TECH LETTER #3

MEASUREMENT OF LINE AND LOAD REGULATION OF DC POWER SUPPLIES

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INTRODUCTION

The measurement of the regulation characteristics of a highly regulated DC power supply involves several subtle procedures and precautions which, if disregarded, may completely invalidate the measurement results.

This tech letter will present two suggested measurement setups--one for measuring the static regulation characteristics of constant voltage power supplies, the other for the measruement of constant current supplies.

THEORY

Load regulation for a constant voltage supply is defined as the change of output voltage ΔV_{out} with a change in load current ΔI_{load}. Load regulation for a constant current supply is defined as the change in output current ΔI_{out} with a change in load voltage ΔV_{load}. Line regulation is defined as the change in output voltage ΔV_{out} (ΔI_{out} for constant current supplies) for a change in line voltage ΔV_{line}.

Regulation can be expressed either as an absolute quantity ΔV_{out} or ΔI_{out} or as a percentage.

The DC output resistance R_O can easily be found by using the equations:

$$R_O = \frac{\Delta V_{out}}{\Delta I_{load}} \quad \text{for constant voltage and}$$

$$R_O = \frac{\Delta V_{load}}{\Delta I_{out}} \quad \text{for constant current}$$

PROCEDURE

I. Regulation Measurement of Constant Voltage Power Supplies. Figure 1 shows a setup suitable for measuring both load and line regulation of a constant voltage power supply. The following precautions and procedures should be observed.

(1) It is essential that the leads connecting the load device to the power supply and the monitoring device to the power supply be completely separate. This cannot be overemphasized. Connecting the monitoring device to points AA' (see Figure 1) instead of the power supply output terminals will result in a measurement not of the regulation characteristics of the power supply, but of the power supply plus the resistance of the leads between the output terminals and points A and A'. Even connecting the load path by means of clip leads to the power supply and then connecting the monitoring path by means of clip leads to the load clip leads will result in a measurement error. Remember that the power supply being measured may have an output impedance of 1 milliohm or less, and contact resistance between clip leads and power supply terminals may be considerably greater than the specified output impedance of the power supply itself.

Because this is undoubtedly the most common error which occurs in the measurement of static regulation of a power supply, Figures 2 and 3 have been included to show the proper method of connecting the monitoring and load leads to the power supply terminals. If the measurement is being made at the front terminals (Figure 2), the load should be plugged into the front of the terminal (at B) while the monitoring device is connected by means of a lead which is inserted through the hole in the neck of the binding posts (at A). In this way the only resistance which is common to both the load and monitoring paths is located from the neck of the binding post back. When the supply is monitored at the rear terminal barrier strip (Figure 3), the load device should be connected to the plus and minus output terminals while the monitoring device should be connected directly to the plus and minus sensing terminals. Since there is only a small current flowing in the leads connecting the sensing terminals to the output terminals, the monitoring device connected to the sensing terminals obtains a valid indication of output performance. In fact, the monitoring device sees the same performance as the feedback amplifier within the power supply which is sensing and correcting the output.

(2) If an ammeter is not included on the front panel of the power supply being measured, then one should be inserted in series with the load resistance so that the full load current which is being imposed on the power supply can be verified to be the same as the full load current rating of the supply.

(3) The load resistor should be chosen to draw the full rated current of the supply at the voltage of measurement. Since the performance of the supply with regard to both load regulation and line regulation will be to a large degree independent of the output voltage setting, the output voltage may be adjusted to a value which, together with the load resistors readily available, will yield the rated value of load current.

(4) The current limit setting of the power supply should be set to its maximum value, well above the value of current actually being drawn from the supply. Failure to observe this precaution may result in the output voltage dropping at full load due to current limiting action.

(5) The monitoring device to be used can be a differential voltmeter, or sensitive digital voltmeter, or even a battery or variable power supply in series with a sensitive multimeter or DC oscilloscope. The meter to be used should be plugged into an AC power line which is reasonably isolated from the AC power line feeding the power supply, since large current changes in the power supply may result in line voltage changes which would cause the reading of the meter to change independent of any output change of the power supply.

