Module 1, Lesson 4 - Potential dividers

Student

45 minutes

Purpose of this lesson

- Use and observe the behavior of potential divider circuits.
- Build potential divider circuits and measure voltages across resistors.
- Investigate how potential divider circuits can be used to change the output characteristics of a sensor.

Materials

Copy of the lesson	1 Beaker
1 Multimeter	Hot water
3 Resistors	Ice
3 Battery snaps	1 Thermometer
6 Alligator clips	1 Thermistor
Graph paper (or Excel)	

Background and Discussion

What is a potential divider or voltage divider?

In the previous lesson you saw that it was desirable to build a sensor whose output varied *positively* and *linearly* with temperature. *Resistance* of your thermistor does not vary positively or linearly with temperature (exponential decay), so it is not a good way to measure temperature. Instead, it is necessary to build a new circuit around the thermistor, from which we will be able to obtain a *voltage* reading which does vary *approximately* positively and linearly with temperature.

The circuit that we will use is called a "potential divider" or "voltage divider" circuit, fig. 1. The circuit contains two resistors – one is the thermistor which changes its resistance value with temperature, the other is a fixed 10kΩ resistor. In the voltage divider circuit, the battery voltage (9V) is "divided" between the two resistors in proportion to their relative sizes.

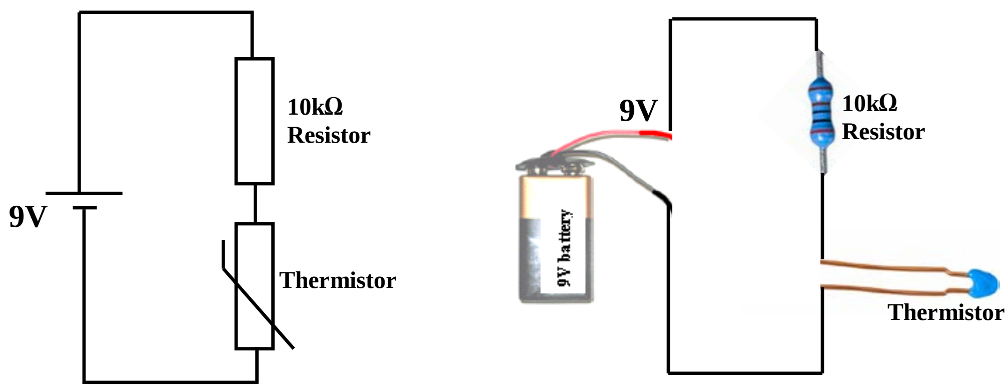

Fig. 1. Circuit diagram and setup for a voltage divider circuit.

*DO NOT BUILD THIS CIRCUIT YET – it is drawn here to help with discussion and understanding. You will build a circuit like this in the next lesson!

For example, if the thermistor also has a resistance of 10kΩ, both resistors are equal (as in fig 2a). Each resistor constitutes exactly half the total resistance. The voltage is divided equally – the resulting voltage across each resistor will be 4.5V, see fig. 2a. As another example, if the thermistor has resistance of only 5kΩ, then the thermistor forms only one third of the total resistance and the fixed 10kΩ resistor forms two thirds of the total resistance. Therfore the 10kΩ resistor will experience two thirds of the total voltage (6V) and the thermistor will experience one third of the total voltage (3V), see fig. 2b.

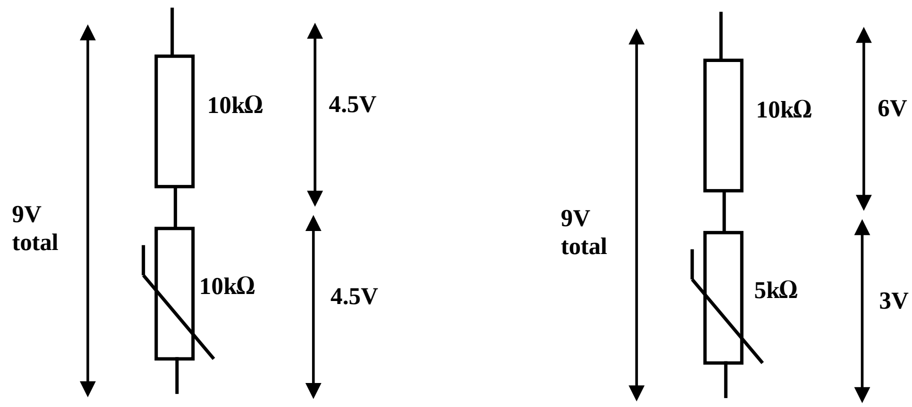

Fig. 2. A voltage divider divides the total voltage up between the two resistors in proportion to their resistances.

a) For two equal resistors, each resistor gets half the total voltage across it.
b) The 10kΩ resistor gets two thirds of the total voltage, whereas the 5kΩ gets one third of the total voltage across it.

