Unit 4 Potential divider

- The current in the resistors in series in a potential divider chain is given by the input voltage divided by the sum of the resistors in the chain.

$$\text{Current} \quad I = \frac{V_{in}}{R_1 + R_2}$$

- The output voltage is given by this current times the resistor across the output.

$$\text{Output voltage} \quad V_{out} = I \times R_2 = \frac{R_2}{R_1 + R_2} \times V_{in}$$

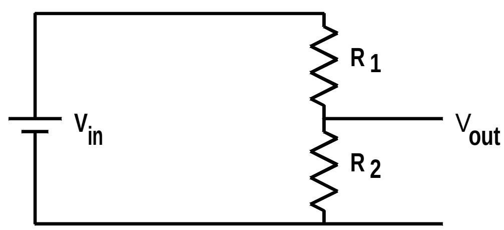

Figure 4.1: Potential divider.

When calculating the output from a potential divider circuit, it is better to obtain the current in the resistor chain first, by getting the equivalent series resistance. The output voltage is then obtained by using Ohm's law to calculate the voltage drop for the resistor across the output. This approach avoids the need to remember which is R_1 and which is R_2 with the consequent possibility of confusion.

Think of the output voltage as a fraction of the input voltage. The output voltage will therefore always be smaller than the input voltage but be careful when using bipolar supplies such as are used in Problem 4.4.

Frequently it is necessary to be able to switch between a set of fixed fractions of the input voltage such as when changing ranges in voltmeters or oscilloscopes. In this case, rotary switches or slide switches are used.

If a continuously variable fraction of the input voltage is required then a rotary or slider potentiometer is used where a wiper varies the contact point along a resistive track of carbon, wire or conductive plastic. Two types of track are used: a linear track where the resistance is proportional to angle of rotation or linear movement and a logarithmic track where the logarithm of the resistance is proportional to angle of rotation or linear movement. The response of the ear to increases in audio power is nonlinear and the perceived loudness of sound is proportional to the logarithm of the sound intensity or watts per square metre, Wm^{-2}. Therefore log pots are often used as volume control potentiometers to give an apparent linear increase in loudness with rotation of the volume control knob.

4.1 Examples

4.1 Calculate the output voltage from the potential divider in Figure 4.2.

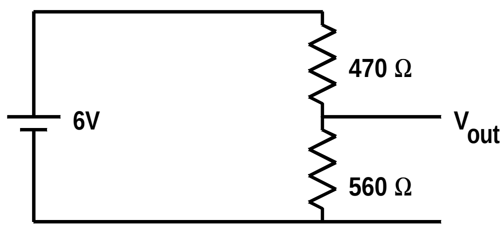

Figure 4.2: Example 4.1.

$$\begin{aligned} \text{Current} \quad I &= \frac{6\,\mathrm{V}}{470\,\Omega + 560\,\Omega} \\ &= \frac{6}{1030} \\ &= 5.82\,\mathrm{mA} \\ \text{Output voltage} \quad V_{out} &= 5.82\,\mathrm{mA} \times 560\,\Omega \\ &= 3.26\,\mathrm{V} \end{aligned}$$

4.2 Calculate the output voltage when the potentiometer shown in Figure 4.3 is set at 0%, 12%, 50%, 75%, 90%, 100% of its range.

$$\begin{aligned} \text{The percentage of range} &= \frac{R_2}{R_1 + R_2} \times 100 \\ \text{Therefore} \quad V_{out} &= 0.00 \times 15\,\mathrm{V} = 0.0\,\mathrm{V} \quad \text{for 0\% setting} \\ V_{out} &= 0.12 \times 15\,\mathrm{V} = 1.8\,\mathrm{V} \quad \text{for 12\% setting} \end{aligned}$$

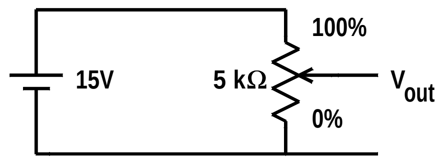

Figure 4.3: Example 4.2.

$$\begin{aligned} V_{out} &= 0.50 \times 15\,\text{V} = 7.50\,\text{V} \quad \text{for } 50\% \text{ setting} \\ V_{out} &= 0.75 \times 15\,\text{V} = 11.3\,\text{V} \quad \text{for } 75\% \text{ setting} \\ V_{out} &= 0.90 \times 15\,\text{V} = 13.5\,\text{V} \quad \text{for } 90\% \text{ setting} \\ V_{out} &= 1.00 \times 15\,\text{V} = 15.0\,\text{V} \quad \text{for } 100\% \text{ setting} \end{aligned}$$

