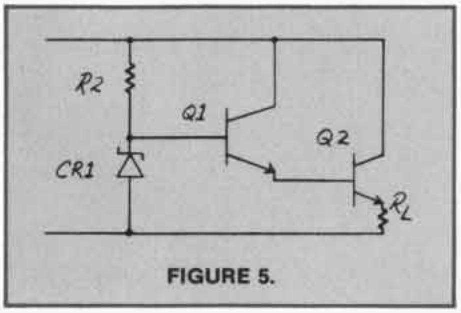


FIGURE 5.

Redrawing this circuit in the more usual way may make it more recognizable. See Figure 6.

Current limiting has been added with a series resistor and several diodes. As increased current flows in the load, additional voltage drop is realized across R3. When the drop across R3 starts to exceed one diode drop, CR4, CR5 and CR6 will start to conduct, robbing base-emitter current away from Q1, causing it to conduct less. This limits the current flow, and the output voltage will drop somewhat.

The resistance of R3 will determine the current limiting point.

It is interesting to note, however, that the circuit has stabilized at maximum current and nearly normal output voltage. Therefore, the power dissipated in the power supply circuit and the load is very high.

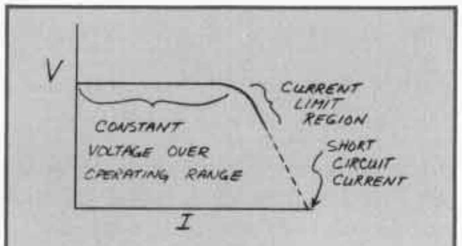


FIGURE 8.

Sharper turnoff can be achieved by adding a transistor to the current limit circuit. See Figure 7. We still will have a high level of power dissipation since enough current must be flowing in R3 to keep Q3 conducting.

A typical plot of voltage vs current is shown in Figure 8.

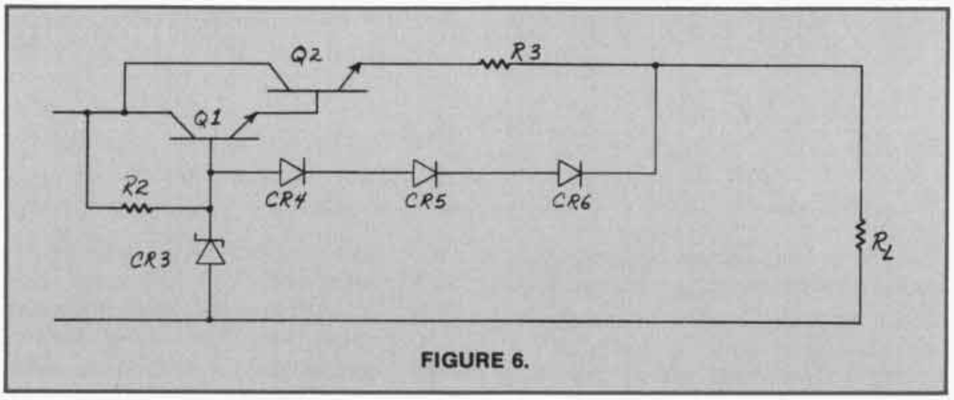


FIGURE 6.

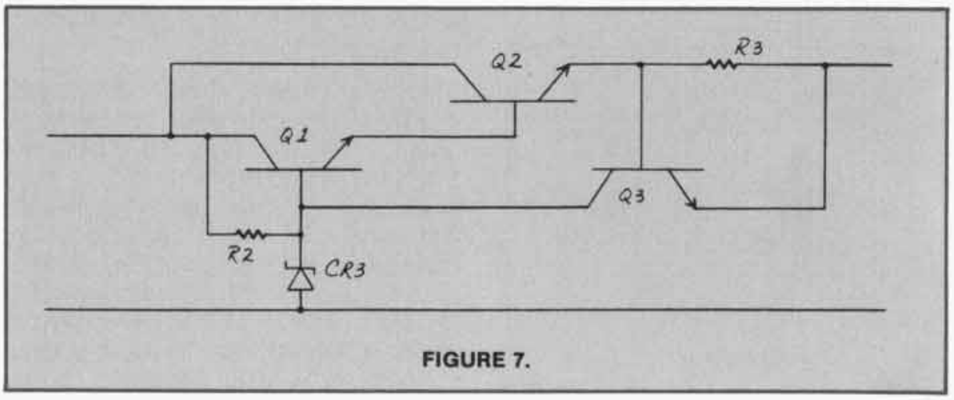


FIGURE 7.

