TECH LETTER # 4

MEASUREMENT OF OUTPUT IMPEDANCE OF A CONSTANT VOLTAGE POWER SUPPLY

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INTRODUCTION

Any load device connected to a power supply seldom is of such a nature as to require a constant flow of power from the supply. Since the load device usually consists of active as well as passive devices, the current drawn from the supply consists of an AC component superimposed on the DC output current. (See Figure 1.) This AC component is usually not sinusoidal in nature, but can, by Fourier expansion, be broken down into purely sinusoidal components. For purposes of describing how constant the output voltage of a power supply can remain in spite of load current variations, it therefore becomes useful to specify the output impedance of the power supply over a wide band of frequencies.

THEORY

This output impedance is defined as

$$Z_O = \frac{E_{AC}}{I_{AC}}$$

where E_{AC} is the sinusoidal voltage across the power supply output terminals as a result of the sinusoidal current, I_{AC}, flowing through the series loop consisting of power supply and the load device.

To measure the output impedance of a power supply at any frequency, therefore, it is necessary to draw a sinusoidal current from the power supply and measure the AC component of voltage which results across the output terminals of the supply. Dividing this AC voltage by the AC component of the load current yields the value of the output impedance of the power supply at the frequency of the sinewave load. A circuit suggestive of the method to be employed for measuring power supply AC output impedance is shown in Figure 2. This circuit is not a practical one, but it does serve to illustrate the measurement principle involved. A signal current, I_{AC}, is caused to flow through the output terminals of the power supply and a current monitoring resistor (R_I) in series. The output impedance of the supply is then:

$$Z_O = \frac{E_{AA'}}{I_{AC}} = \frac{E_{AA'}}{\frac{E_{BB'}}{R_I}} = R_I \frac{E_{AA'}}{E_{BB'}}$$

However, there are still several shortcomings to the circuit shown in Figure 2. These include:

(1) The signal generator may be incapable of withstanding the DC voltage across the power supply output terminals. A blocking capacitor is therefore desirable between the power supply and the signal generator.

(2) If a capacitor is added, the power supply is unloaded at DC. This is corrected by addition of R_L as in Figure 3. R_L is much greater than Z_O and therefore does not affect the measurement of Z_O.

(3) Because of the low AC load impedance, the oscillator may be mismatched, with resulting waveform distortion. The high frequency components of this distorted wave will result in a larger voltage across the power supply due to the higher impedance at higher frequencies. A matching resistor (R_M) may be necessary.

(4) At low frequencies, the output impedance of the power supply is low and the current which is required in order to obtain a readable voltage across terminals AA' may be very large (e.g. assume a power supply output impedance of 1 milliohm. In order to get a 1 millivolt signal for presentation on an oscilloscope, it is necessary to feed a 1 ampere current I_{AC} through terminals AA'). Thus, a power amplifier with low output impedance may be necessary.

(5) Since the AC current which will be required in order to generate a readable signal across AA' is large, the power supply would be called upon to accept (rather than deliver) high values of current, if not properly DC loaded. However, a DC power supply is essentially a unilateral device. It can conduct current in one direction only. Any attempt to force current in the reverse direction through the power supply terminals during half of the AC cycle will simply result in the output capacitor of the power supply being charged to a voltage higher than the normal output voltage.

Similarly, if too much peak current is drawn from the supply, the current limit circuit might be activated. Therefore, I_{DC} and I_{AC} must be correctly adjusted.

PROCEDURE

A basic equipment arrangement is shown in Figure 3. Below is the basic procedure to be followed.

(1) The value of the load resistor (R_L) is chosen so that the current drawn through it at the DC output voltage will be equal to or greater than the peak value of the signal current, I_{AC}, and so that the maximum instantaneous sum of I_{AC} and the DC current is less than the setting of the current limit or the rating of the supply. An optimum value of load current is one half the rated current.

(2) Since the measurement of output impedance can be no more accurate than the tolerance of R_I, it is important to know the exact value of R_I and to be certain that its impedance is constant over the band of frequencies measured. One convenient way of obtaining a suitable 1 ohm resistor for R_I is to take ten 1 watt Allen-Bradley 10 ohm resistors and put them all in parallel, twisting their pigtails together tightly. The resulting 1 ohm resistor will be flat within 10% over a frequency band up to (and possibly beyond) 1 megacycle.

