EQUIVALENT EQUIPMENT CIRCUITS

INTRODUCTION

The student will analyze the internal properties of the equipment used in lab. The input resistance of the oscilloscope and digital multimeter when used as a voltmeter will be measured. The output resistance of the function generator will similarly be determined. The student will also determine the Thevenin and Norton equivalent a complex circuit using SPICE.

BACKGROUND

When an electrical instrument is connected to a circuit to provide power or take measurements it becomes part of the circuit. Often the resistance of the connected instruments is neglected as they have been designed to not interfere with most circuits. Even though electricity flows through multiple elements inside of the instrument, these components may be modeled as a simple resistor or resistor and source.

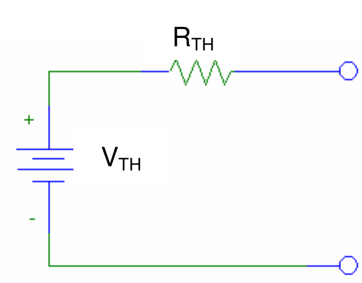
To determine the internal resistance of an instrument it is usually only necessary to vary a single component of an exterior connected circuit. Enough measurements are available throughout the exterior circuit to provide information for basic circuit analysis techniques to calculate the internal properties of an instrument.

Root Mean Square (RMS)

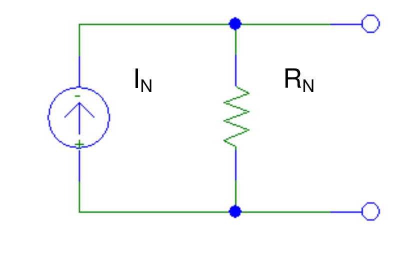
The current and voltage in alternating current (AC) systems is not constant. Thus, one cannot easily apply ohm's law to a circuit with an AC source. If one thinks of a resistive element, current traveling forward will heat the element up just as much as current traveling backwards. Taking the average of the absolute value of an AC waveform will result in the DC equivalent. If one desires to use ohm's law to analyze an circuit with an AC source, RMS values for voltage and current must be calculated or measured.

Thevenin and Norton Equivalents

Thevenin's theorem states that a two terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{TH} in series with a resistor R_{TH} where V_{TH} is the open-circuit voltage V_{OC} at the terminals and R_{TH} is equivalent to the resistance at the terminals when all independent sources are turned off.



Norton's theorem states that a two terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N, where I_N is the short -circuit current I_{SC} through the terminals and R_N is the input or equivalent resistance at the terminals when the independent sources are turned off.



Mathematically these relationships can be described as follows:

$V_{TH} = V_{OC}$ $I_N = I_{SC}$ $R_{IN} = R_{TH} = R_N = (V_{TH} / I_N)$

PROCEDURE

Determining the internal resistance of the oscilloscope

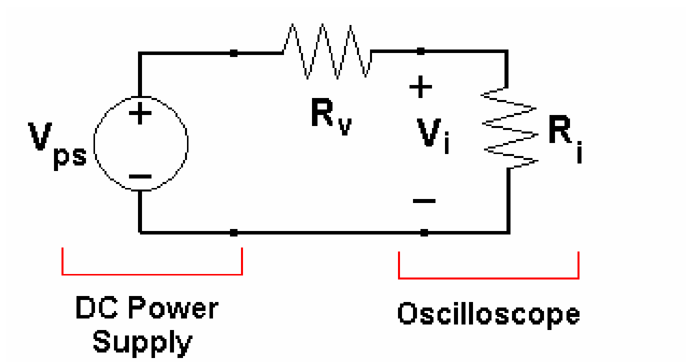


Figure 1: Input Resistance Measurement

Connect the oscilloscope directly to the DC power supply. In this manner the circuit in Figure 1 is constructed with the variable resistance R_v set to 0 volts and R_i denoting the internal resistance of the oscilloscope.

Adjust the DC power supply until the oscilloscope measures 8 volts.

V_{PS} = ________ Volts

Select a nominal 10 MΩ resistor and measure its resistance using the digital multimeter.

R_V = _________ Ohms

Using the nominal 10 MΩ resistor as R_V, construct the circuit displayed in Figure 1 and measure the voltage across the oscilloscope terminals V_i.

V_i = _________ Volts

Knowing three of the four variables of the circuit displayed in Figure 1, calculate the internal resistance of the oscilloscope, denoted as R_i in the figure. Include calculation in lab report.

Oscilloscope Internal Resistance = R_i = _________ Ohms

Determining the internal resistance of the multimeter used as a voltmeter

Set the multimeter to measure voltage and connect directly to the DC power supply. In this manner the circuit in Figure 1 is constructed with the variable resistance R_v set to 0 volts.
Adjust the DC power supply until the multimeter reads 16 volts. Make sure the multimeter is set to measure DC, not AC voltages.

V_{PS} = _______ Volts

Record the measured value of the nominal 10 MΩ resistor used in the previous section.

R_V = ________ Ohms

Using the nominal 10 MΩ resistor as R_V, construct the circuit displayed in Figure 1 and measure the voltage across the multimeter terminals V_i.

V_i = _________ Volts

Knowing three of the four variables of the circuit displayed in Figure 1, calculate the internal resistance of the multimeter, denoted as R_i in the figure. Include calculation in lab report.