FOLDBACK

Since current limiting comes into play when there is a failure (or other abnormality), it may be advantageous to be able to shut off the power supply circuit, rather than continue to dissipate all that power. This technique is called foldback and is shown graphically in Figure 9. In the +180V supply in Figure 10, once the Q2 circuitry is turned on, it will continue to conduct, holding Q1 off.

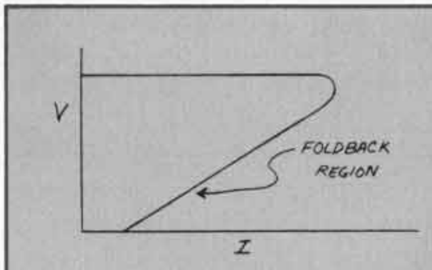


FIGURE 9.

Notice that the +5V regulator circuitry is integrated into a TO3 package. While this package looks like an ordinary power transistor, it contains the series pass transistor(s), breakdown reference diode and associated circuitry needed for proper regulation. These fixed voltage regulators can be purchased for the more commonly used power supply voltages such as 5V and 12V. Some are available with current limit capability.

RIPPLE

Modern electronic circuits require very clean (ripple-free) power supplies. Looking back at Figure 4, we see that the output voltage is very dependent on the voltage dropped across CR3. But this will vary slightly with the current through it (recall that a breakdown diode has a nominal internal resistance of about 10Ω). Therefore if the line voltage increases, the voltage on C2 will increase, resulting in increased current through CR3 and an increase in the output voltage. Also the voltage on C2 varies during each rectification cycle. The peak of the rectified sine wave (ripple) will be passed through Q1 to some extent. Since even this small variation in the output voltage may be undesirable, you may see power supply circuits with a constant current source for CR3. See Figure 11.

In essence, a constant voltage is dropped across diodes CR7 and CR8. This limits the B-E current of Q4, resulting in a constant current through CR3.

In actuality, the voltage across CR7 and CR8 will vary slightly and the next evolution would be a constant current source for them. This can be done easily with two transistors. See Figure 12. Transistor Q4 receives a constant bias from the drop across Q5. This gives a constant current through R5, which keeps a constant bias on Q5 and a constant current through CR3.

PROTECTION

Current limiting may not be enough protection for the load. What happens if there is a failure in the power supply circuit, such as a shorted Q2? The output would rise to the full unregulated voltage.

If this were the +5 volt supply for all the IC's in an instrument, most of the IC's would very likely be destroyed. Therefore, it may be

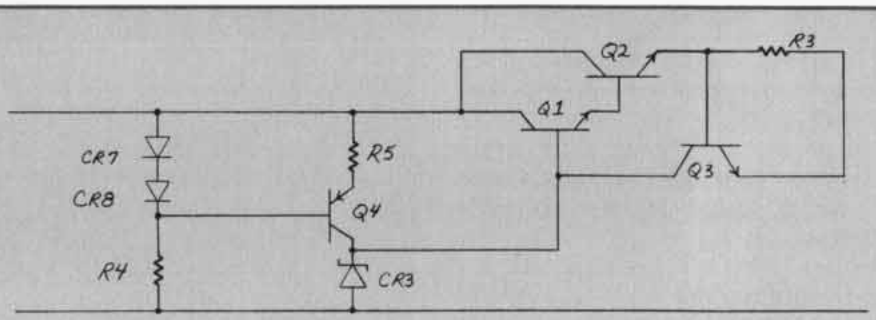


FIGURE 11.