(3) R_M should be chosen so that in conjunction with the output impedance of the power supply, R_I, and the impedance of the coupling capacitor, C, the total impedance into which the oscillator (or amplifier) looks is equal to the nominal output impedance of the oscillator (or amplifier).

For low and medium frequency measurements, H-P Model 4301A includes a suitable oscillator and power amplifier in one convenient package.

(4) The blocking capacitor, C, should be an electrolytic chosen to have a value large enough so its impedance will be small compared to the impedance of the oscillator (or amplifier, if included) at the lowest frequency of measurement.

(5) It is essential that the wires BB' be connected directly across the monitoring resistor R_I so that the voltage measured across BB' includes only the voltage drop of the resistor R_I and not the voltage drop across R_I plus some amount of leads connected to it.

(6) Also, when measuring the voltage across AA', it is essential that the monitoring device be connected directly across the output terminals of the supply. Thus, the measurement of the voltage across AA' is valid and does not include the effect of any IR drop in the leads carrying the signal current to the power supply terminals.

(7) The monitoring device used should be an oscilloscope with a minimum of 1 millivolt per centimeter sensitivity. When using the oscilloscope, it is advisable to check the waveshape of the voltage across AA' and BB' for the presence of undue amounts of waveform distortion. Furthermore, a large value of 60 cycle component across AA' should be considered as indicative of ground problems in the measurement setup and should be resolved before the measurement proceeds. A voltmeter is not suitable as a monitoring device since it may give erroneous results due to normal 120 cycle ripple on the output of the supply.

(8) The output voltage setting of the power supply does not materially affect measurement of output impedance; it can be set at any convenient value.

(9) The current limit control of the power supply should be set to its maximum value.

(10) I_{AC} should be held to a peak-to-peak value of less than the current rating of the supply or twice the DC current through R_L, whichever is smaller.

(11) The equation, $Z_O = R_I \left(\frac{E_{AA'}}{E_{BB'}} \right)$ is used to determine the output impedance of the power supply.

(12) It is suggested that the impedance measurements made should be plotted on log-log paper. Normally, one would expect the output impedance to be essentially resistive (flat with frequency) at low and medium frequencies and inductive (rising at 6 DB per octave or 20 DB per/decade) at high frequencies. It is also possible that shorter inductive regions may exist in the output impedance characteristic at midfrequencies (see Harrison Laboratories' spec sheets for typcial output impedance characteristics.)

