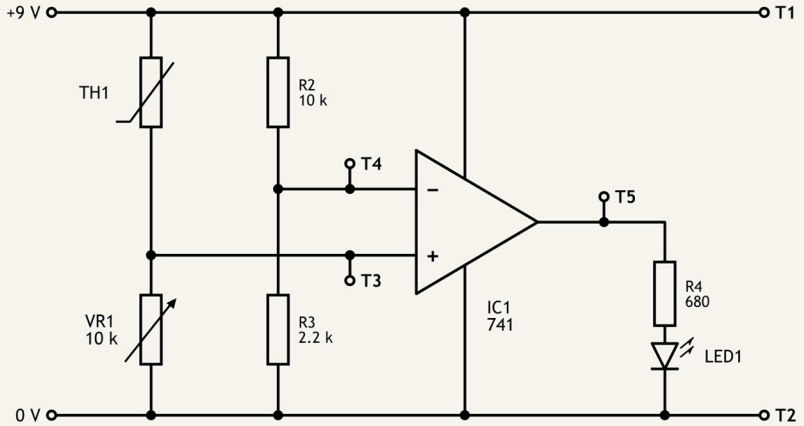
The Op-amp Comparator

How does a circuit know it is hot enough to switch on an LED?



National 5 Practical Electronics

Daily Review



1	**State** where the probe's **wires** go.	Red +V, black 0 V
2	Probe on **pin 7** is green. **Explain** why.	It is joined to 0 V
3	**State two** reasons to **simulate** first.	Test it; improve it
4	Thermistor: 50 kΩ at 20 °C, 10 kΩ at 80 °C. **Predict** 60 °C.	About 20 kΩ
5	Violet, green, red. **Determine** the **value**.	7.5 kΩ

PART 1

The Comparator

We are learning what a comparator does and how to find V_{ref}.

By the end of this part…



1. I can **state** when the **output** is **high**
2. I can **calculate** the **reference voltage**

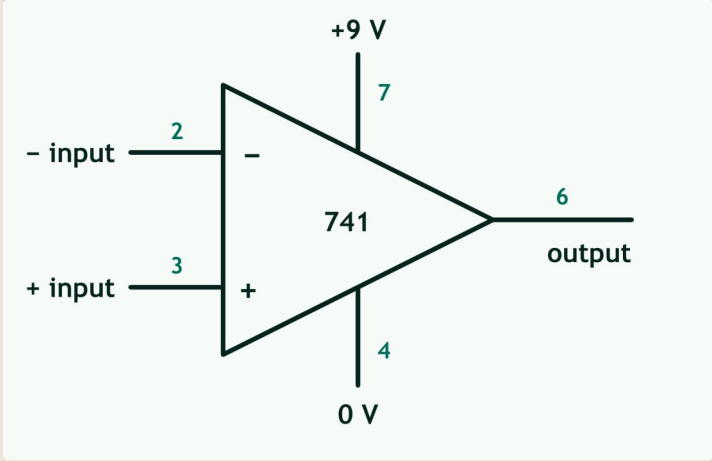
What a Comparator Does

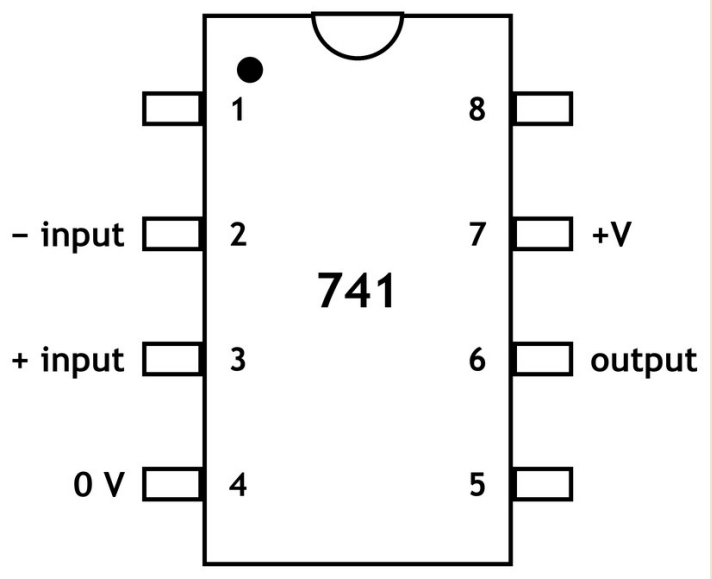
Compares **pin 3** (+) with **pin 2** (−).