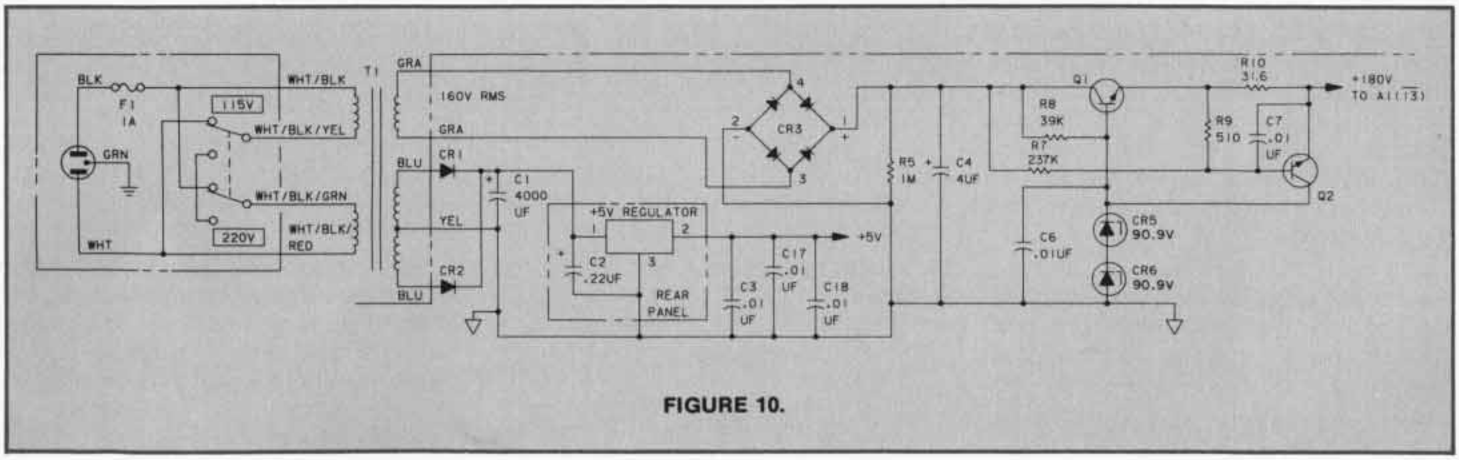


FIGURE 10.

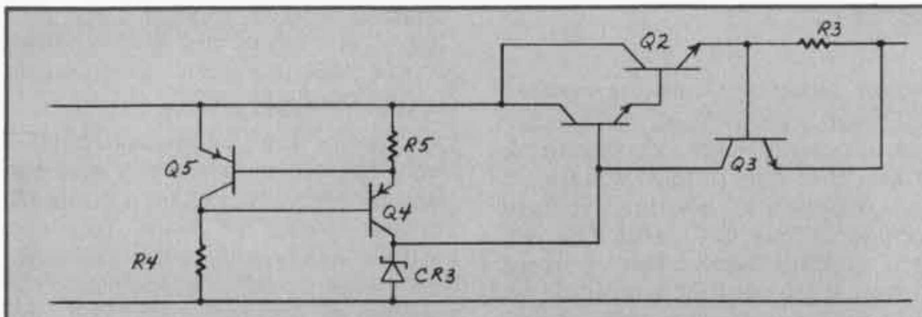


FIGURE 12.

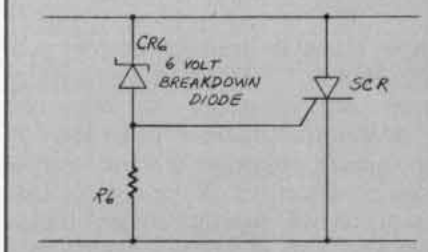


FIGURE 13.

advisable to build in additional protection in the form of a "crowbar circuit". This is generally an SCR that monitors the output voltage and shorts it to ground if the voltage rises too high. See Fig. 13. If the supply voltage rises above 6 volts, CR9 would start to conduct, developing a voltage across R6. This would cause the SCR to fire, shorting out the power supply line (and hopefully blowing a fuse).

