

Experiment 7: DC Measurements and Meter Loading

Introduction

Meters used to measure voltage or current have an internal resistance. Since the meter must be connected to the circuit to make a measurement, the circuit is changed by the resistance of the meter. This is referred to as the meter's "loading effect".

Most meters have amplifiers built in so that only a small amount of power is needed from the circuit, and the loading effects are minimized. But this is not always the case.

A voltmeter is connected in parallel with the circuit across which the voltage is being measured. The loading effect of the meter will be minimal if the meter resistance is much larger than the circuit resistance. Ideally, the voltmeter resistance should be infinite. Practically, most electronic voltmeters (DMMs) have a resistance of 10 megohms.

The effect of the voltmeter resistance, R_m , across a circuit element, R_c , can be calculated using the parallel resistor equation:

$$R_t = \frac{R_c \cdot R_m}{R_c + R_m}$$

An ammeter is connected in series with the circuit in which the current is being measured. The loading effect of the meter will be minimal if the meter resistance is much smaller than the circuit resistance. Ideally, the ammeter resistance should be zero.

Practically, the resistance of most electronic ammeters (DMMs) varies with the range setting, with the highest ranges having the least resistance. This is one case where setting the range for the most significant digits may not always result in the most accurate reading.

The effect of the ammeter resistance, R_m , in series with circuit element, R_c , can be calculated using the series resistor equation:

$$R_t = R_c + R_m$$

Even if the meter loading effect is insignificant there will be an uncertainty in the measured value due to measurement errors caused by the accuracy of the meter.

Objectives

A series-parallel circuit will be connected on a solder-less breadboard. Voltage and current measurements will be made on the circuit and the results will be compared to theoretical expectations. The effect of the resistance of the meter will be determined.

Procedure

Equipment and Parts

DMM, Power Supply, and Breadboard.
Resistors: 100, 220, 1 Meg, 2.2 Meg, ¼ watt, 5%.

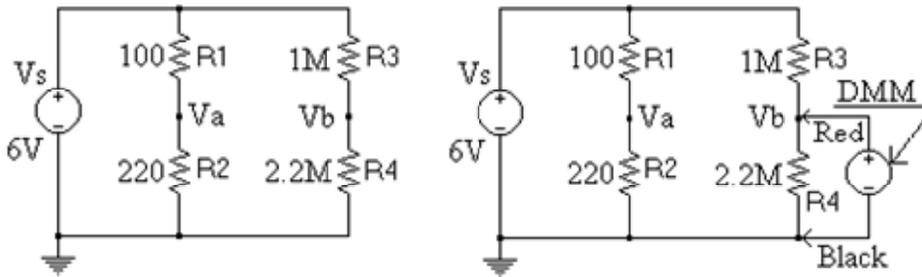
Part A: Voltage Measurement

1. Measure and record the values of the resistors in the circuit. You will use these measured resistor values for your calculations and for LTSpice input in experiment 8.

R1: _____ R2: _____

R3: _____ R4: _____

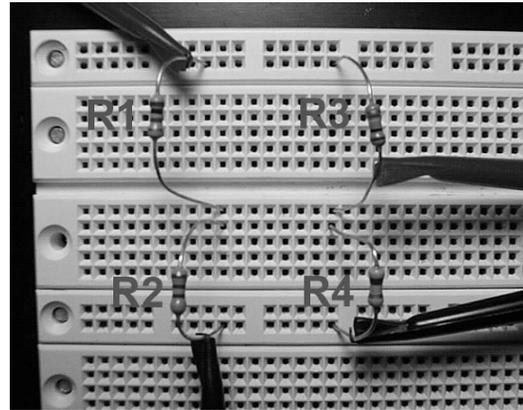
2. Connect the circuit below on the left and set the power supply voltage to 6.0V.



Lay out the circuit on the breadboard so it looks similar to the schematic diagram. Use the minimum number of wires to connect the circuit.

Note that the positive power supply lead is connected to the top of R1 and the that negative power supply lead is connected to the bottom of R2.

The voltmeter is connected across R4.



3. Measure and record V_a , V_b and V_{ab} ($V_{ab} = V_a - V_b$).

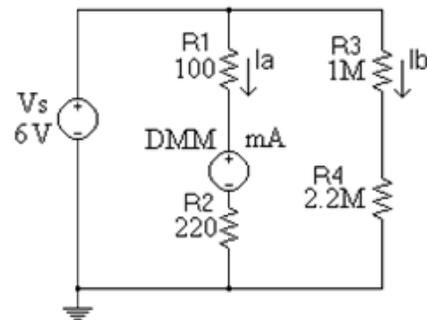
V_a : _____ V_b : _____ V_{ab} : _____

4. Obtain and record the internal resistance, R_i , of your voltmeter. R_i : _____

Part B: Current Measurement

1. The circuit on the right shows the DMM connected in series with the 100Ω and 220Ω resistors.

You need to break the connection between R1 and R2 and insert the meter as shown. The meter will read the current through the 100Ω and 220Ω resistors.



- The internal resistance of a DMM on the current ranges varies with the range. Check the manual on your DMM to see what its internal resistances are on the current ranges. If you don't have a manual, your instructor should provide the information. Record the meter resistances below.

$R_m(0.2\text{mA})$: _____ $R_m(2\text{mA})$: _____

$R_m(20\text{mA})$: _____ $R_m(200\text{mA})$: _____

- Measure and record the current through the 100Ω and 220Ω resistors with the meter on the 20mA range.

$I_{a_{20}}$: _____

- Measure and record the current through the 100Ω and 220Ω resistors with the meter on the 200mA range.