(6) The Variac to be used to vary the input AC line voltage should have an adequate current rating; a line regulator should not be used anywhere in the line feeding the power supply. Failure to observe these precautions may result in waveform distortion of the input line voltage to the power supply with resulting degradation of the regulating performance or, in the case of SCR regulated or preregulated supplies, serious malfunctioning of the firing circuit.

(7) The AC Voltmeter should be known to have an accuracy over the span from 105-125 volts of 1% or better. Wherever possible this voltmeter should be connected directly to the power supply input terminals rather than to the output terminals of the Variac--particularly in the case of high current power supplies, since the input voltage at the power supply terminals may differ significantly from the output voltage of the Variac due to the IR drop in the power lines connecting the Variac to the power supply.

(8) Measurement of line regulation should be accomplished by changing the input line voltage from 105-125 and 125 -105 volts at the desired output voltage and current combination.

(9) Load regulation should be measured by throwing the switch S-1 and noting the change in the output voltage while the supply is being energized with any line voltage within its input rating. Notice should be taken of the direction in which the output voltage changes. An output voltage drop concurrent with an increase in load current is indicative of a positive output resistance at DC, whereas an output voltage rise concurrent with an increase in load current is indicative of a negative output resistance.

II. Measurement of Load and Line Regulation of Constant Current Supplies. Figure 4 shows a suitable setup for measurement of a constant current supply. Comments Nos. 6, 7, and 8 under Measurement of a Constant Voltage Regulation apply to the measurement of constant current regulation. In addition, the following precautions should be followed.

(1) The series monitoring resistor should have a reasonably small value so that the voltage drop across it is only a small fraction of the total output voltage of the power supply. It should be a wirewound resistor using 20 ppm/°C wire (or better) and should be operated at a power level of less than 1/10 of its rating. This last precaution is necessary so that the surface temperature of the power resistor will be only slightly higher than the ambient temperature. Failure to observe this precaution will result in a surface temperature "bobble" of the power resistor with a corresponding change in the value of R_I. This causes short-term variations in the measured voltage drop across this resistor which are not the result of output current changes of the power supply.

(2) The load resistance should be chosen so that the voltage drop across it at the current level of measurement is equal to the voltage rating of the power supply minus the drop across the sensing resistor.

(3) Switch S-2 should be placed in parallel with the load so that the current regulation of the power supply will be effectively measured between a very low voltage (equal to the voltage drop across R_I) and the maximum rated voltage of the supply.

(4) The voltage adjust control should be set well above the maximum rated voltage of the supply so that voltage limiting will not occur under the condition of maximum load resistance. If the voltage control is set at too low a value, voltage limiting may occur with the result that the output current will drop under the condition when switch S-2 is opened.

(5) The monitoring device should be a differential voltmeter, digital voltmeter, DC oscilloscope or other voltage monitoring device capable of measuring accurately the low voltage drop across the chosen value of R_I.

(6) It is imperative that no voltmeter be connected across the terminals BB' of Figure 4. Such a meter will have a constant resistance, and with the change in voltage which will occur across the power supply output terminals as a result of load resistance change, the current drawn by the monitoring device connected between BB' will vary. Even if the true output current of the power supply were to remain constant under this condition, the small current change through terminals BB' would be compensated by an equal current change through the monitoring resistor R_I, with the result that the voltage drop across this resistor would change even though the total power supply current had not changed at all. It is desirable to use a voltmeter in shunt with the load resistor or use the front panel voltmeter of the power supply itself as an indication of the output voltage. Special circuitry has been included in Harrison Laboratories constant current supplies so that the presence of the front panel voltmeter does not degrade the constant current performance.

(7) Load regulation should be measured by throwing the switch S-2 and noting the change in the output voltage as measured across R_I while the supply is operated with any line voltage within its rating. Then:

$$\Delta I = \frac{\Delta V \text{ across } R_I}{R_I}$$ is used to calculate the load regulation.