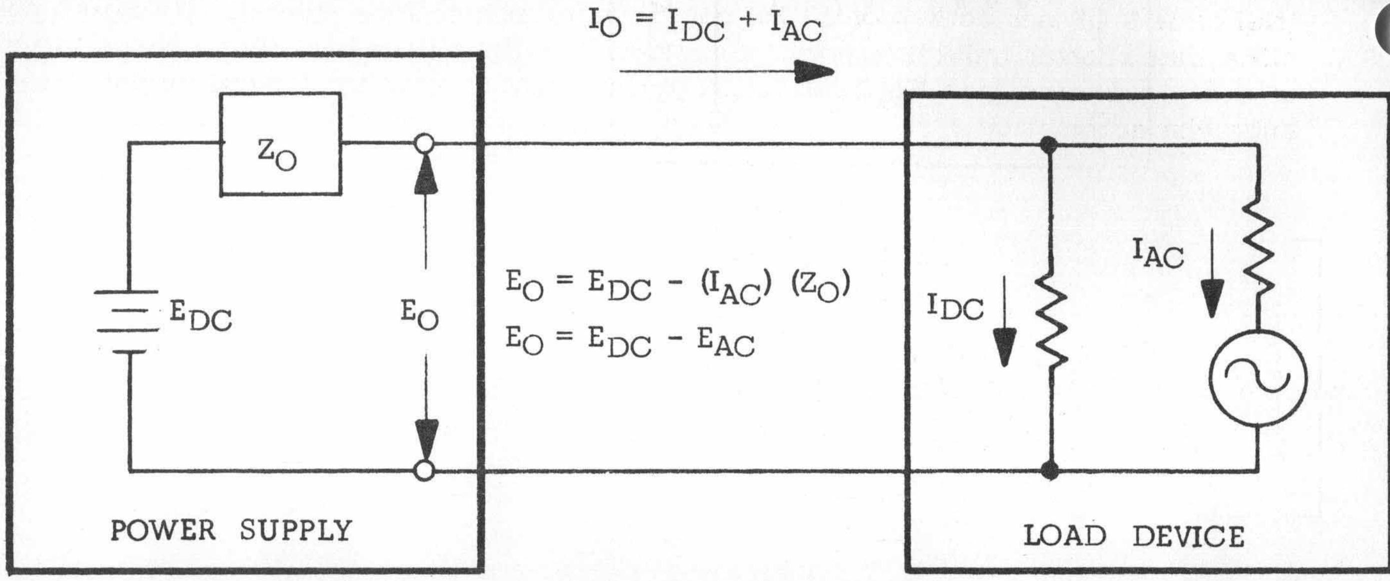

Figure 1. Power Supply Feeding Active Load Device

Superimposed on desired DC output voltage E_{DC} is an AC component, E_{AC}, resulting from interaction of AC component of load current I_{AC} with power supply output impedance Z_O.

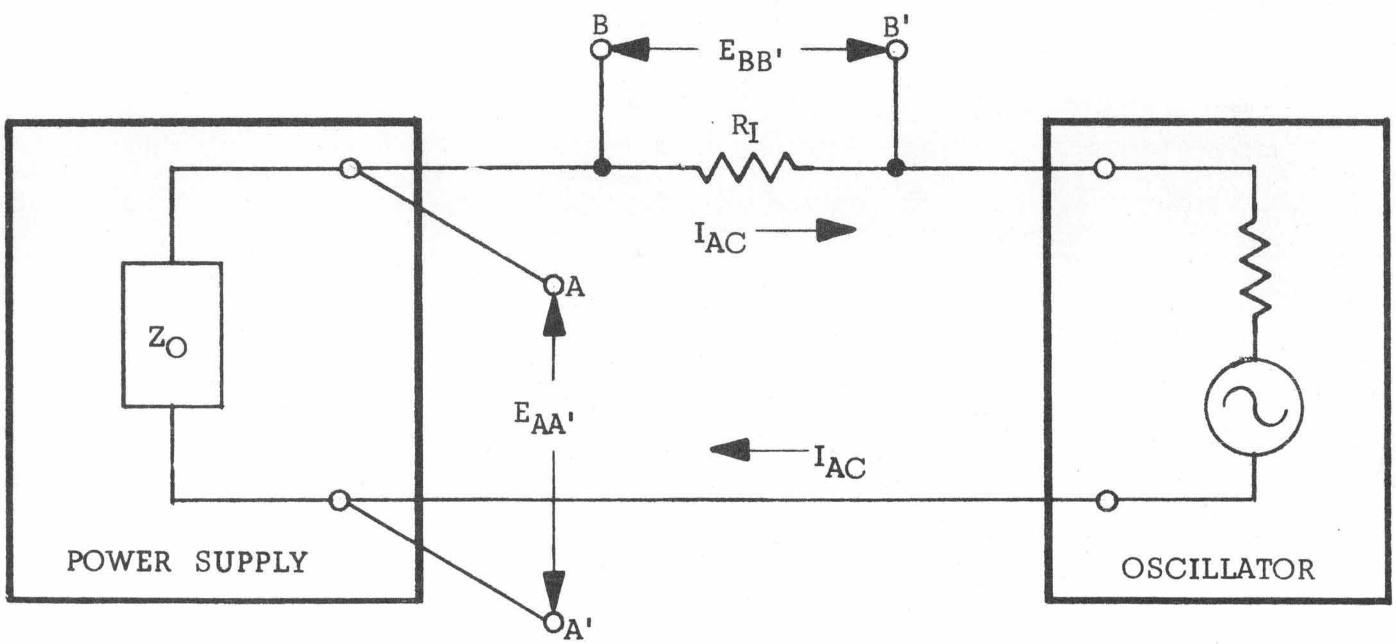

Figure 2. Circuit Principle Involved in Measurement of Power Supply AC Output Impedance