+ bigger: output **high**.

Otherwise: output **low**.

Output: **pin 6**.





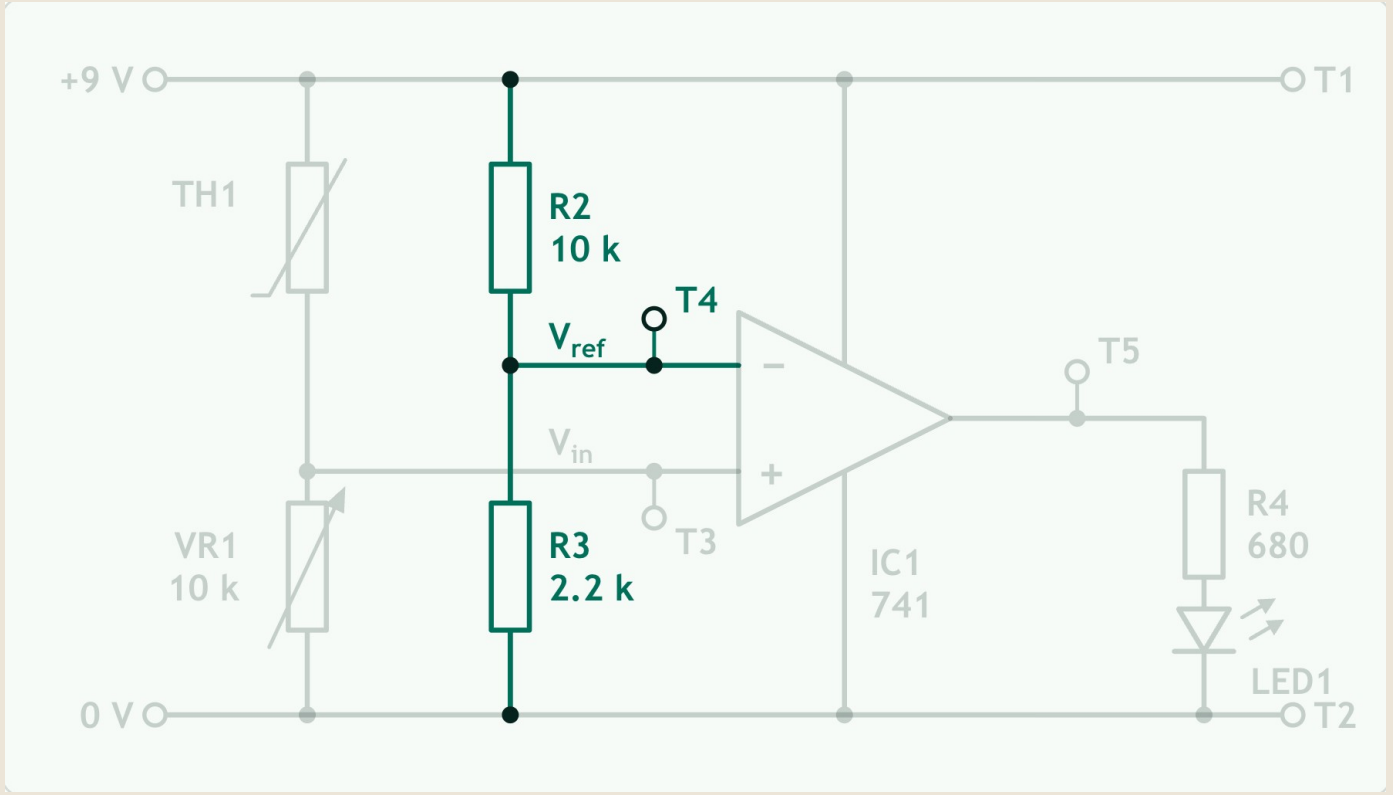
Show Me: State the Output

1	**State** the **output**: pin 3 at **4.0 V**, pin 2 at **3.0 V**.	High
2	**State** the **output**: pin 3 at **1.2 V**, pin 2 at **2.5 V**.	Low
3	**State** the **output**: pin 2 at **6.0 V**, pin 3 at **5.9 V**.	Low
4	+ input **2.1 V**, – input **1.6 V**. **State** the **output**.	High
5	**State** the **pin** the **output** comes from.	pin 6

Two Voltage Dividers

Input divider: TH1 over VR1. V_{in} goes to +.