Part 1 - Measuring voltages across resistors in a voltage divider circuit

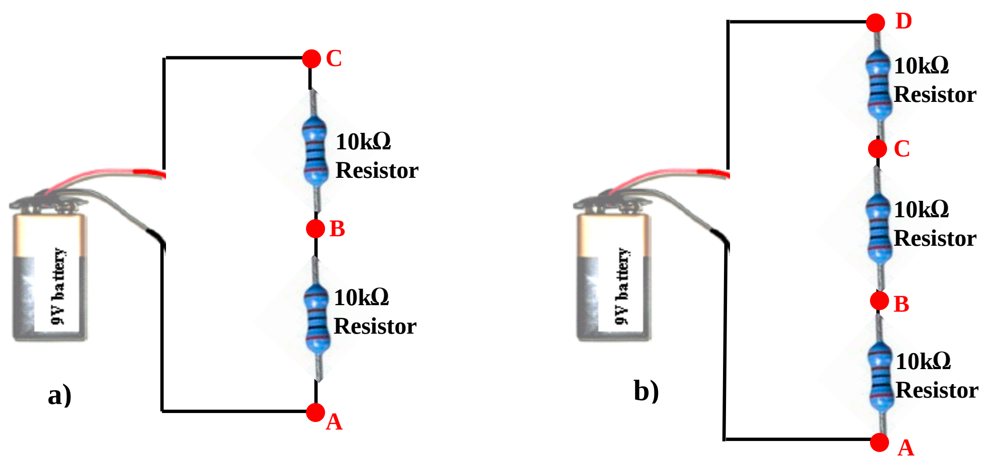

Fig. 3. a) Voltage divider circuit with 2 resistors.
b) Voltage divider circuit with 3 resistors.

1a) Build the circuit shown in fig 3a.

- Use your multimeter to measure the voltage between point A and point B.
- Use your multimeter to measure the voltage between point B and point C.
- Use your multimeter to measure the voltage between point A and point C.
- Record the measurements:

V_{AtoB}______________ V_{BtoC}______________ V_{AtoC}______________

i) What is the resistance between points A and B, points B and C, and points A and C? NOTE: Disconnect the battery before measuring the resistances, otherwise the resistance in the other side of the circuit will affect the measurement. Write these down:

R_{AtoB}______________ R_{BtoC}______________ R_{AtoC}______________

1b) Build the circuit shown in fig. 3b.

- Measure voltage between points A and B, then points B and C, then points C and D.
- Measure the voltage between points A and C, and then points B and D.
- Measure the voltage between point A and point D.
- Record the measurements:

V_{AtoB}______________ V_{BtoC}______________ V_{CtoD}______________

V_{AtoC}______________ V_{BtoD}______________ V_{AtoD}______________

i) What is the resistance between points A and B, points A and C, and points A and D? Record the measurements:

R_{AtoB}______________ R_{AtoC}______________ R_{AtoD}______________

Assessment

1) Look at fig. 3a).

a) Calculate $R_{AtoB} \div R_{AtoC}$ and then calculate $V_{AtoB} \div V_{AtoC}$ using the voltages you measured for circuit 3a).

b) Calculate $R_{BtoC} \div R_{AtoC}$ and then calculate $V_{BtoC} \div V_{AtoC}$ using the voltages you measured for circuit 3a).

c) Do you notice any relationship between the resistances and the voltages? Explain.

2) Look at fig. 3b)

a) Calculate $R_{AtoB} \div R_{AtoD}$ and then calculate $V_{AtoB} \div V_{AtoD}$ using the voltages you measured for circuit 3b).

b) Calculate $R_{AtoC} \div R_{AtoD}$ and then calculate $V_{AtoC} \div V_{AtoD}$ using the voltages you measured for circuit 3b).

c) Do you notice any relationship between the resistances and the voltages? Explain.