Multimeter Internal Resistance = R_i = _________ Ohms

Measuring the output resistance of the function generator

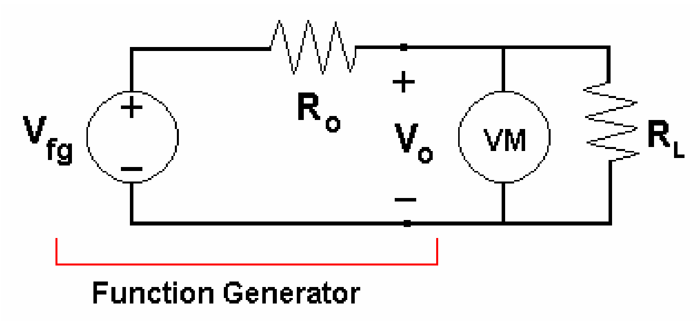


Figure 2: Output Resistance Measurement

Connect the digital multimeter directly to the function generator. In this manner the circuit in Figure 2 is constructed with the load resistance R_L set to 0 volts. We will neglect the internal resistance of the voltmeter for the purposes of this experiment and assume that the circuit is open, thus V_O is equal to V_{fg} with R_L removed.

Adjust the function generator to a sinusoidal frequency of 50Hz. Adjust the amplitude until the digital multimeter displays 1.6 volts. Make sure the digital multimeter is set to measure AC RMS, not DC.

V_{fg} = __________ Volts RMS

Select a nominal resistor of about 50Ω and measure its resistance using the digital multimeter.

R_L = ___________ Ohms

Using the 50 Ω resistor as R_L, construct the circuit displayed in Figure 2 and measure the voltage displayed on the digital multimeter V_O.

V_O = ___________ Volts RMS

Knowing three of the four variables of the circuit displayed in Figure 2, calculate the output resistance of the function generator, denoted as R_O in the figure. Include calculation in lab report.

Function Generator Output Resistance = R_O = __________ Ohms

Norton and Thevenin Analysis by means of SPICE

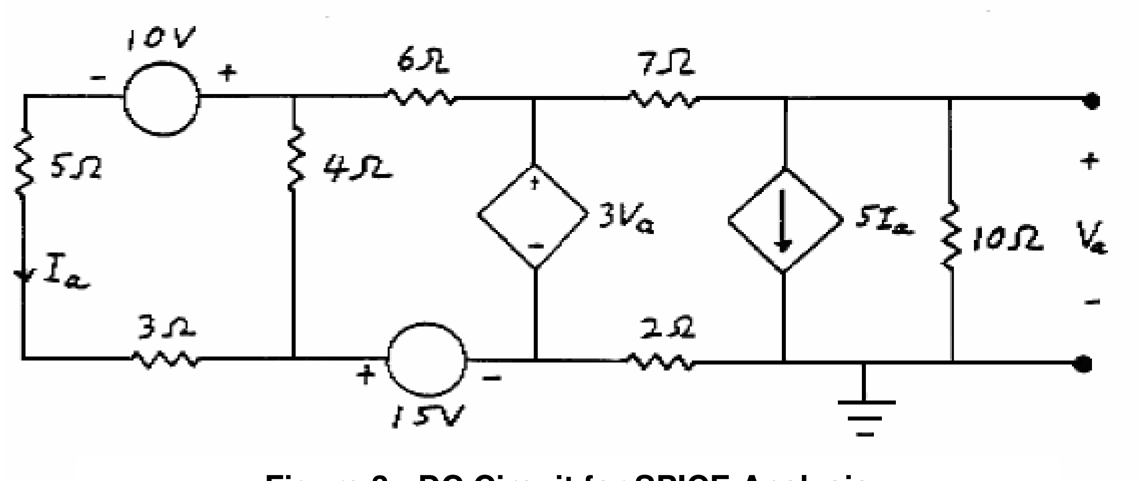


Figure 3: DC Circuit for SPICE Analysis

Assume that the circuit represented in Figure 3 can only be analyzed by taking measurements at the open terminals represented by the voltage V_a.

Create a PSPICE schematic to measure the open circuit voltage V_{OC} at the open terminals of the circuit displayed in Figure 3.

V_{OC} = ____________ Volts

Modify the schematic to measure the short circuit current I_{SC} between the open terminals.

I_{SC} = ______________ Amps

Include a screenshot of schematic in report.

Knowing the open circuit voltage V_{OC} and the short circuit current I_{SC}, calculate the Thevenin voltage V_{TH}, the Norton current I_N, the Thevenin resistance R_{TH} and the Norton Resistance R_N.

V_{TH} = _____________ Volts I_N = _____________ Amps

R_{TH} = _____________ Ohms R_N = ____________ Ohms

QUESTIONS

When measuring the internal resistance of the oscilloscope and digital multimeter we did not take into effect the output resistance of the DC power supply. Did this make a substantial difference in your calculated results? Why or why not?

When measuring the internal resistance of the function generator we did not take into effect the internal resistance of the oscilloscope even though it was connected in parallel across R_L. Does this make a substantial difference in your calculated results? Describe why or why not mathematically utilizing values for R_L and the value determined to be the internal resistance of the oscilloscope.

It is common to find 10X oscilloscope probes that have ten times the impedance of a normal probe. In what circumstances would one use a 10X probe? Would there be any drawbacks to always using a 10X probe?

Norton and Thevenin theory was clearly applied in the SPICE portion of the lab exercise. However, this theory was applied earlier in the lab. Describe where and how this theory was applied.