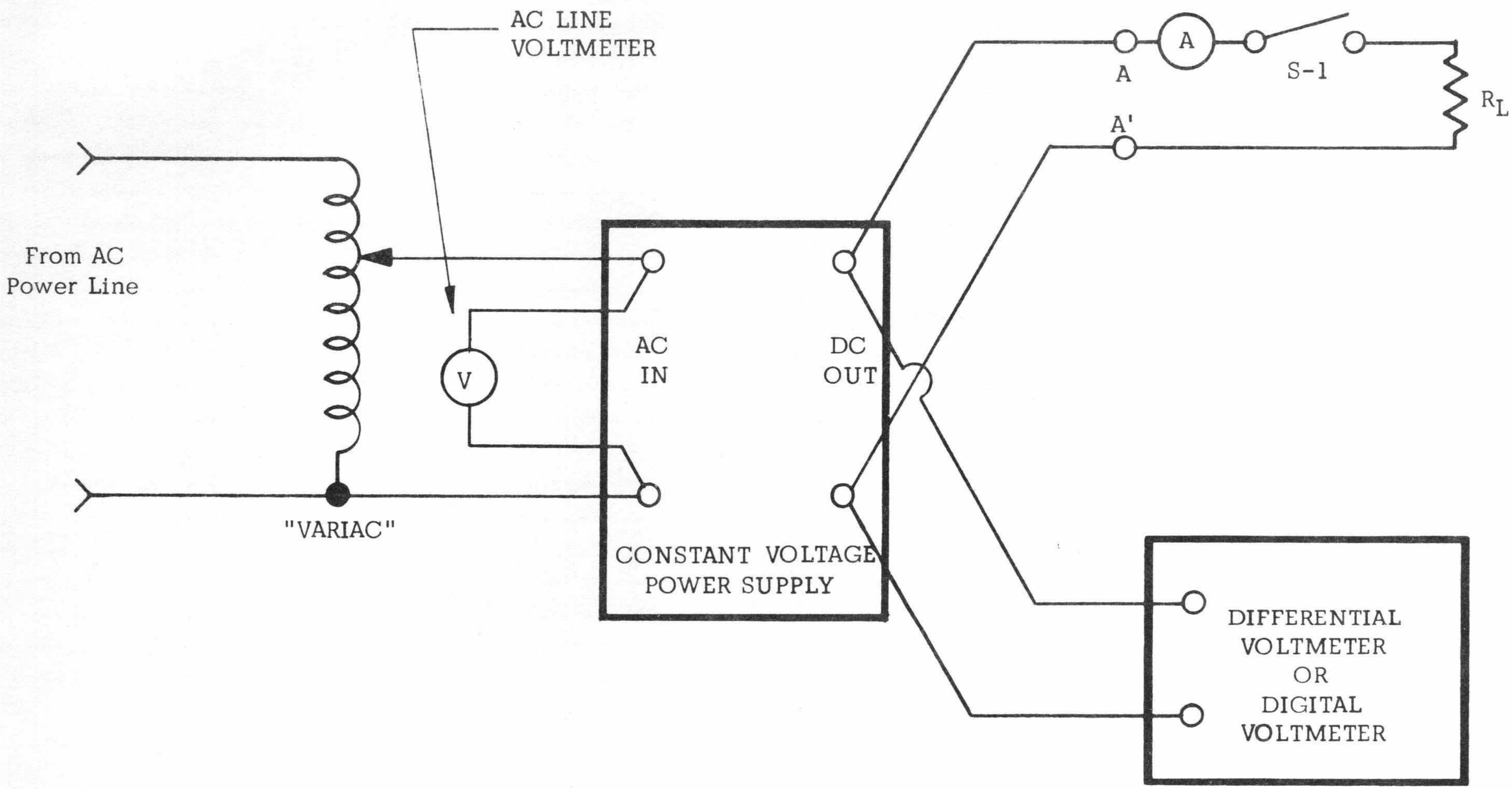

FIG 1

Measurement Circuit for Load and Line Regulation of a Regulated DC Constant Voltage Power Supply.

