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DIVISION

INCREASED OUTPUT RESISTANCE FOR DC REGULATED POWER SUPPLIES

APPLICATION NOTE 83

SEPTEMBER, 1966

INTRODUCTION

Normally it is desired to use a regulated Constant Voltage power supply with output impedance as close to zero as possible. In some cases, however, it is desired to increase the output resistance in a predictable and controlled fashion. Such applications arise, for example, when it is desired to simulate a battery, a less well regulated power supply, or to produce a power supply whose output voltage decays linearly with output current according to some prescribed formula. In this Application Note is given a method for accomplishing the increase of output resistance of a well-regulated Constant Voltage power supply on an exact basis. This method is applicable to all Constant Voltage supplies which are remotely programmable (regardless of rating), and has the additional advantage of decreasing the dissipation associated with the resistive loss.

METHOD OF INCREASING OUTPUT RESISTANCE

IDEAL CONSTANT VOLTAGE POWER SUPPLY

Figure 1 shows the Thevenin equivalent circuit and the output characteristic associated with an ideal Constant Voltage power supply. The equivalent source voltage E_O is adjustable but has no series equivalent resistance; at any output level, the voltage presented to the load is independent of the current required by the load. Modern well regulated power supplies conform remarkably well to the characteristic of Figure 1, with output resistances of less than 1 milliohm at DC.

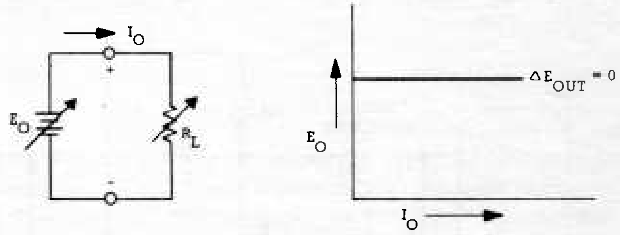

Figure 1. Ideal Constant Voltage Power Supply

EFFECT OF OUTPUT RESISTANCE ON CONSTANT VOLTAGE POWER SUPPLY OUTPUT

Figure 2 shows the Thevenin equivalent circuit for a Constant Voltage power supply in series with some equivalent source resistance R_T. The output voltage at no load equals E_T, the Thevenin equivalent open circuit voltage. As the current through the load is increased due to a decrease in load resistance, the output voltage decreases, in proportion to the resistance R_T.

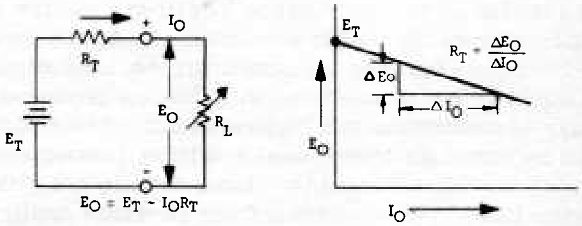

Figure 2. Constant Voltage Power Supply with Series Output Resistance

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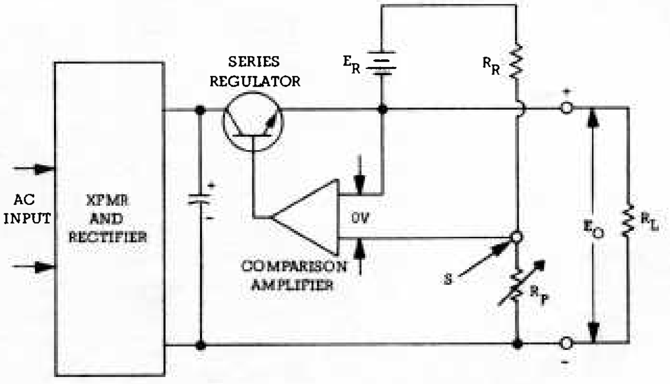
Printed in U.S.A.

NORMAL WELL-REGULATED CONSTANT VOLTAGE POWER SUPPLY CIRCUIT

Figure 3 shows the simplified circuit diagram applicable to nearly all ⓗⓟ regulated Constant Voltage power supplies. This diagram, although shown in terms of a supply which uses an NPN series regulator and a reference circuit tied to the positive output buss, can also be applied to supplies employing a PNP series regulator and a reference circuit tied to the negative output buss — merely change all plus signs to minus, all minus signs to plus, and invert the reference battery symbol.



$E_O = E_R\ (R_P/R_R)$

Figure 3. Regulated Constant Voltage Power Supply

The rectified DC is fed through a series regulator to the output terminals of the load. A reference circuit develops a voltage across R_P equal to the desired output voltage. If the output voltage does not equal the voltage across R_P, the input voltage to the comparison amplifier is not zero, and the amplified output of the comparison amplifier changes the conduction of the series regulator. This changes current through the load resistor until the load voltage is equal to the desired output value. Alternative ways of describing this null-seeking servo action can be based on operational amplifier concepts or bridge feedback concepts. More details are given in the Hewlett-Packard/Harrison Division Application Manual.

Any of these methods of analysis leads to the output voltage equation $E_O = E_R\ (R_P/R_R)$, where E_R is the internal reference voltage, R_P is the front panel voltage control, R_R is the resistor connecting the summing point S to the reference source, and the feedback amplifier is assumed to have a very high value of open loop gain.

