Core practical 12: Calibrate a thermistor in a potential divider circuit as a thermostat

Objectives

- To research temperature scales
- To determine the temperature variation of a thermistor
- To design a potential divider circuit that can be used to control temperature

Safety

- Although students are not assessed against CPAC 3 here, they should carry out this work with due attention to safety. They should produce an appropriate risk assessment.
- Thermistor should not exceed its voltage rating.

Specification links

- Practical techniques 1, 2, 3, 6, 7
- CPAC 2a, 2c, 4a, 5

Procedure

Research

1. Find out how fixed points are used in the construction of a temperature scale.
2. Find out how the resistance of a negative temperature coefficient (NTC) thermistor varies with temperature and compare this to other thermometric properties.
3. Explain why temperature scales depend on the type of thermometer being used.
4. Devise a plan to measure the resistance of a thermistor over the range 0–100 °C. Your plan should include a risk assessment and you should consider how you will make your results as accurate as possible.

Practical

Carry out your planned practical and draw a graph to show the resistance of a thermistor in the range 0–100 °C. You should plot this using logs – the 'All the maths you need' and 'Analysis of results' section will help. Use a graph plotting program to draw your graph.

Design

1. Use your graph to help you design a potential divider circuit that uses your thermistor and a variable resistor. Your circuit should give an output of 3.0 V at 40 °C from a 6 V DC supply.
2. Construct your circuit and test your design. To do this, set up the Bunsen burner, tripod, gauze and heatproof mat, then raise the temperature of the water in the beaker to 40 °C as measured by the alcohol thermometer. Measure the output voltage from your circuit using the ohmmeter.

Notes on procedure

- Students might carry out the research phase before starting the practical work and you can use this to assess them against CPAC 5.They should also plan their experiment and produce a risk assessment that safeguards the equipment as well as the personnel – this will help in the assessment against CPAC 3a if this is needed.
- Students will need to be told the range of variable resistors available.
- CPAC 2a and 4a can be judged in part by considering how close their experimental value is to the design value.
- Part of the practical challenge is how the student manages to get thermal equilibrium and hence accurate results for CPAC 2c.

Answers to questions

1. Students should consider the percentage difference between their experimental and design values, and compare this with their estimate of the percentage uncertainty in temperature. They might also consider how straight their log graph is.
2. They should use the idea that heating very slowly will allow the temperature of the semiconductor to be close to that of the water, and hence the alcohol thermometer as well. This long time span makes the use of a datalogger with resistance and temperature probes very helpful and will improve accuracy.
3. Students should consider how well they maintained safety as the temperature increased, for example, not only personal safety but also keeping the leads away from the hot gauze and supporting the thermometer.

Sample data

θ /°C	R/kΩ
21	5.920
22	5.530
34	3.290
44	2.190
55	1.480
61.5	1.089
76	0.698
86	0.556
96	0.428
100	0.308

Final results will depend on the student's choice of resistor.

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All the maths you need

- Recognise and make use of appropriate units in calculations.
- Use ratios, fractions and percentages.
- Use calculators to find and use power, exponential and logarithmic functions.
- Use an appropriate number of significant figures.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Use logarithms in relation to quantities that range over several orders of magnitude.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that $y = mx + c$ represents a linear relationship.
- Determine the slope and intercept of a linear graph.
- Interpret logarithmic plots.
- Use logarithmic plots to test exponential and power law variations.

Equipment

- thermistor
- ohmmeter
- alcohol thermometer
- beaker containing water
- power supply unit (PSU)
- Bunsen burner, tripod, gauze and heatproof mat
- ice
- variable resistor

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Analysis of results

1. The resistance R of a thermistor varies with absolute temperature T according to the formula

   $R = R_0\ e^{\left(\frac{b}{T}\right)}$ so $\ln R = \frac{b}{T} + a$ where $a = \ln R_0$

   and a graph of $\ln R$ against $\frac{1}{T}$ will give you a straight line which is easier than a curve to read accurately.

Learning tip

- Thermal experiments can be very difficult to control due to the thermal inertia of the components, so measuring the temperature of the actual semiconductor rather than the temperature of the water requires careful thought.

Questions

1. Consider the uncertainty in your measurement of temperature during your practical and comment on the outcome of your design.
2. State two ways in which you might improve your experiment – not your design.
3. Comment on how well your risk assessment worked and describe any safety issues that arose as you were carrying out the experiment.

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Equipment per student/group	Notes on equipment
thermistor	Negative temperature coefficient (NTC) with room temperature resistance of approximately 5 kΩ, although this is not critical
ohmmeter	Standard laboratory multimeter
alcohol thermometer	Range 0–100 °C
beaker containing water	100 cm^3 or 250 cm^3 of water would be suitable for this practical.
PSU	Voltage must be limited to 28 V AC or 40 V DC.
Bunsen burner, tripod, gauze and heatproof mat	
ice	Sufficient to reduce temperature of thermistor to 0 °C
variable resistor	The value of the resistor is to be determined by students. A selection including 1 kΩ, 2.2 kΩ, 4.7 kΩ and 10 kΩ should suffice. Variable resistors should be in a range offering the student a real choice when designing the thermostat.

Notes