Lab 9: Design Project

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Introduction

Designing new circuits without full blueprints and testing them to meet specification is the most fundamental job of electrical engineers. Learning how to approach open-ended problems and solve them is the core concept that differentiates engineers from other professions.

Adjustable Voltage Source Calculations

To get a voltage between -2 V and 2 V from -5 V and 5 V for the 1 MΩ load resistor, two resistors in series on either side of a potentiometer are used like so, were the potentiometer is arbitrarily set to one of the three available values (10 kΩ):

The next set is to calculate the resistance R for which the voltage across the potentiometer is always 4 V. Since both resisters are R, the voltage on one end of the potentiometer is the negative of the other (-2 V to 2 V).

The potentiometer acts as a voltage divider given by:

$$V_o = 2V_1x$$

Where V_1 is the voltage at the positive terminal of the potentiometer (mirrored at the negative terminal, thus times 2) and x is the fractional resistance set internally, which splits the potentiometer into “two” seperate resistors who add up to 10 kΩ.

If we assume $x = 1$, then V_1 must equal 2 V, since the resistance of the “top” resistor in the potentometer is 0 (short-circuit). otherwise the circuit goes beyond the allowed voltage range.

Nodal analysis can be used to find the value of R:

$$\frac{5-2}{R} = \frac{2}{1000000} + \frac{2-(-5)}{R+10000}$$

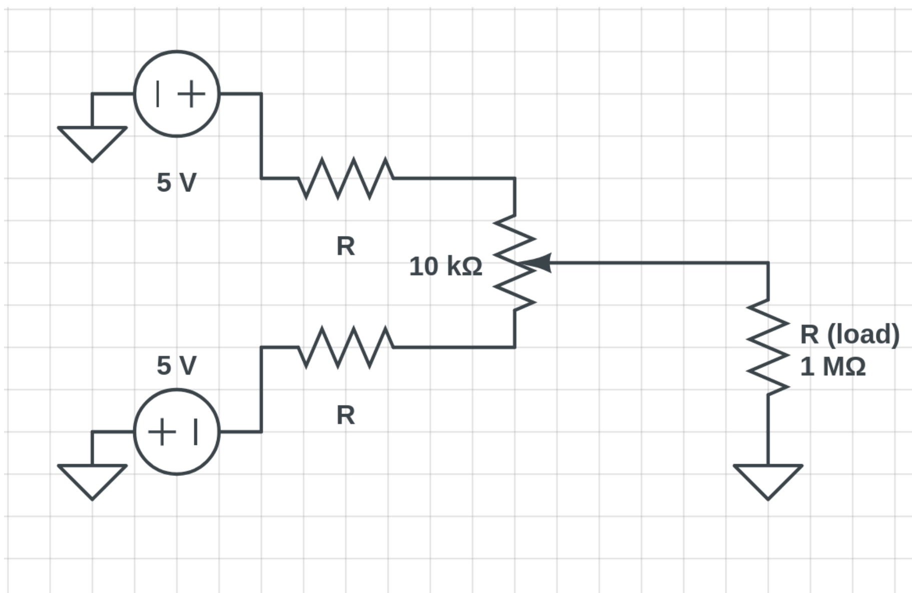

Figure 1: Circuit Diagram

Skipping the algebra done on paper for conciseness, we arrive at a quadratic equation for R, where the *positive* resistance is the one in question:

$$0 = (2 \times 10^{-6})R^2 + 4.02R - 30 \times 10^3$$

$$\boxed{R = 7435.183\,\Omega}$$

The maximum current through any part of the circuit is the current across the resistor connected to the positive terminal of the potentiometer when it short-circuits. Using Ohm's law, this is:

$$I_{\text{max}} = \frac{3}{7435.183}\,\text{A} = \boxed{0.403\,\text{mA}}$$

Results

To make the 7.4 kΩ resistors, I combined two 2.2 kΩ and two 1.5 kΩ resistors for each. A voltage of $\pm$ 5 V is set on each side by the Digilent which also reads the output voltage and has ground leads.

The voltmeter showed a maximum voltage of around 2 V, as shown in red, and minimum of 2 V, as shown in blue. The circuit works perfectly. When the 1MΩ resistor is swapped for a 100 kΩ one, the voltmeter is the same:

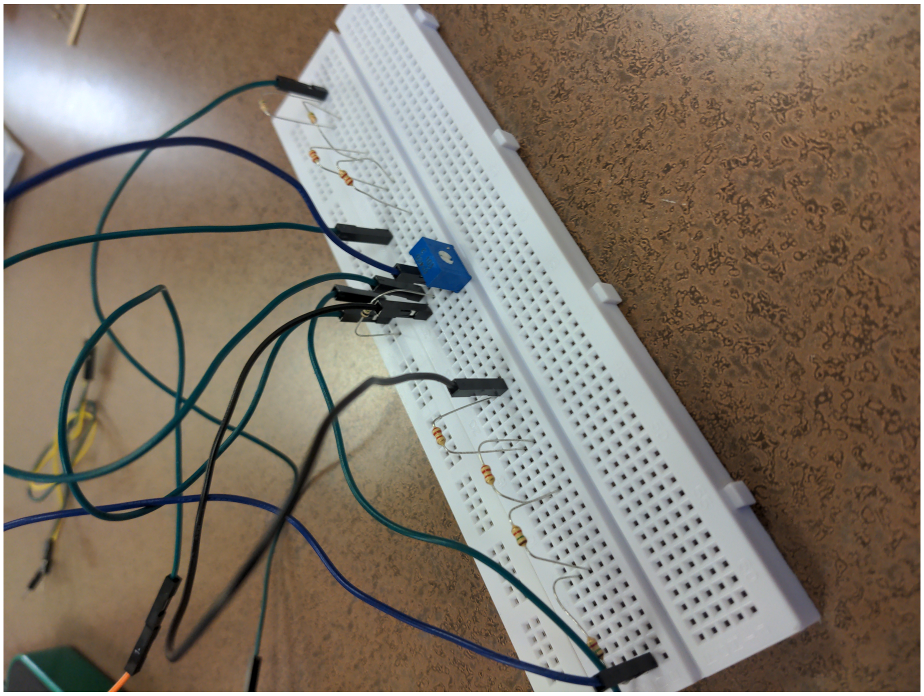

Figure 2: Real Circuit

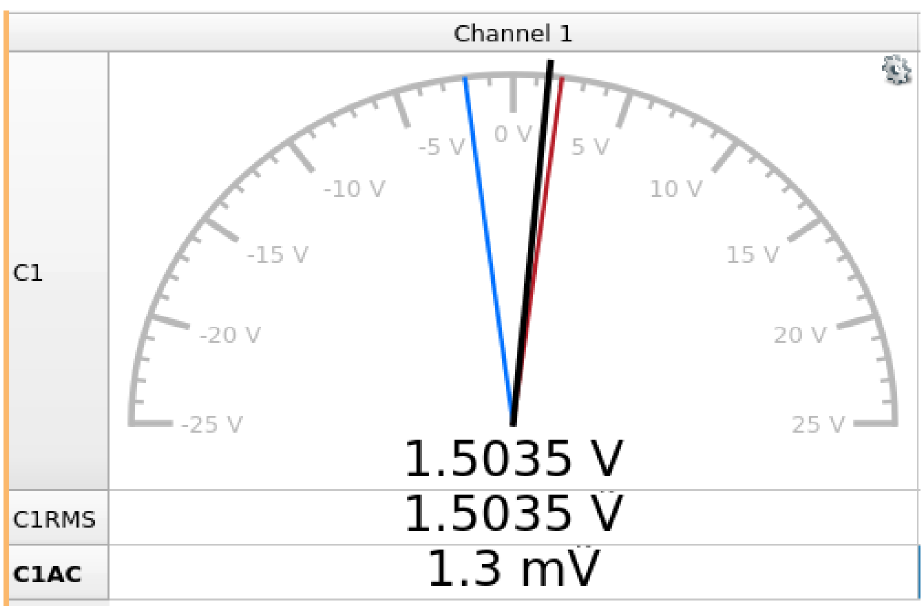

Figure 3: Voltmeter

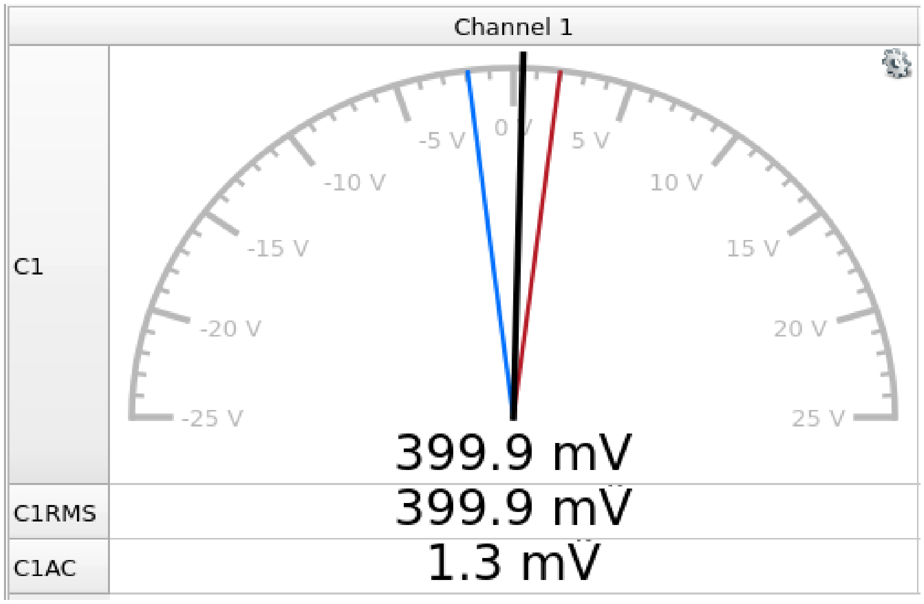

Figure 4: Voltmeter

Conclusion

The circuit designed here works for any load resistance, ignoring the max current specification of 50 mA. Taking the max current into account, the lowest load resistance is:

$$R_{L,min} = \frac{2}{0.050}\,\Omega = \boxed{40\,\Omega}$$

Overall, the uses of the potentiometer were demonstrated thoroughly in this lab, and the aspects of design and testing too.