**The big gay Lab 1**

**Instrumentation – DC Measurements: Report**

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Complete a report on Lab 1 by providing the following results from your measurements and adding your conclusions where requested. Also insert graphs and tables as appropriate.

This should be handed in at the start of Lab 2.

**1. Continuity with DMM (Section 3.1)**

Show a basic sketch of your breadboard and indicate the internally electrically connected pattern on the board.

**2. Current and voltage measurements (Section 2.1 and Section 3.2)**

(a) Show your calculated currents and voltages from Section 2.1 for the circuit in Figure 8.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| I1 (mA) | I2 (mA) | I3 (mA) | V1 (V) | V2 (V) | V3 (V) | P1 (mW) | P2 (mW) | P3 (mW) |
| 16 mA | 10 mA | 6 mA | 1.6 V | 3.4 V | 3.4 V | 0.0256w | 0.034w | 0.0204w |

(b) Now show your measured values from Section 3.2 for the actual circuit:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| I1 (mA) | I2 (mA) | I3 (mA) | V1 (V) | V2 (V) | V3 (V) | P1 (mW) | P2 (mW) | P3 (mW) |
| 16.27mA | 10.21 mA | 6.04 mA | 1.62V | 3.33V | 3.35V | 0.0265w | 0.058w | 0.0204w |

**(c) How does the calculated and measured values of current, voltage and power compare? List the % difference between these two sets of values in the table below:**

% Difference between calculated and measured:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| I1 (mA) | I2 (mA) | I3 (mA) | V1 (V) | V2 (V) | V3 (V) | P1 (mW) | P2 (mW) | P3 (mW) |
| 1.68% | 2.1% | 2/3% | 2.63% | 2% | 1.47% | 3.07% | 2.06% | 2% |

**(d) Can you explain why the observed values would differ from the calculated values ?**

There will be inaccuracies in the mesurements of the DMM (digital multi-meter) due to there being resistances on the leads attached to the meter, aswell as inate resistance and capacitance within the breadboard. There will also be tolerances attached to the resistors being used, adding another layer of inacuracy to the circuit that could cause the observed differences.

**3. Internal resistance of ammeter and voltmeter (Section 2.3)**

**(a) Show the expected voltages calculated across RA and RB in Figure 10 for the different values of RA and RB.**

|  |  |  |  |
| --- | --- | --- | --- |
| RA | RB | VRA | VRB |
| 1 kΩ | 10 kΩ | 3/11 V | 30/11 V |
| 100 kΩ | 1 MΩ | 3/11 V | 30/11 V |

**(b) Now assume that these voltages are measured with voltmeters with resistances (i) RM = 10 kΩ, (ii) RM = 1 MΩ, and (iii) RM = 10 MΩ. Use a table to show your expected voltages across RA and RB for the different resistances as dependant on the different values of RM.**

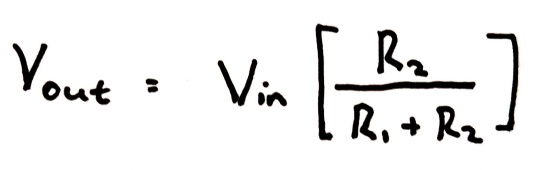
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| RM | RA | RB | VRA | VRB |
| 1 kΩ | 1 kΩ | 10 kΩ | ¼ V | 11/4 V |
| 1 kΩ | 100 kΩ | 1 MΩ | 0.2762 V | 2.973 V |
| 1 MΩ | 1 kΩ | 10 kΩ | 0.2724 V | 2.7275 V |
| 1 MΩ | 100 kΩ | 1 MΩ | 0.25 V | 2.75 V |
| 10 MΩ | 1 kΩ | 10 kΩ | 0.2727 V | 2.7272 V |
| 10 MΩ | 100 kΩ | 1 MΩ | 0.2702 V | 2.729 V |

**(c) How does the accuracy of the measurements depend upon the relationship between RM and RA and RB? What value of RM is necessary for the measured voltage to be accurate? Explain the influence of RM in obtaining accurate measurements.**