ISOLATING POWER SUPPLY DRIFT

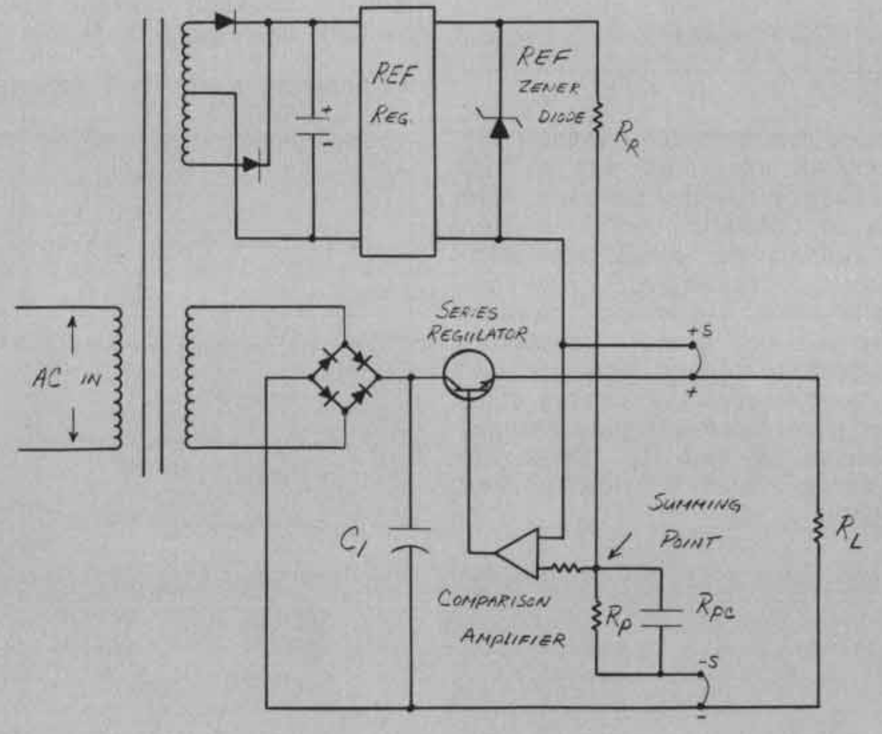
by John Whidden

What is the most effective way to isolate a drift problem in a power supply?

To answer that question, let's look at how a power supply normally operates.

The programming input to a power supply consists of a resistive divider (R_R and R_p) connected between reference zener and -S terminal. (Refer to figure.) The common point of R_R and R_p is the input to the amplifier and is called the summing point. When the power supply is operating properly, the output voltage equals the sum of voltage across R_p plus the offset voltage. Therefore, variation in either of these will cause a change in the output voltage.

The most effective way to isolate a drift problem is measure and record the reference supply voltage, the summing point voltage and the output voltage at any convenient interval (such as every half hour).