Reference divider: R2 over R3. V_{ref} goes to −.



The Divider Relationship

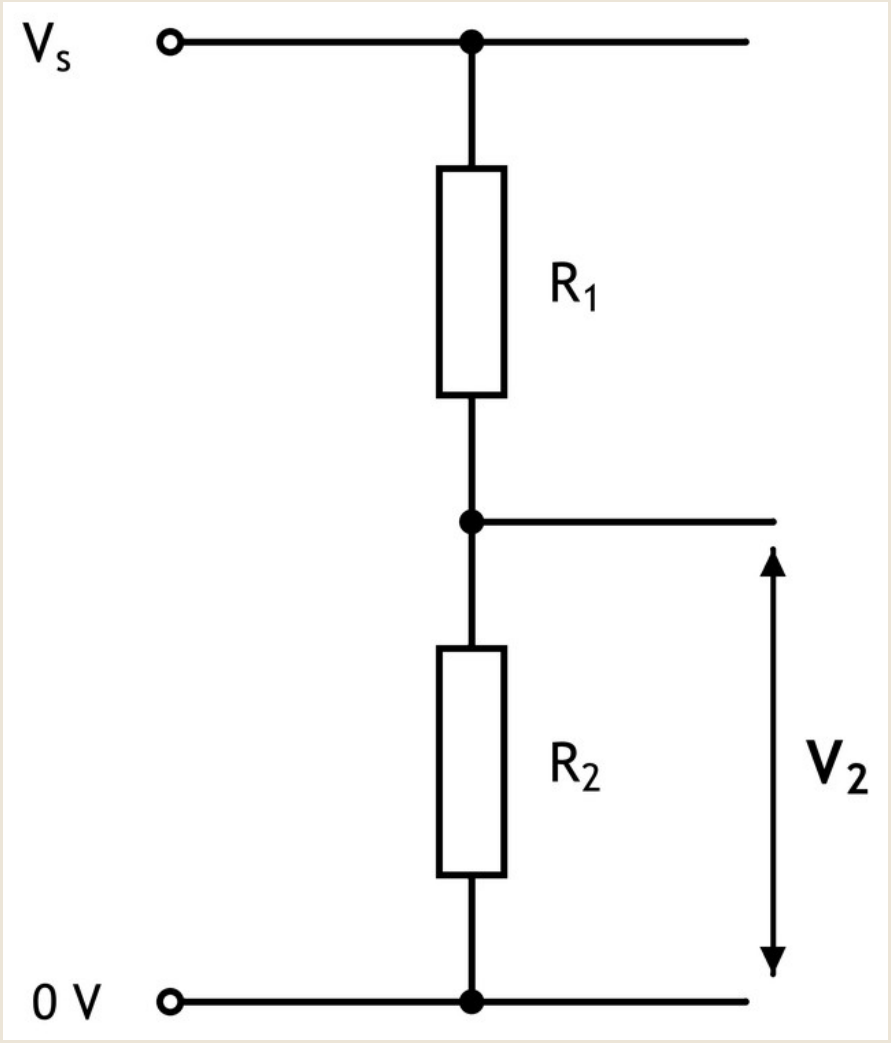
$$V_2 = R_2/(R_1 + R_2) \times V_s$$

V_2: the voltage across R_2

V_s: the **supply** voltage

R_1 on **top**, R_2 at the **bottom**

Exam papers call V_2 V_x or V_{ref}



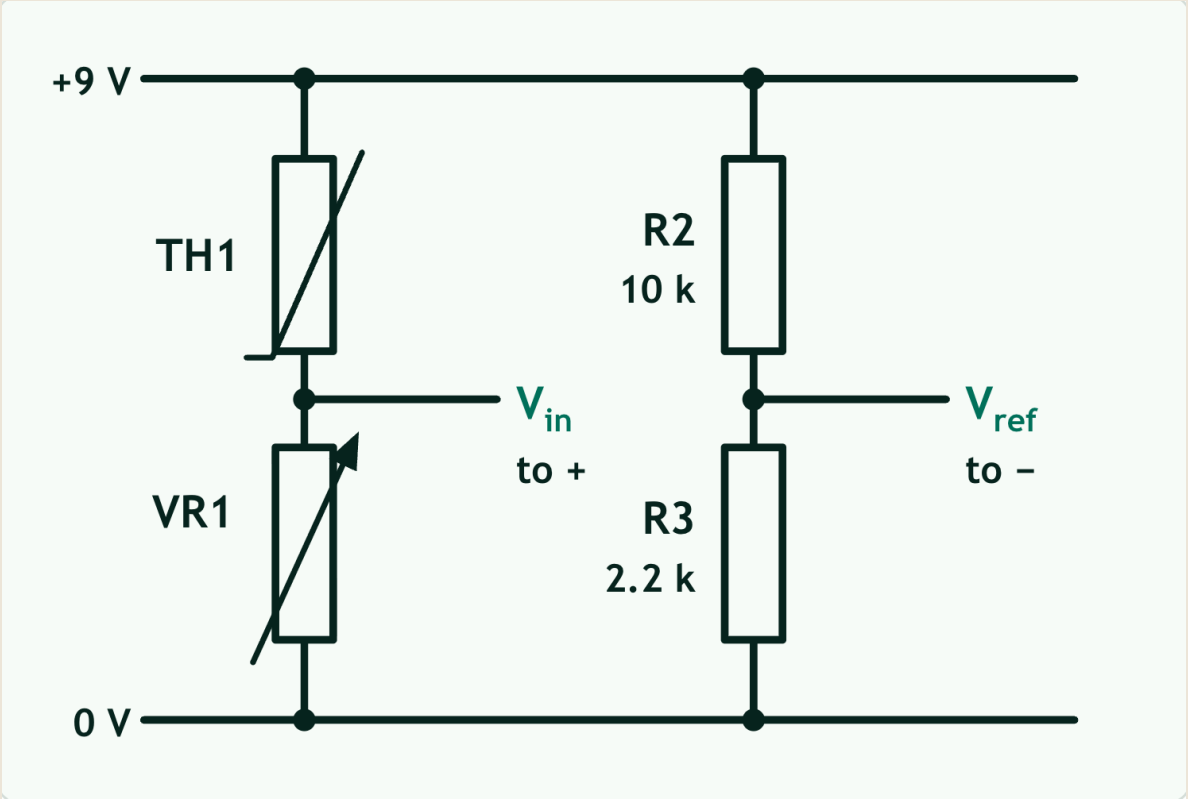
The Comparator and V_{ref}

+ input bigger than **– input**: output **high**. Otherwise **low**.

V_{ref} comes from a **voltage divider**.