4.2 Problems

4.1 The rotary switch connects the output to one of the points 1 to 5 in the circuit of Figure 4.4. The total resistance of the series of resistors is to be $1\,\text{M}\Omega$. Calculate the values of R_1, R_2, R_3 and R_4 such that the output voltages are given by:

$$V_1 = V_{in},\ V_2 = \frac{V_{in}}{2},\ V_3 = \frac{V_{in}}{10},\ V_4 = \frac{V_{in}}{20},\ V_5 = 0$$

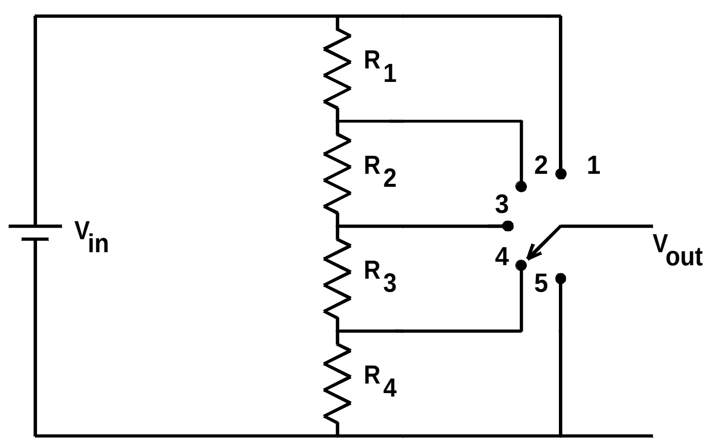

Figure 4.4: Problem 4.1.

4.2 Calculate the output voltage for each setting of the rotary switch shown in Figure 4.5. Why should a make-before-break switch be used, if the output voltage is never to exceed $2\,\text{V}$? Why does this difficulty not arise with the circuit configuration used in Problem 4.1?

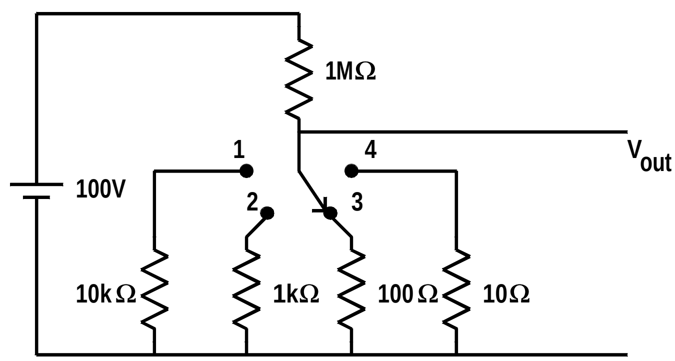

Figure 4.5: Problem 4.2.

4.3 Plot a graph of the output voltage as a function of the percentage range setting of the 1 kΩ potentiometer in Figure 4.6.

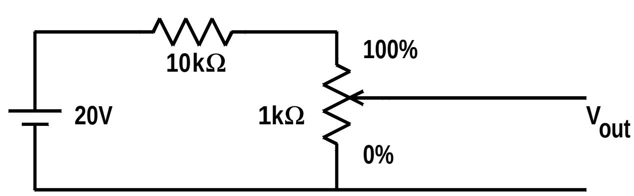

Figure 4.6: Problem 4.3.

4.4 Calculate the voltages, measured wrt ground, which you would expect to observe at points A, B, C, D, E and F of Figure 4.7. Follow the convention that ground is the line at the bottom of the circuit unless otherwise indicated. (Take care to note the polarity of the battery supplies.)

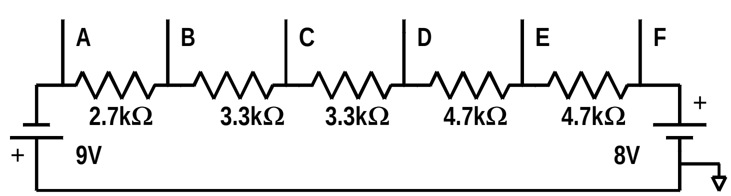

Figure 4.7: Problem 4.4.