CONSTANT VOLTAGE POWER SUPPLY WITH PROGRAMMABLE OUTPUT RESISTANCE

If it is desired to increase the output resistance of a Constant Voltage power supply of small or even moderate output current capability, it is practical to add a resistor of the desired value in series with the output terminal. However, if it is desired to increase the output resistance of a high current power supply, or to conveniently vary this output resistance, the method of adding a single output resistor becomes impractical because of the dissipation required and the lack of easily varied high power resistors. In such instances, the external addition of a small load current resistor R_S and an associated feedback resistor R_U causes the load voltage to drop with output current in a predictable and remotely controllable fashion.

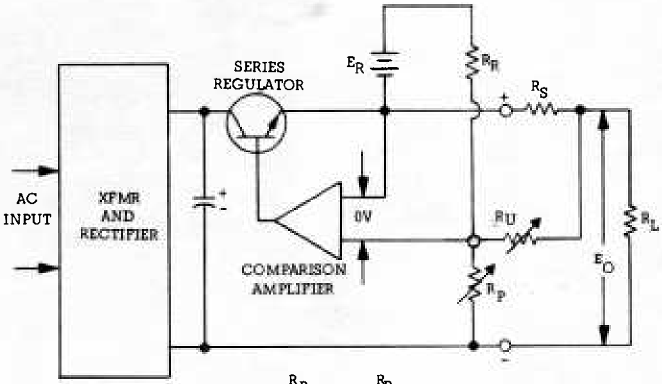
The output voltage equation is

$$E_O = E_R \frac{R_P}{R_R} - I_O R_S \left(\frac{R_P}{R_U} + 1\right).$$

This equation is of the form $E_O = E_T - I_O R_T$, where $E_T = E_R\ (R_P/R_R)$, the Thevenin equivalent open circuit voltage, and R_T equals the source resistance seen by the load,

$$R_T = R_S \left(\frac{R_P}{R_U} + 1\right).$$

Thus the circuit of Figure 4 exactly reproduces the output characteristic of Figure 2. As compared with the approach of merely inserting a power resistor R_T in series with the output terminal, the circuit of Figure 4 dissipates in resistor R_S only $R_U/(R_P + R_U)$ times the power that otherwise would be associated with R_T.



$E_O = E_R \frac{R_P}{R_R} - I_O R_S \left(\frac{R_P}{R_U} + 1\right)$

Figure 4. Constant Voltage Power Supply with Programmable Output Resistance

In operation, one first sets R_P to the desired output voltage value E_T with no load applied; then, R_L is attached and varied until some designated output current is flowing through the load. R_U is then adjusted so that the voltage across the load E_O becomes the desired value at that load current.

DESIGN EXAMPLE

It is desired to add components to a standard 6269A power supply (rated 0-40V at 0-50A) so that its output voltage, instead of remaining constant with increasing current, falls linearly as shown in Figure 5.

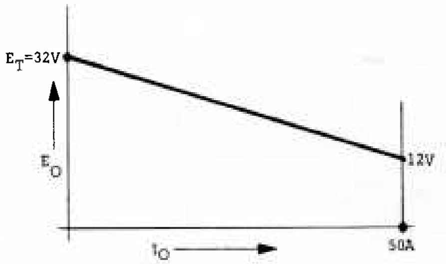


Figure 5. Desired Output Characteristic

Step 1

$$R_T = \frac{\Delta E_O}{\Delta I_O} = \frac{32 - 12}{50 - 0} = \frac{20}{50} = 0.4 \text{ ohms}$$

Step 2

At full output the dissipation that would be required if a 0.4 ohm resistor were added in series with the output of the 6269A would be:

$P = I_O^2 R_T = 50^2 \times .4 = 1000W$. Assuming it is not desirable to dissipate 1 KW of power, or that it is desired to make the characteristic of Figure 5 easily adjustable without changing the value of a high wattage resistor, the configuration shown in Figure 4 will be employed.

Step 3

E_T = 32V and R_P equals 500 ohms/volt X 32V = 16,000 ohms. The programming coefficient of 500 ohms/volt is obtained from the specification sheet for Model 6269A.

Step 4

For convenience, R_S is selected to dissipate no more than 20 watts. Therefore, the resistance must be 1/50th (20w ÷ 1000w) of the value previously calculated for R_T, or R_S = 8 milliohms.

Step 5

Thus $R_P/R_U + 1 = R_T/R_S = .4/.008 = 50$, and $R_P/R_U = 49$. $R_U = 16{,}000/49$, approximately 327 ohms. In order to obtain some range of control and provide for component tolerances, as well as limiting the possible setting of R_U, it would be advisable to use a 300 ohm fixed resistor in series with a 100 ohm rheostat. Current through these components will be very small, since the total voltage across R_U, in Figure 4, equals the output current drop across R_S—in this case, a maximum of 0.4V. The variation of R_U will, of course, vary the slope of the characteristics shown in Figure 2, but will in no way affect the current limiting or Constant Current properties of the power supply, which are independent of the operation of the comparison amplifier shown in Figure 4. Since a separate amplifier circuit is used to perform the Constant Current or current limiting protection function, no accidental manipulation of the controls R_U and R_P will cause damage to the power supply or result in its output current setting being exceeded.

Questions concerning the use of this externally connected circuit modification or variations of this technique should be forwarded to the nearest Hewlett-Packard sales office or Harrison Division/ Hewlett-Packard Co., Berkeley Heights, New Jersey.

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