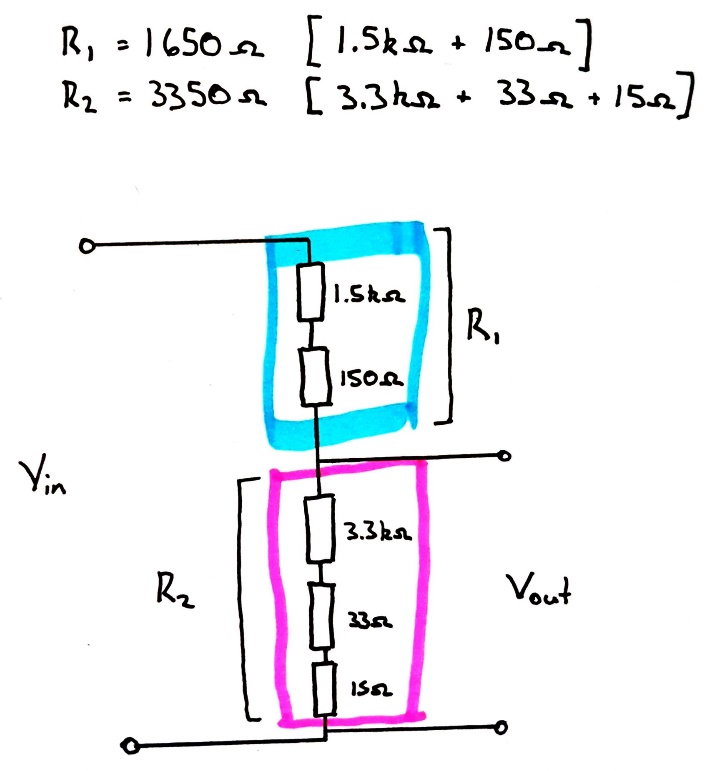
Since RM is in parallel with whatever resistor you are measuring across, it will have a current flowing through it that is dependent on the ratio between RM and the measured resistor. Because of this the current and voltage through and across the resistor will change, affecting the reading. To ensure that readings are accurate, it would be recommended that RM is 2 orders of magnitude larger than the measured resistor.

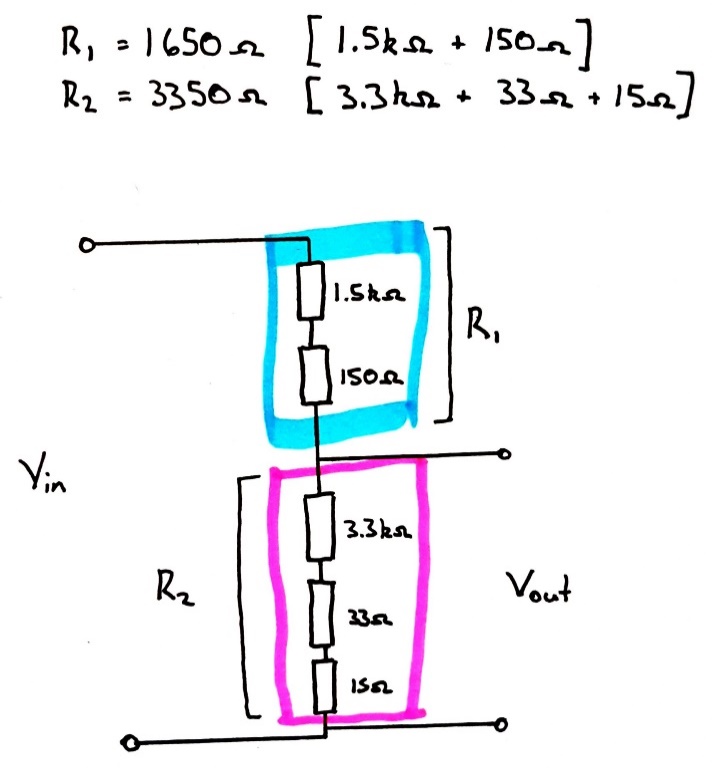
**5. Voltage divider circuits (Section 3.3)**