$V_2 = R_2 \ / \ (R_1 + R_2) \times V_s$

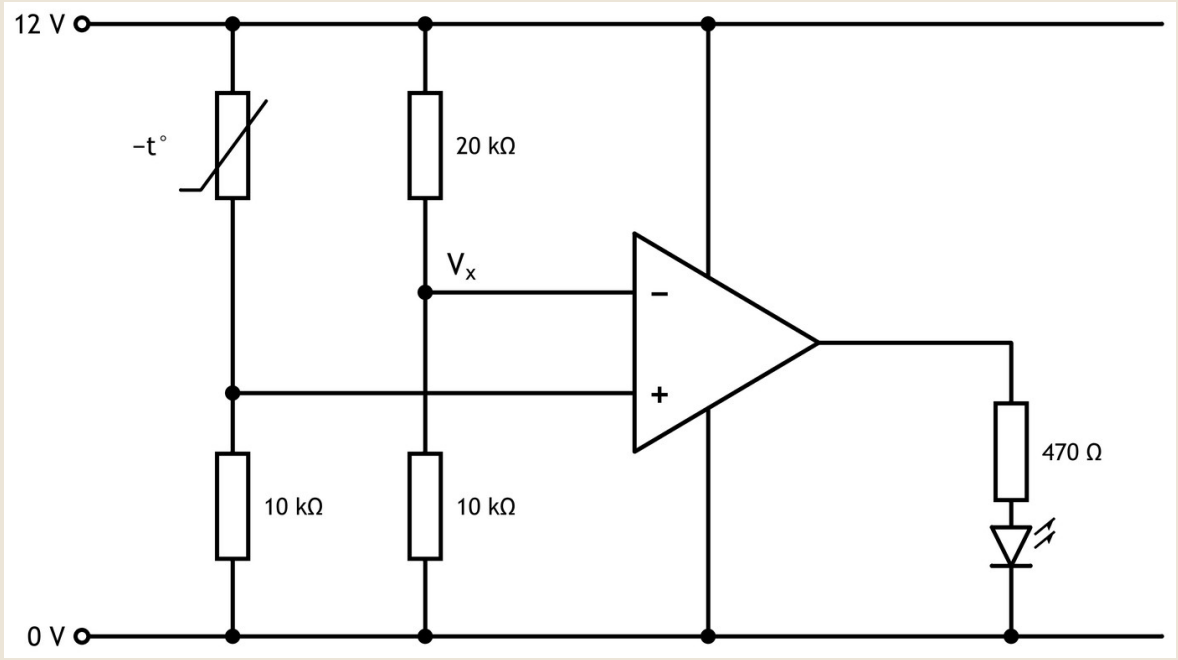
Draw the **two dividers** beside your notes.



Worked Example 1

A heat alarm is controlled using a LM741 comparator circuit as shown.

