Designing a divider input

LEARNING INTENTION

We are learning to design a voltage divider that gives the right input signal for a control circuit.

SUCCESS CRITERIA — I CAN

- ☐ choose the sensor and its position for a given condition
- ☐ calculate the resistor value for a switching point
- ☐ choose a suitable standard (E12) value
- ☐ state expected results in terms of V_{out}

A design routine

1 · Condition

When must the output switch on? (cold, hot, dark, light)

2 · Sensor

Which sensor detects that condition? (thermistor or LDR)

3 · Position

Put the sensor where its resistance change makes V_{out} **rise** in that condition.

4 · Value

At the switching point V_{out} = switching voltage. Calculate the other resistor.

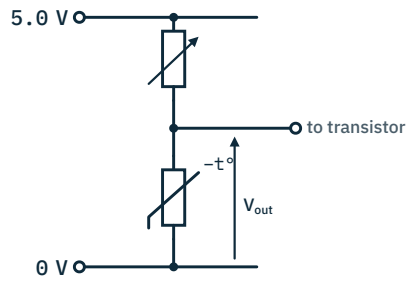
5 · Standard part

Use a variable resistor bigger than your value, or the nearest E12 fixed value.

6 · Expected results

State what V_{out} should do above and below the switching point.

Worked design



Cold-sensing points heater input

Condition: cold. Sensor: NTC thermistor. Cold → resistance up, so it goes at the **bottom** to make V_{out} rise.

From the graph, at 2 °C the thermistor is about 30 kΩ.

WORKED EXAMPLE Points heater for Highland Rail Services

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 5.0 V switch on at 2 °C R_{th} at 2 °C = 30 kΩ switch at V_{out} = 0.7 V	R_{var} (top)	$V_1 = V_s - V_{out}$ $V_1/V_2 = R_1/R_2$	V_1 = 5.0 − 0.7 = 4.3 V 4.3/0.7 = R_{var}/30 R_{var} = 30 × 4.3 ÷ 0.7	**R_{var} = 184 kΩ** use a 220 kΩ variable resistor

Highland Rail Services is fictional. Points heaters stop rail points freezing in winter.

Designing a divider input

Check the design: at 0 °C, V_{out} = 0.77 V (on). At 5 °C, V_{out} = 0.62 V (off). ✓

Choosing a standard value

Resistors are made in standard (E12) values: 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2 and these × 10, × 100…

If you need 184 kΩ, the nearest fixed value is 180 kΩ. A 220 kΩ variable resistor lets you set it exactly.

Stating expected results

SHORT CIRCUIT

× WHAT EXAMINERS SAW

Asked to describe expected results, many pupils wrote “the buzzer will sound when it is cold”. The task asked for results in terms of V_{out}, so no marks.

✓ THE FIX

Give V_{out} on both sides of the switching point: “Above 2 °C, V_{out} will be below 0.7 V, so the heater stays off. At 2 °C and below, V_{out} will be 0.7 V or more, so the heater switches on.”

Course reports 2024 (Task 3c) and 2025 (Task 1c): expected results must be stated in terms of V_{out}.

WRITING FRAME · EXPECTED RESULTS

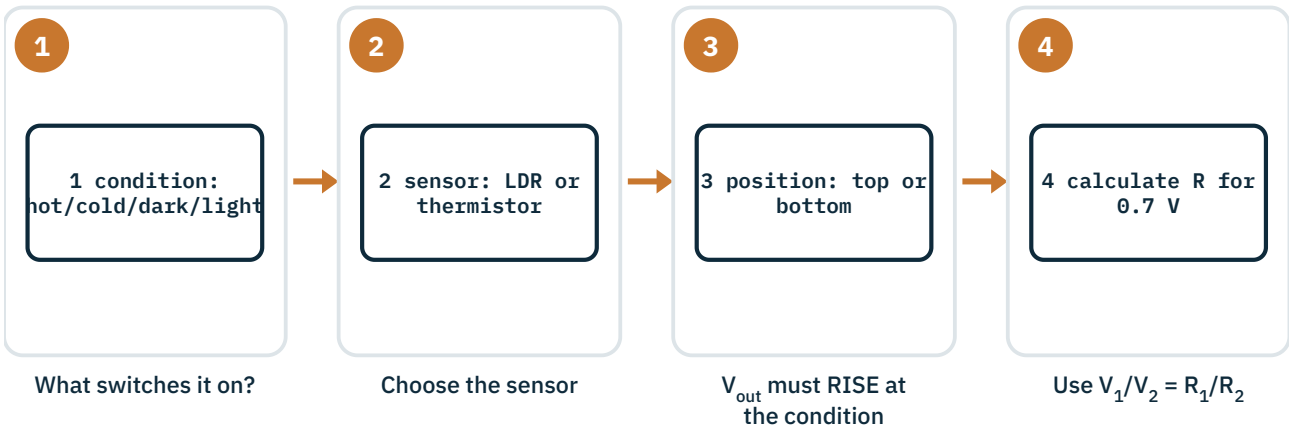
When the _____ is above/below _____, V_{out} will be _____ V, so the _____ will be _____.