**(a) Write an expression for the voltage Vout observed in Figure 9 in terms of R1, R2 and the supply voltage Vin.**



**(b) Sketch the circuit for the voltage divider design in Section 2.2 (b). Indicate the values of all resistors in your design.**





**(c) Show the results of the test of your voltage divider (Section 3.3) as a function of different values of input voltage Vin.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Vin (V) | 1 | 2 | 3 | 4 | 5 |
| Vout (V) | 0.333 V | 0.680 V | 1 V | 1.311 V | 1.656 V |
| Vin/Vout % | 33.3% | 34% | 33.3% | 32.78% | 32.12% |

**(d) Show the results of the test of your voltage divider (Section 3.3) for an input voltage Vin = 3 V and different values of the load resistance RL.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| RL | 100 Ω | 500 Ω | 1 kΩ | 5 kΩ | 10 kΩ | 50 kΩ | 100 kΩ |
| Vout (V) | 0.08 V | 0.3 V | 0.47 V | 0.81 V | 0.89 V | 0.97 V | 0.98 V |

**(e) Explain your observations in (d) above and how this may limit the use of such a voltage divider circuit as a stable voltage source in a circuit.**

The effect show in (d) is known ad “loading”, as we are applying a load across the output V**out.** This happens because we are now changing the circuit by applying a load to it in parallel with one of the resistors. Because of this affect, a voltage divider is not a suitable way of providing a stepdown voltage source of Vin. However, if a voltage follower (op-amp) were to be placed between the circuit and the load then this would be remedied.

**4. Resistance measurement with a DMM (Section 3.4)**

(a) Show your resistance measurements of different resistors and also the % difference from the indicated value.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Stated resistor value | 1 Ω | 10 Ω | 100 Ω | 1 kΩ | 10 kΩ | 100 kΩ | 1 MΩ |
| Measured resistor value | 1.5 | 10.3 | 100.5 | 986 | 10.05k | 98.3k | 1.016M |
| % Difference | +50% | +3% | +0.5% | -1.4% | +0.5% | -1.7% | +1.6% |

**(b) Comment on the observed difference vs. the expected tolerance from the resistor.**

All resistors were within their expected tolerances, except for the 1 Ω resistor. This can be assumed to be due to inerrancies on very small resistances with our DMM

**5. Measuring low resistances (Section 3.5)**

**(a) Compare the resistance value obtained by using the Fluke DMM to that obtained from the four wire measurement with the benchtop instrument.**

|  |  |
| --- | --- |
| 2 Wire Fluke Measurement | 0.3 Ω |
| 4 Wire Measurement | 0.184 Ω |

**(b) Explain how a 4 wire measurement produces a much more accurate value for low resistances.**

By using 4 leads, you can use 2 leads to provide a constant current through the resistor, and then 2 leads to read the voltage drop across the resistor. By doing this we can achieve readings with a higher accuracy since the voltmeter theoretically has infinite impedance meaning that there is no voltage drop across it. Because of this the only voltage drop will be across the resistor that we are testing.

**(c) It is given that the copper wire used as the low resistance sample is 1.34 meter long and has a diameter of 0.4 mm. Use your four wire resistance measurement to calculate the conductivity of the copper wire. How does your calculated value compare to the conductivity values for Cu that are quoted in the literature ? [Reference the values for σCu that you can find in the literature].**

Calculated conductivity: 5.8x105

Quoted conductivity: 5.96x107

My calculated conductivity is far lower than that from the literature, I assume this to be because of the equipment that we have to measure this, as well as measuring errors.

