

Lab 1: Basic Circuit Construction and Electronic Instrumentation

Objective:

Learn how to use:

- A breadboard to build electronic circuits
- The Wavetek 85XT handheld digital multi-meter (DMM) to measure V, I, and Ω .
- The Agilent HP34401 digital multi-meter (DMM) to measure V, I, and Ω .
- The Tektronix TDS1002 Oscilloscope.
- The B&K 4003 Function Generator.
- The Agilent E3640A Programmable Power Supply.

Reading Assignments:

- "Prototype Board Explanation", "Instruments"
- "HP34401 manual ('select' pages)"
- "XYZs of Oscilloscopes" (reference material)
- "AVG and RMS Values of Periodic Waveforms"

PreLab Questions:

- [PL1] Explain the relationship between the average and RMS values for a time-varying signal.
- [PL2] After reading **XYZs of Oscilloscopes**(pg. 18-21, 27-31 in particular), answer the following questions:
- In an oscilloscope trace, what measured quantities are displayed on the vertical and horizontal axes?
 - How do I change the units per division being displayed for the horizontal and for the vertical axes?
 - What is the purpose of the trigger?
 - What is the difference between AC and DC coupling?
- [PL3] What value of resistor is needed, in series with a 9V battery, to limit the current to 15mA?
- [PL4] In order to produce a 1V RMS reading, what does the peak value of a sine wave have to be?
- [PL5] What is the expected RMS value for a 1V peak square wave?
- [PL6] What is the expected RMS value for a 1V peak triangle wave?

Lab Exercises:

A. Electronic Instrumentation (~60-70 min: estimated amount of time)

1. Set both the Wavetek handheld digital multi-meter (DMM) and the Agilent HP34401 DMM to read resistance. Short the input leads of each meter. Record the readings. **[~5 min.]**

[Q1] Compare the results between the two meters. Do they both read exactly 0Ω ?

2. Measure the resistance of 5 different resistors in the resistance substitution box. Do this first using the Wavetek handheld DMM, and then the Agilent DMM. Pick resistance values that range from very low to very high. **NOTE:** *The correct terminals to use on the resistance substitution box are the two green binding pots, (NOT the binding post labeled 'ground').* **[~15 min.]**

[Q2] Compare the results between the two meters.

3. Use the Agilent Programmable Power Supply to supply exactly 9.00V. Measure the voltage at its output terminals using both DMM's. **[~10 min.]**

[Q3] Compare the results between the two meters.

4. Using the Tektronix oscilloscope to measure the output of the B&K function generator. Set the function generator to output a 100Hz sine wave. Set the amplitude control (AMPL) to about mid-range. Turn the DC offset off (*push the OFFSET button in*). Plug the output directly into the input of Channel 1 on the scope.
 - a. Manual Scope Adjustment:
Adjust the timebase of the scope ("Horizontal" section, SEC/DIV) to display about 2 complete cycles of the sine wave. Adjust the gain of Channel 1 ("Vertical" section, VOLTS/DIV) to display the full peak-to-valley extent of the sine wave. **[~5 min.]**

[Q4] What is the peak-to-peak (Pk-Pk) measurement on the scope?

[Q5] What is the RMS measurement on the scope?

[Q6] What is the period?

[Q7] What is the frequency measurement on the scope?

Change the function generator to a frequency of 10kHz, and increase the amplitude to full-scale (fully clockwise). Notice that the trace on the scope appears totally black (displaying too many cycles across the screen to resolve them individually). Now, instead of manually adjusting the scope...

- b. Automatic Scope Adjustment: **[~5 min.]**

Push the AUTOSSET button. Life couldn't be easier. After doing this, you still have the ability to manually make any adjustments. The AUTOSSET button just gives you a great starting point. Make good use of the AUTOSSET button.

- c. Waveform Comparison: **[~10 min.]**

Switch between the first 3 waveforms that are on the function generator. These are a Sine, Rectangle, and Triangle function. Set the DC OFFSET control to off. For each waveform, set the amplitude to 2V peak-to-peak. Use the AUTOSSET button to display each waveform.