When the _____ reaches _____, V_{out} will rise to _____ V, so the transistor switches on and the _____ _____.

Not for use during the assignment

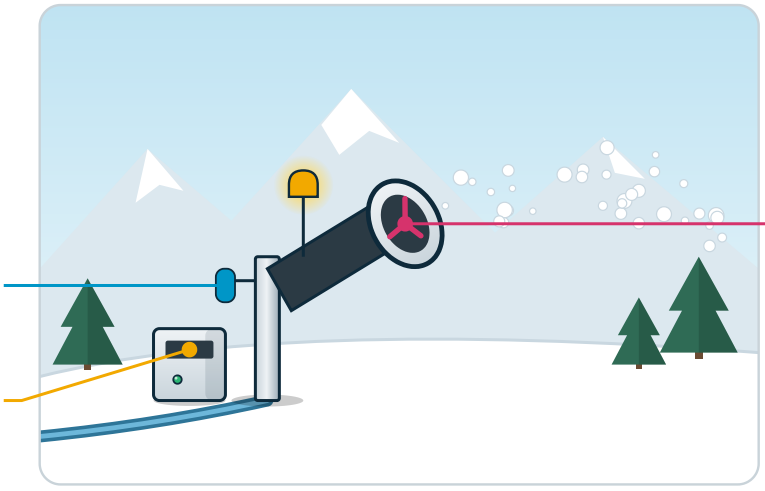
Design routine as a flow

THE DESIGN ROUTINE



Designing a divider input

Cairnloch snow cannon (fictional)



Thermistor (bottom):
INPUT

Transistor + relay
PROCESS

Fan and pump
OUTPUT

WORKED EXAMPLE Hot-sensing design

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 9 V fan on at 30 °C thermistor at 30 °C = 8.0 kΩ switch at 0.7 V	position + R	hot → thermistor top V_{top} = 8.3 V across thermistor	R/8.0 = 0.7/8.3 R = 8.0 × 0.7/8.3	**675 Ω (E12: 680 Ω)**

WORKED EXAMPLE Night-light design

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 5 V on at 20 lux (LDR 62 kΩ) switch at 0.7 V	position + R	dark → LDR bottom V_{top} = 4.3 V	R/62 = 4.3/0.7 R = 62 × 4.3/0.7	**381 kΩ**

Designing a divider input

WRONG

Fan when hot:
thermistor bottom

V_{out} falls when hot: fan never switches on.

RIGHT

Fan when hot:
thermistor TOP

V_{out} rises as it gets hotter.

REAL ENGINEERING · HIGHLAND RAIL SERVICES

Snow and ice can jam rail points. Many points in the Highlands have electric heaters.

A temperature sensor switches each heater on only when it is needed. This saves energy and cuts carbon emissions compared with running heaters all winter.



PROBE · QUICK CHECKS

1. Frost alarm: should the thermistor go at the top or bottom? _____
2. Dark-activated light: should the LDR go at the top or bottom? _____
3. What is the nearest E12 value to 4.5 kΩ? _____

EXAM READY · 8 MARKS

1 A frost alarm must sound when the temperature falls below 0 °C. **State** whether the thermistor should be the top or bottom resistor. **[1]**

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2 At 0 °C the thermistor is 34 kΩ. V_s = 6.0 V and the alarm switches on at V_{out} = 0.7 V. **Calculate** the value of the variable resistor (top). **[3]**

3 **Describe** the expected results of testing the frost alarm, in terms of V_{out}. **[2]**

4 **Explain** why the designer used a variable resistor instead of a fixed resistor. **[2]**