$I_{a_{200}}$: _____

Analysis, Part A

- Calculate the theoretical values of the voltages: V_a , V_b , and V_{ab} , without taking the meter resistance into account. Calculate the percent error between the theoretical and measured results.
- Calculate the voltages: V_a , V_b , and V_{ab} taking the meter resistance into account. Calculate the percent error between the measured and calculated results.

Analysis, Part B

- Calculate the theoretical current, I_a , (without taking the meter resistance into account). Calculate the percent error between the theoretical and measured values (both current ranges).
- Calculate the current, I_a , taking the meter resistance into account. Calculate the percent error between the calculated and measured results.
- Briefly explain the significance of the error analysis in steps 1 and 2 above.

Experiment 8: LTspice Circuit Simulation

Introduction

LTspice IV will be used to simulate the circuit of experiment 7. It is important to always use your measured part values so that you can compare your measured results to your simulation results.

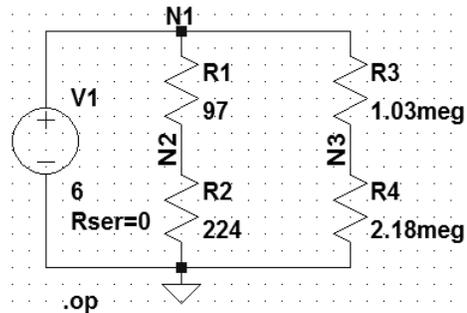
Drawing the Circuit

1. Start the *LTspice* program. In the main menu bar, click on **File** and select New Schematic.



2. Create the new schematic. Left click on the resistor symbol and drag and place the resistor, R1. Get three more resistors and place them as shown on the right.

Right click on the “R” of each resistor. Change the values to the measured values from Experiment 7.

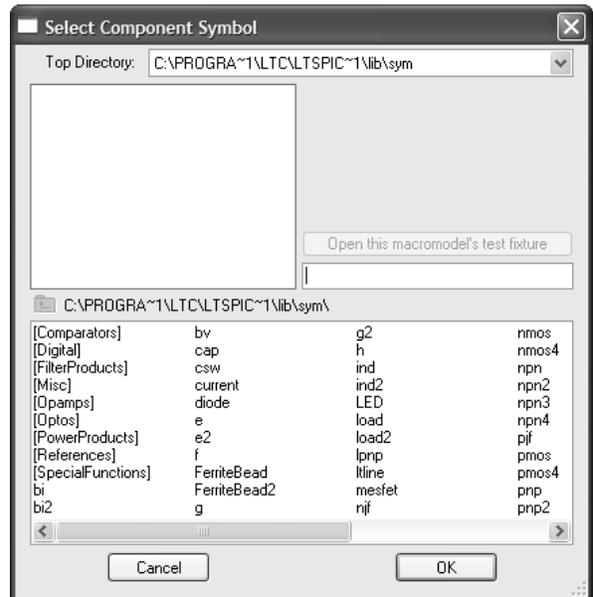


3. Left click on the gate symbol between the diode and the hand in the main menu to get the dialog box on the right. Select the part “*voltage*”. place it in the schematic.

Click on the ground symbol and place it under R2.

4. Left click on the pencil in the main menu to connect the components.

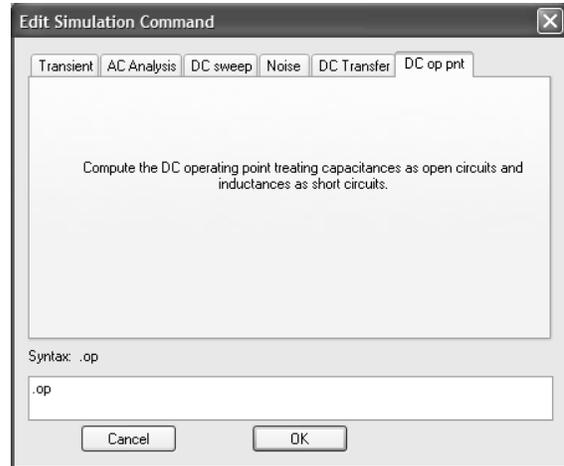
5. Left click on the A between the ground symbol and the resistor symbol to label the nodes *N1*, *N2*, and *N3* as shown on the schematic by dropping the dot on the nodes.



Click “Help” in the menu for more information on creating the schematic.

6. Click on **Simulate** and then select the *Edit Simulation Cmd* in the menu. Select *DC op pnt as shown on the right*. Click on *ok*. A “.op” command will appear which can be placed anywhere on the schematic.
7. Click on *Simulate* and then select *Run*. If there are no errors, you will see an “*Operating Point*” file.

The Spice netlist shows the connections of the parts, part models, and types of analysis to be performed.



```

--- Operating Point ---
V(n1):          6          voltage
V(n2):          4.18692    voltage
V(n3):          4.07477    voltage
I(R4):          1.86916e-006 device_current
I(R3):          1.86916e-006 device_current
I(R2):          0.0186916  device_current
I(R1):          0.0186916  device_current

Netlist
R1 N1 N2 97
R2 N2 0 224
R3 N1 N3 1.03meg
R4 N3 0 2.18meg
V1 N1 0 6 Rser=0
.op
.backanno
.end

```

Exercise and Analysis

1. Simulate the loading effect of the voltmeter at nodes 2 and 3 using a resistor whose resistance is equal to the meter’s internal resistance. Compare simulated results to Experiment 7 measured results.
2. Simulate the loading effect of the ammeter using a resistor whose resistance is equal to the meter’s internal resistance. Compare simulated results to Experiment 7 measured results.