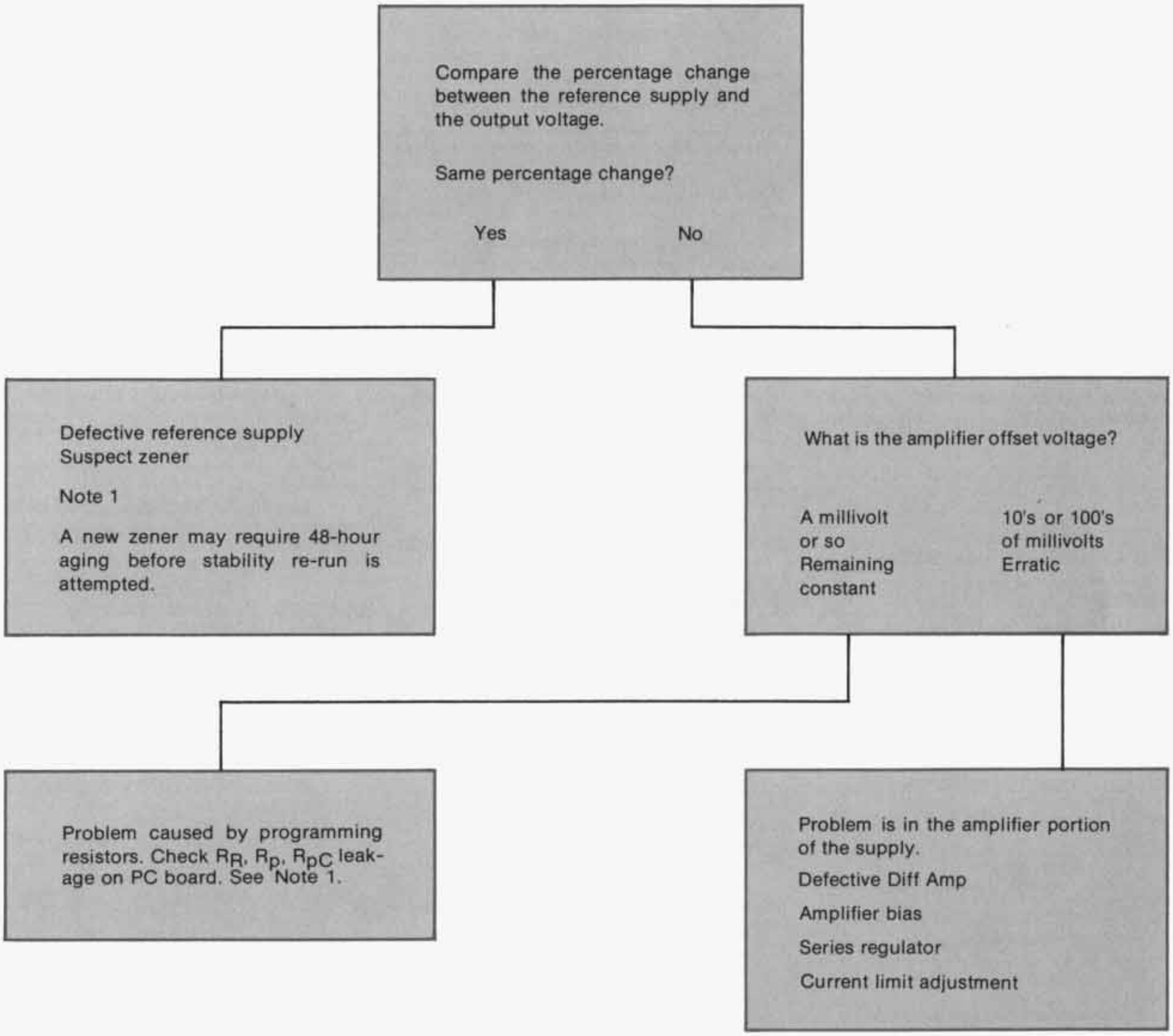


Measure and record the following voltages:

1. +S to -S (output)
2. +S to summing point (offset)
3. +S to reference zener (reference)

The important thing is not how often the measurements are made but that they are made in the same manner and with the same equipment. Usually only 3 or 4 sets of measurements are necessary to evaluate the power supply.

The following algorithm may be useful to narrow the trouble:



Compare the percentage change between the reference supply and the output voltage.

Same percentage change?

Yes No

Defective reference supply
Suspect zener

Note 1

A new zener may require 48-hour aging before stability re-run is attempted.

What is the amplifier offset voltage?

A millivolt or so Remaining constant

10's or 100's of millivolts Erratic

Problem caused by programming resistors. Check R_R, R_p, R_{pC} leakage on PC board. See Note 1.

Problem is in the amplifier portion of the supply.

Defective Diff Amp

Amplifier bias

Series regulator

Current limit adjustment

Note 1. Circuit coolant sprayed on individual 20PPM resistors will generally cause 0.25 and 0.5% change in the output. A defective resistor might cause a 1% to even 25% change.

John Whidden joined HP in 1961 and became involved with power supply service and applications for field service and customer training. John now provides factory back up for field service and prepares service information for instruction manuals and service notes.

supplement to BENCH BRIEFS SERVICE NOTE INDEX

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1331A/C-12. 1331A serial prefix 1424A through 1448A; 1331C serial prefix 1426A and below. Intermittent erasing. Supersedes 1331C-3.

1331A/C-13. 1331A serial prefix 1424A and below; 1331C serial prefix 1426A and below. Modification to add pattern correction adjustment.

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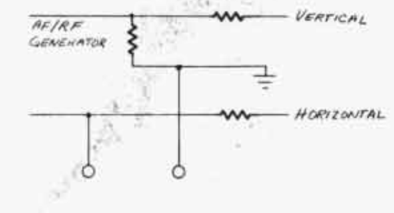
If there is something you have to share with other *Bench Briefs* readers, let us hear from you.

Mr. Stanley:

The transistor checker (Sept-Oct '74 and Nov-Dec 74) can also be used for impedance matching by the following alteration:



Also by use of AF or RF generator, I assume the checker can be used to show faulty transistors which instead of bad junctions the h_{fe} has deteriorated. I am going to pursue this but my scope is only good to 10 Mc which handicaps my results. Perhaps you might try it.

Incidentally, the checker obviously can be used to locate bad connections, open PC patterns, open lamps, poor solder connections (especially if they exhibit resistance or act as a diode), and any other applications where continuity is required.

After locating the area of the failure, I immediately switch to the checker and appear to cut servicing by at least 75% total time. I found the circuit in Radio-Electronics magazine about 3 years ago, but your articles have allowed expansion of the use as now I know WHY it works as it does.

Sincerely,

J.R. Chamberlin
R7 School District
Lee's Summit, Missouri

h_{fe} rarely deteriorates as it is primarily set by the doping ratios which do not change easily. However, leakage can change which causes an operating point shift. Also, h_{fe} decreases with frequency and this is why the data sheet value is given at a specific frequency. Any external (or internal) capacitance change will thus cause a change in this high frequency value of h_{fe}.

George Stanley

More on Transistor Checker

The resistance values for the transistor checker (Figure 8) in the November-December issue are slightly different than those shown in the September-October issue. The two circuits are electrically identical for all practical purposes. In one case, the switch shorts out a resistor and in the other case it adds a resistor in parallel. Incidentally, in the November-December issue, the output voltage of the transformer (Figure 8) is not shown. It is 6 volts AC --- the same as in the September-October issue.

We're thinking of running a series of pictures on the interpretation of transistor checker waveforms. Some are mighty strange especially when doing incircuit testing. Even an out-of-circuit germanium power transistor can show an unusual collector-base waveform because of its relatively high I_{CEO} leakage current.

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