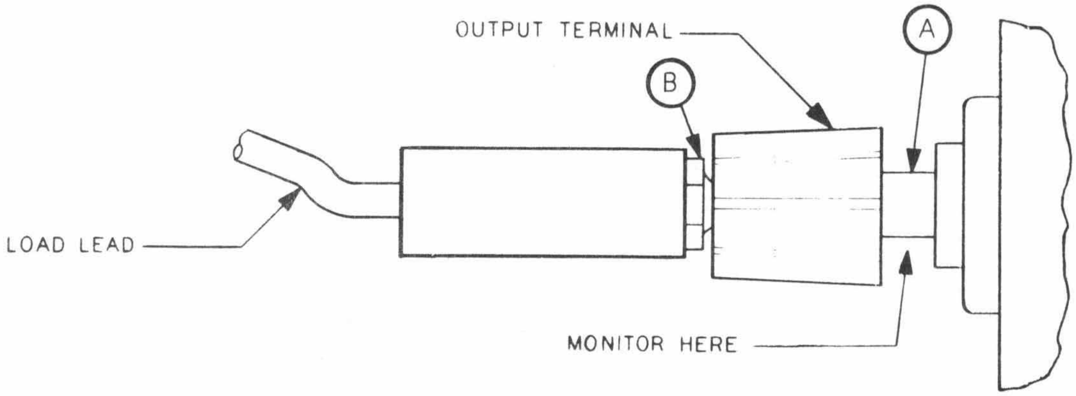

FIG 2

Proper Method of Connecting Monitoring and Load Lead Connections to Front Panel Terminals.

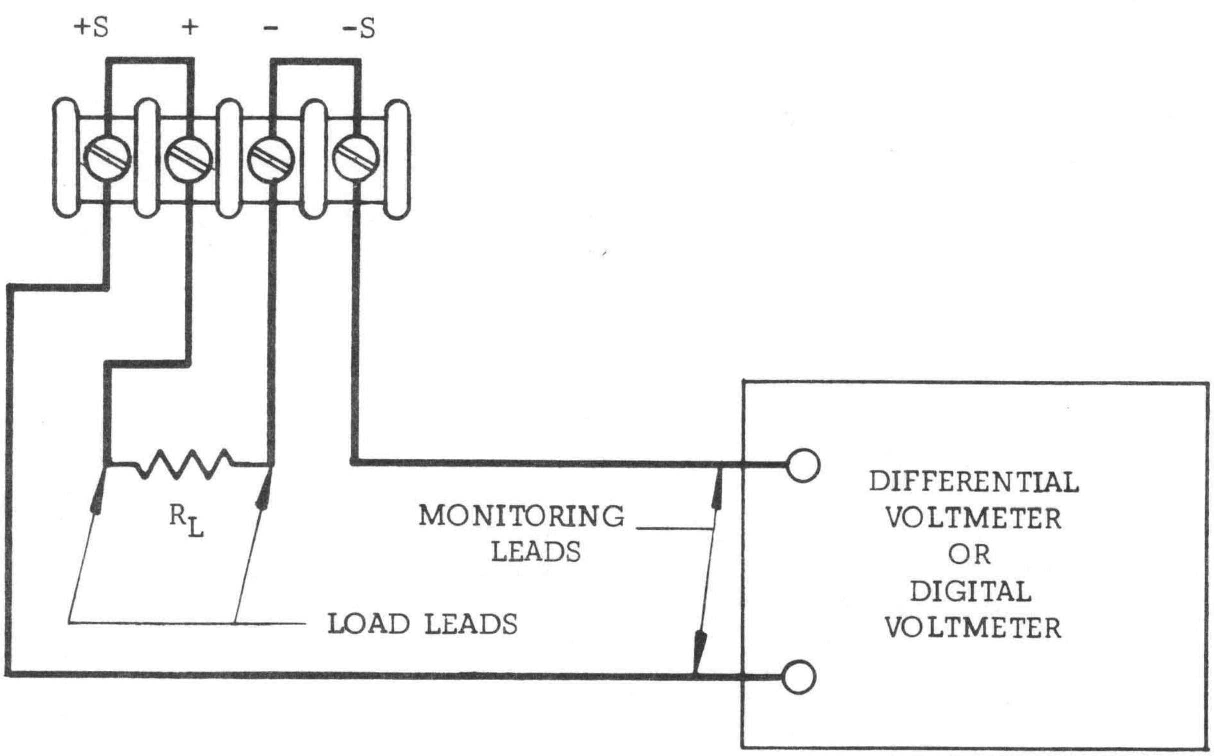

FIG 3

Proper Method of Connecting Monitoring and Load Lead Connections to Barrier Strip Terminals.