Part 2 - Using your thermistor in a voltage divider circuit

Look at the circuit shown in fig. 4. DO NOT BUILD THIS CIRCUIT YET – you will build something like this in the next lesson, but for now just think about how this circuit might behave. We will try to predict what results you will measure when you really do build this circuit in the next lesson.

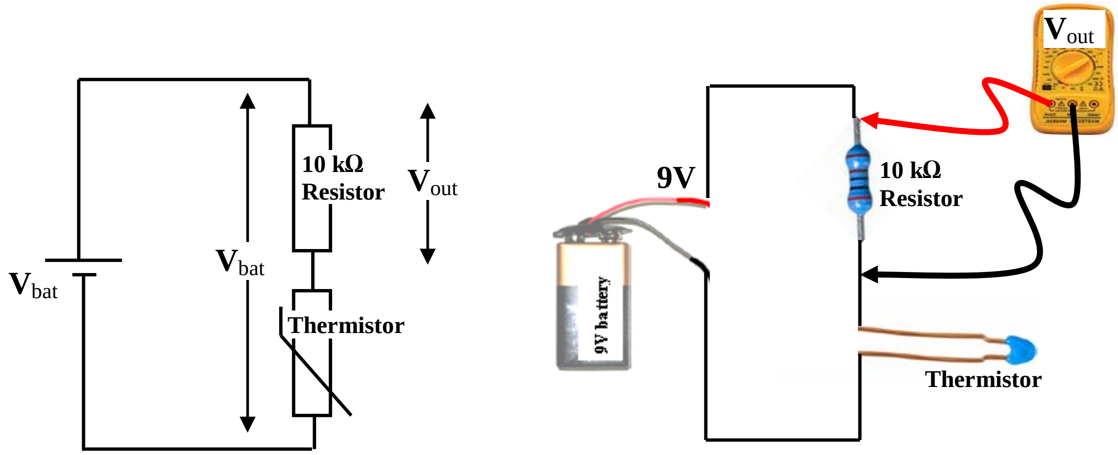

Fig. 4. Circuit diagram and setup for incorporating a thermistor into a voltage divider circuit. voltage divider circuit. We will call the voltage across the 10kΩ resistor the "output voltage" and we can measure this output voltage with a multimeter.

The voltage across the 10kΩ resistor is the "output voltage" of the voltage divider, labeled V_{out}. R_T is the resistance of the thermistor and V_{bat} is the battery voltage.

By analyzing the cicuit using Ohm's law, and remembering that the 10kΩ resistor has a resistance of 10000 Ohms, you can prove the following relationship:

$$V_{out} = \frac{10000\Omega}{R_T + 10000\Omega} \times V_{bat}$$ **(equation 1)**

This is a general way of writing down the relationship seen in part 1. The total battery voltage is divided between the resistors in proportion to their resistance.

Assessment

1) Look at your results for *Lesson 3 - Temperature vs. resistance characteristics of a thermistor*. Use the values that you recorded for the thermistor resistance, R_T (expressed in Ω), versus temperature, and record in the table below.

2) Combine these with equation 1 from above, to calculate what output voltage, V_{out}, you will expect to measure at different temperatures, for the circuit shown in figure 3. Assume the battery voltage, V_T, is exactly 9Volts.

3) Record these predictions in the table:

Temperature, ºC	0	10	20	30	40	50	60	70	80
Thermistor resistance, R_T (kΩ)									
Convert from kΩ to Ω by multiplying by 1000									
Thermistor resistance, R_T (Ω)									
Output voltage, V_{out}									

2) Plot these predictions on a graph of temperature versus V_{out}. Use the vertical (y) axis for temperature, and use the horizontal (x) axis for V_{out}.

3) What do you notice about the shape of the graph? Is this relationship (V_{out} versus temperature) more useful than the relationship you found in part 2 (R_T versus temperature)? If so, why?

4) When measuring the resistance of circuits, why is it important to disconnect the battery before measuring the resistances?

5) Could you use the battery voltage and the voltage across the resistor to calculate the voltage across the thermistor? Explain how.