[Q8] Make a drawing of each waveform, with the DC OFFSET set to 0V. Show the gridlines of the oscilloscope in your drawing.

Again, switch between the Sine, Rectangle, and Triangle functions. Now, set the DC OFFSET control to +2V. Use the AUTOSET button to display each waveform. **[~10 min.]**

[Q9] Make a drawing of each waveform, with the DC OFFSET set to +2V. Show the gridlines of the oscilloscope in your drawing.

d. Pulses: **[~5 min.]**

Set the function generator to each of the last 2 functions. Set the DC OFFSET so that each waveform is unipolar and positive-going from 0V. Study their waveforms.

[Q10] Measure the duty-cycle of each of these waveforms.

d. Triggering: **[~5 min.]**

With the sine or triangle functions that you were using, adjust the triggering knob. Observe what is happening to the waveform as you adjust the trigger knob.

[Q11] Where does the trigger level have to be in order to see a stable display?
When you set the trigger to be above or below the waveform, what happens?

B. RMS vs. Peak Values of Periodic Waveforms (15-20min: estimated amount of time)

1. Use the scope to set the function generator to produce a 100Hz sine wave, with a 2V peak-to-peak amplitude. (Not that this is a 1V peak value of the sine wave.) Manually adjust the time base to display about 2 complete cycles of this waveform.

[Q12] Make a drawing of this waveform, showing the gridlines of the oscilloscope.

Next, connect the Agilent DMM to the output of the function generator (in parallel with the scope). Use a BNC "T" connector to do this. Set the DMM to read AC volts ("AC V")

[Q13] What is the RMS measurement from the DMM? Compare the value to the theoretical value for a sine wave. (They should match, as this is a "True RMS-reading" DMM).

[Q14] What is the RMS measurement on the scope? Compare to the value obtained on the DMM. Do they match? (Does the scope accurately calculate the RMS value?)

2. Repeat for a square wave having a peak voltage of 1V (2V Pk-Pk).

[Q15] Make a drawing of this waveform.

[Q16] What is the measured RMS value?

3. Repeat for a triangle wave having a peak voltage of 1V (2V Pk-Pk).

[Q17] Show this waveform in your lab notebook.

[Q18] What is the measured RMS value?

C. Fundamental Electrical DC Circuits

1. Ohm's Law (15min: estimated amount of time):

In this exercise, we will measure the current through, and simultaneously the voltage across, a 10kΩ resistor to verify Ohm's Law. A plot of current vs. voltage should yield a straight line, and the slope should equal the inverse of the resistance. The intercept should be zero (no potential across the resistor results in no current flow):

$$V = I \cdot R \quad (1)$$

$$y = mx + b \text{ where } m = \frac{1}{R} \text{ and } b = 0 \quad (2)$$

Use the Agilent power supply as an accurate (and stable) voltage source across a 10kΩ resistor. Place the Wavetek DMM in series with the power supply and the resistor (to measure the current through the resistor). Place the Agilent 34401A DMM in parallel with the resistor (to measure the voltage across the resistor). Set the DMM to read DC volts ("DC V").

Step the power supply from 0 to 10V with step size of 1V. Take readings of the voltage and current at each setting.

[Q19] Plot the current vs. the voltage and determine the resistance from the graph. Does your result verify Ohm's Law? Is the value you calculate within the tolerance marked on the body of the resistor?

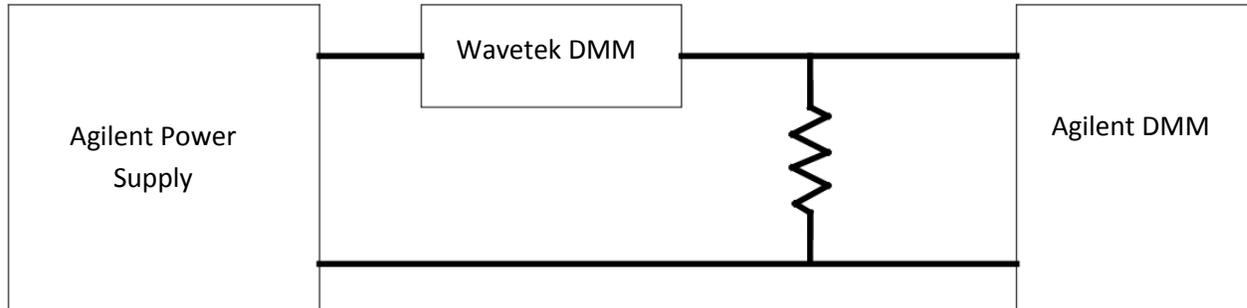


Figure 1. Ohm's Law Verification Circuit Block Diagram

Now measure the resistance using the internal ohmmeter functions of both the Agilent DMM and the Wavetek DMM.