**(c) Calculate what the resistance will be for a Si wire of the same dimensions as the copper (assuming we could draw Si into a wire !) if it is given that undoped (intrinsic) Si will have a carrier density of 1 x 1010 cm-3 and electron and hole mobilities μe = 1350 cm2.V-1.s-1 and μh = 450 cm2.V-1.s-1 at room temperature.**

σ = neμe + peμh

= 2.88x10-6

R = L/A

=1.5x109 Ω

**6. Additional Questions**

**6.1 Calculation of conductivity from an I-V graph**

The “lead” in an old fashioned pencil is of course not lead, but manufactured from a composite that is a mixture of clay/polymer and graphite. The more graphite the composite contains the darker the writing will be and the “softer” the pencil is. Figure 1 below gives an indication of this softness/hardness scale and how this will influence the colour of the writing from the pencil.



**Figure 1:** The influence of the % of graphite loading in pencil lead on the softness of the lead.

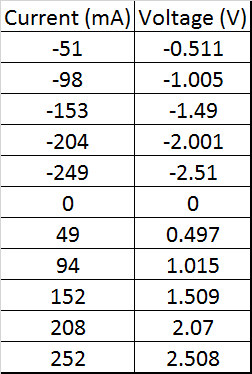
However, graphite (a form of carbon) is an electrical conductor and adding this material to the clay will also make the pencil lead electrically conductive. We can thus view the pencil lead as a resistor with the value of resistance dependant on the % graphite content.

In an industrial control process in a pencil factory a four wire resistance measurement is used to measure the resistance of pencil lead and from these measurements calculate the approximate graphite content. The circuit for the measurement is shown in Figure 2, and the voltage drop over the pencil lead is measured for different values of the current through the pencil lead.



**Figure 2:** Circuit for measurement of pencil lead resistance by measuring the I-V curve.

The results from this current – voltage measurement is shown below.



The pencil lead under measurement is 13.5 cm in length and have a circular cross section with a diameter of 1.8 mm. We must now use this data to calculate the electrical conductivity of the pencil lead in order to use it as a quality control measure in the manufacturing process.

(a) Use the measured data and plot a graph of voltage vs current. Insert your graph below.

**(b) Use this graph to calculate the electrical resistance of the pencil lead. Clearly show your method.**

The electrical resistance of the pencil is the gradient of the voltage vs current graph. From this we can see the resistance of the pencil to be 0.01 Ω.

**(c) Use this resistance value as well as the geometry of the pencil lead (length, cross sectional area) to calculate resistivity and conductivity of this material.**

 = RA/L

= 1.88x10-4

 = 1/

= 5305

**(d) Discuss at least two reasons why a series of I-V measurements and a calculation of the resistance from these measurements may be better than a single measurement as performed by a DMM.**

When taking many measurements and averaging them we are decreasing the overall total error. This is because every measurement will have some level of inaccuracy, however this will be on either side of the actual true reading. By taking multiple measurements we can eliminate this error by cancelling it out.

Also, by separately recording voltage and current we are more likely to achieve an accurate reading.

**(e) What do you think is the purpose of the 330 Ω resistor in the measurement circuit as shown in Figure 2.**

The purpose of the 330 Ω resistor is to decrease the voltage dropped across the pencil, and thereby the power over the pencil. If the resistor were removed, all 5V would be dropped the pencil lead causing it to become damaged.

**6.2 Design of a bipolar voltage signal:** You must design a circuit that will supply a variable -5V to +5V output that can be used for a reference signal. To do this you are given two 9V batteries, a 10 kΩ potentiometer and you have access to a full range of resistors. Sketch your circuit design.

A potentiometer is a variable resistor, typically with three contacts as in the sketch below. The third contact, called the wiper, can be manually moved to make contact at any point with the fixed resistive strip. As the point of contact changes, the resistances R13 and R23 will also change. If the wiper moves closer to contact 2, R13 will increase while R23 will decrease. The opposite will happen when the wiper moves closer to contact 1. The resistance R12 will always be constant.

By turning the potentiometer knob you should now create an output voltage that will vary between – 5V (potentiometer in the one extreme position) to + 5V (potentiometer in the opposite extreme position).



**Figure 3:** A potentiometer

(a) Sketch the circuit you will construct and clearly show the position of the output voltage. Also show the values of all resistors that you will use in the construction of your circuit.

(b) Calculate the power consumption of your circuit assuming that no load is connected to it.