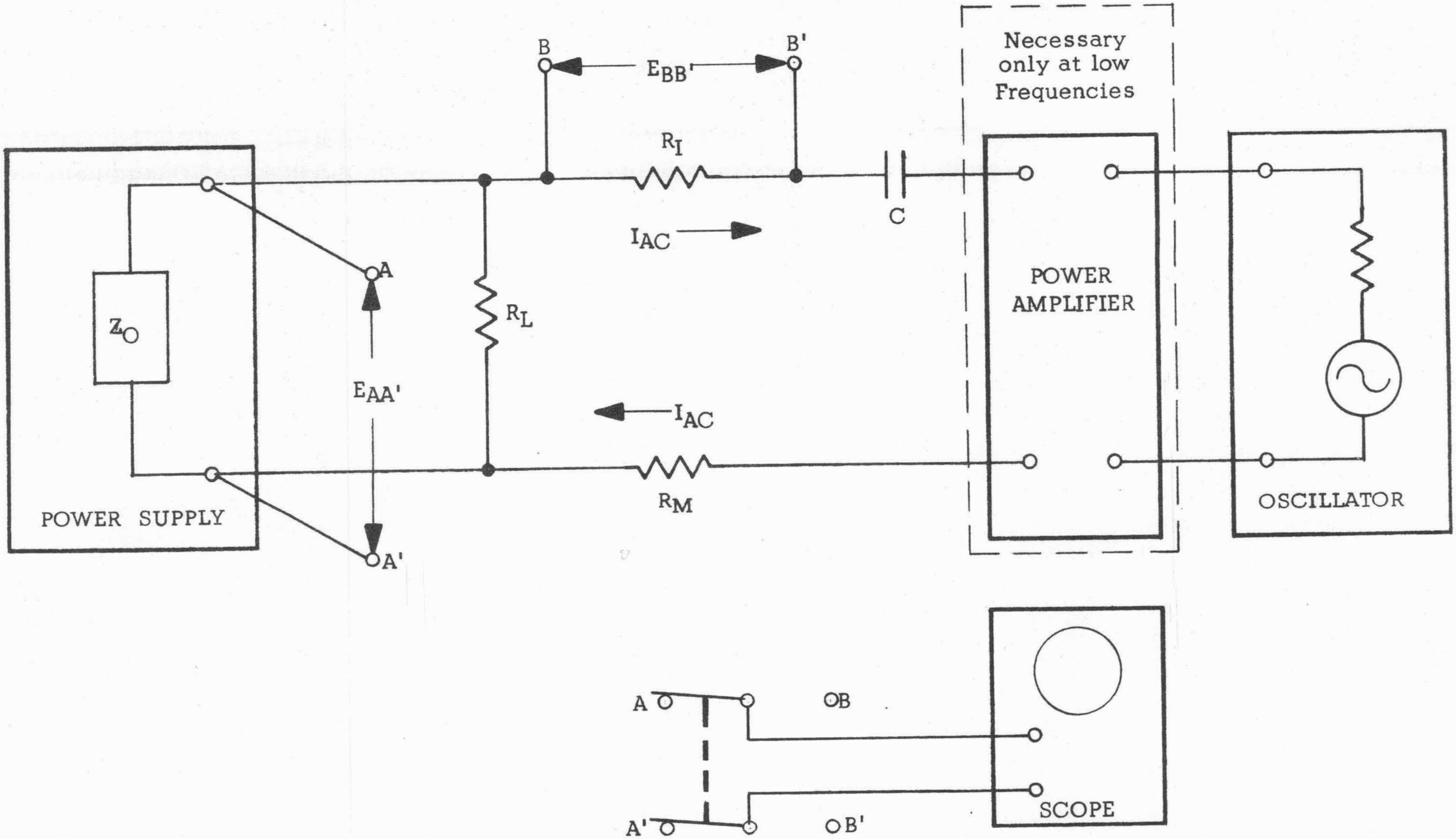

Figure 3. Practical Circuit for Measurement of Power Supply AC Output Impedance