[Q20] Compare to the marked value of 10kΩ. Are the measured values within the tolerance marked on the body of the resistor?

2. Voltage Divider (15min: estimated amount of time):

Wire the circuit shown, omitting R3. Use two resistance substitution boxes for R1 and R2 and set them initially to 10kΩ each. Measure the voltage between points B and C and between points A and C (the overall supply voltage).

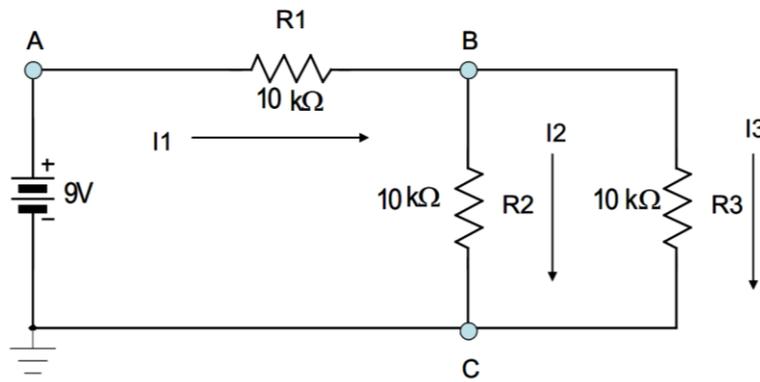


Figure 2. Current/Voltage Divider Circuit

[Q21] Compare the voltage between B and C to the result predicted for this voltage divider.

Then, adjust both R_1 and R_2 while keeping the sum of (R_1+R_2) approximately the same (to ensure that the current remains below $\approx 1\text{mA}$). Again, measure the voltage between points B and C and between points A and C, and also record the resistance values. Do this for 5 different combinations of the resistances.

[Q22] Compare the voltage between B and C to the results predicted for these 5 voltage dividers.

3. Current Divider (15min: estimated amount of time):

Now replace the resistance substitution boxes with $10\text{k}\Omega$ resistors, and use a resistance substitution box for R_3 , the load resistor. You will need to use the breadboard to wire the circuit up in this manner. Measure the voltage and current between points B and C and between points A and C, for values of R_3 ranging from $1\text{k}\Omega$ up to $1\text{M}\Omega$. Remember to record the values of R_3 .

[Q23] Compare the voltage between B and C to the results predicted for these voltage dividers.

[Q24] Compare the current between B and C to the results predicted for these current dividers.

4. Thevenin Equivalent (30min: estimated amount of time):

Determine the Thevenin equivalent of a nine-volt battery. It is rated at 500 mA-hr and a typical current draw is 15 mA . (The obvious procedure for determining the Thevenin equivalent of a voltage source is to decrease the value of the load resistance, R_{load} , until the terminal voltage is 50% of the open-circuit voltage, V_{th} . At this point the internal resistance (R_{th}) equals the external resistance (R_{load}). This is sort of brutal, due to a relatively high current draw from the battery. Very quickly this heats up the battery internally, causing R_{th} to increase and V_{th} to drop.)

Develop a procedure to determine the Thevenin equivalent that is easier on the battery. Experimentally, use the resistance substitution box as a load resistor in series with the battery. Use the Wavetek DMM to measure the current through this load resistor, and use the Agilent DMM to measure voltages.

“Dial in” a load resistance so that the current flowing through it is $\approx 15\text{ mA}$. To be safe and not draw too much current, start with a high resistance like $1\text{M}\Omega$ and decrease it.

[Q25] Make measurements to determine V_{th} and R_{th} of the battery. Report these values.