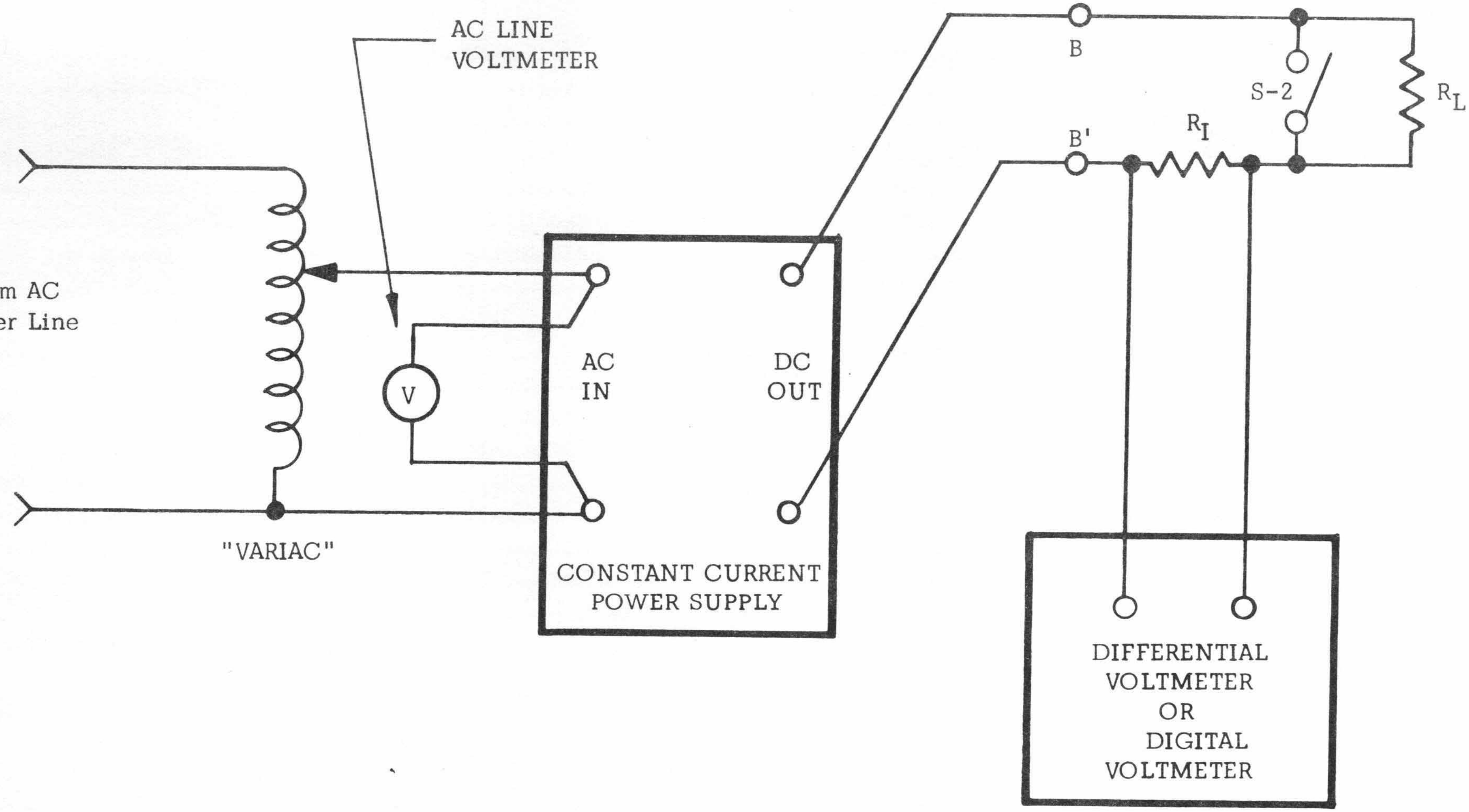

FIG 4

Measurement Circuit for Load and Line Regulation of a Regulated DC Constant Current Power Supply