Calculate the reference voltage V_x. **3**



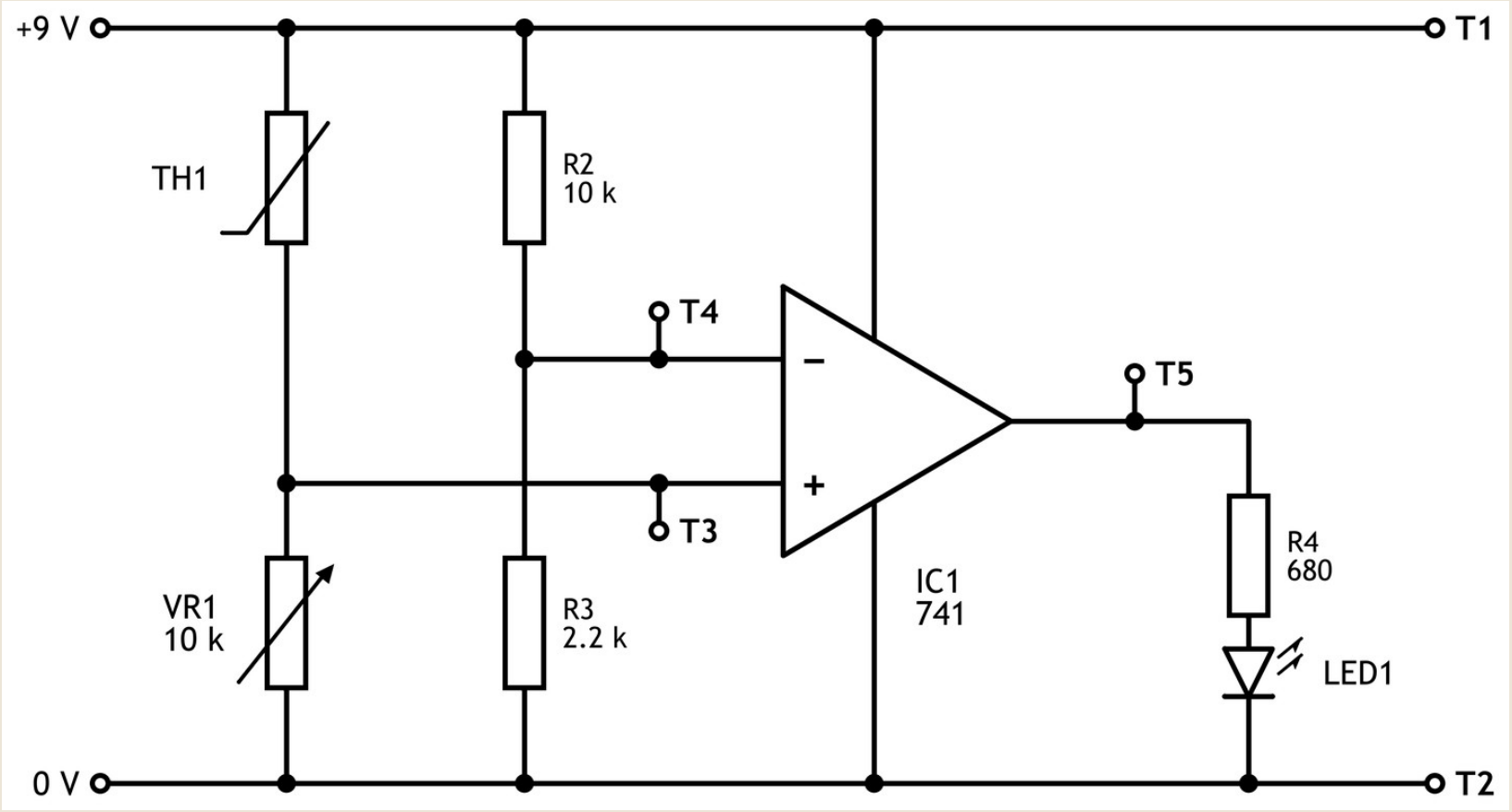
Marking: Worked Example 1

Question	Expected response	Max mark	Additional guidance
	$V_x = R_2 / (R_1 + R_2) \times V_s$ (1 mark) $V_x = 10\,000 / (20\,000 + 10\,000)$ $\times 12$ (1 mark) $V_x = 4$ V (1 mark)	3	Accept (10/30) × 12 1 mark for both substitutions 1 mark for final answer including unit Correct answer with unit and no working: 3 marks

Show Me: Calculate V_{ref}

1	Calculate V_{ref}: **9 V**, **5 kΩ** on top, **4 kΩ** below.	4.0 V
2	Calculate V_{ref}: **6 V**, **2 kΩ** on top, **1 kΩ** below.	2.0 V
3	Calculate V_{ref}: **5 V**, **3 kΩ** on top, **7 kΩ** below.	3.5 V
4	Calculate V_{ref}: **12 V**, **1 kΩ** on top, **3 kΩ** below.	9.0 V
5	Calculate V_{ref}: **9 V**, two **equal** resistors.	4.5 V

Read the Diagram



T3: V_{in} on the + input. **T4**: V_{ref} on the – input. **T5**: the output.

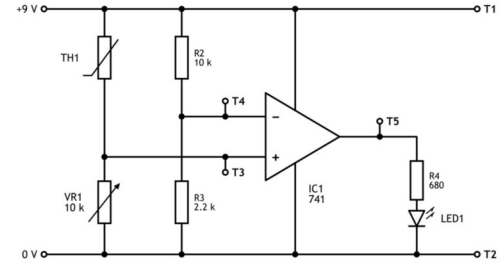
Your Turn: Read the Diagram

Task 1 (B6-L2-p11-12)

Answer questions **1** to **5**.

Show your **working** for V_{ref}.

TASK 1 — Read the diagram



1. **Name** the input sensor. (1)

2. **State** which test point measures V_{in} and which measures V_{ref}. (2)

3. **Calculate** V_{ref}. (3)

Space for working and answer

4. TH1 warms up and its resistance falls. **State** what happens to V_{in}. (1)

Look back — by the end of this part…



1. I can **state** when the **output** is **high**
2. I can **calculate** the **reference voltage**

Daily Review

1	**State** the output: pin 3 2.0 V, pin 2 1.5 V.	High
2	**Calculate** the voltage across 1500 Ω: 5.0 V, 1000 Ω over 1500 Ω.	3.0 V
3	**Name** what changes a **thermistor**.	Temperature
4	10 Ω and 40 Ω in **parallel**. **Calculate** R_T.	8 Ω
5	Fourth band **gold**. **State** the **tolerance**.	±5%

PART 2

How It Works

We are learning how a thermistor comparator works and how to test it.

By the end of this part…



1. I can **describe** how the circuit **works**
2. I can **test** it in Yenka with **voltmeters** and a **logic indicator**

How It Works

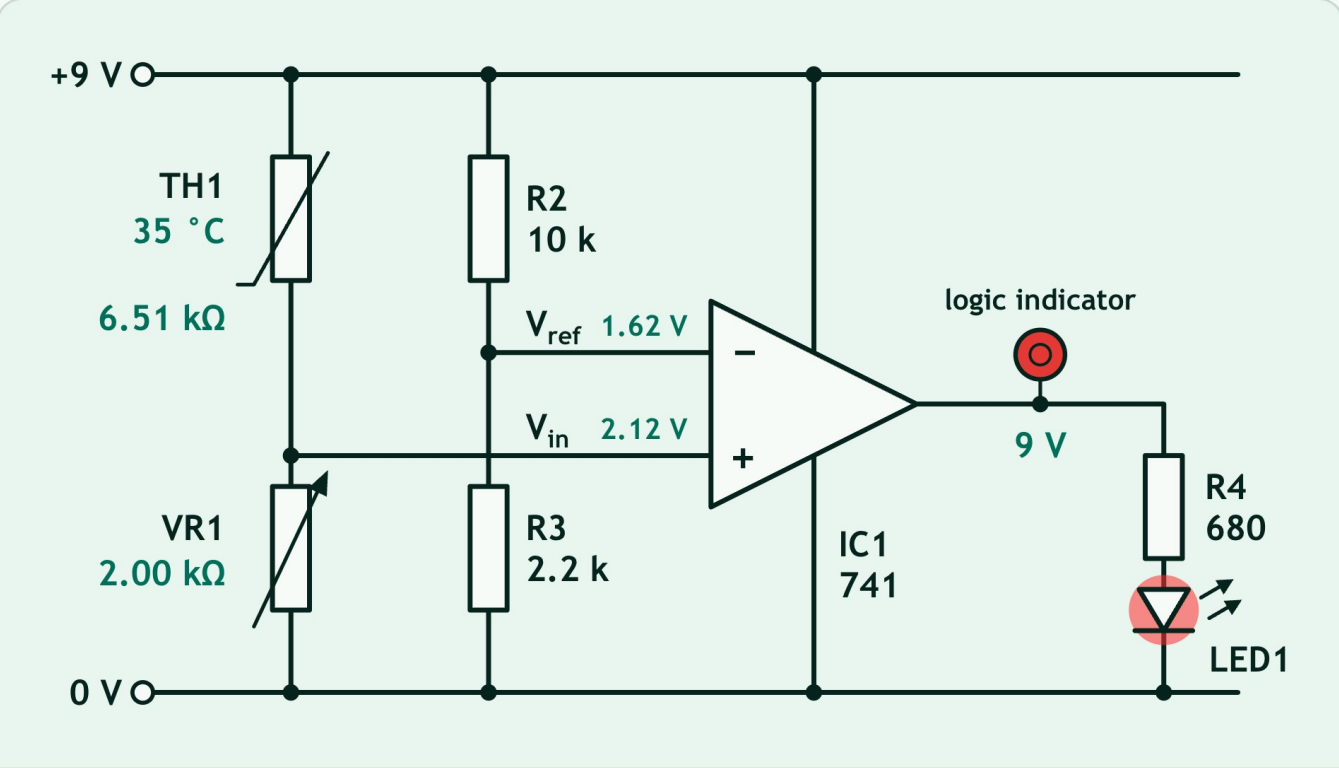
TH1 **warms up.**

Its **resistance falls.**

V_{in} **rises.**

V_{in} becomes **bigger** than V_{ref}.

Output **high**: LED1 **on.**

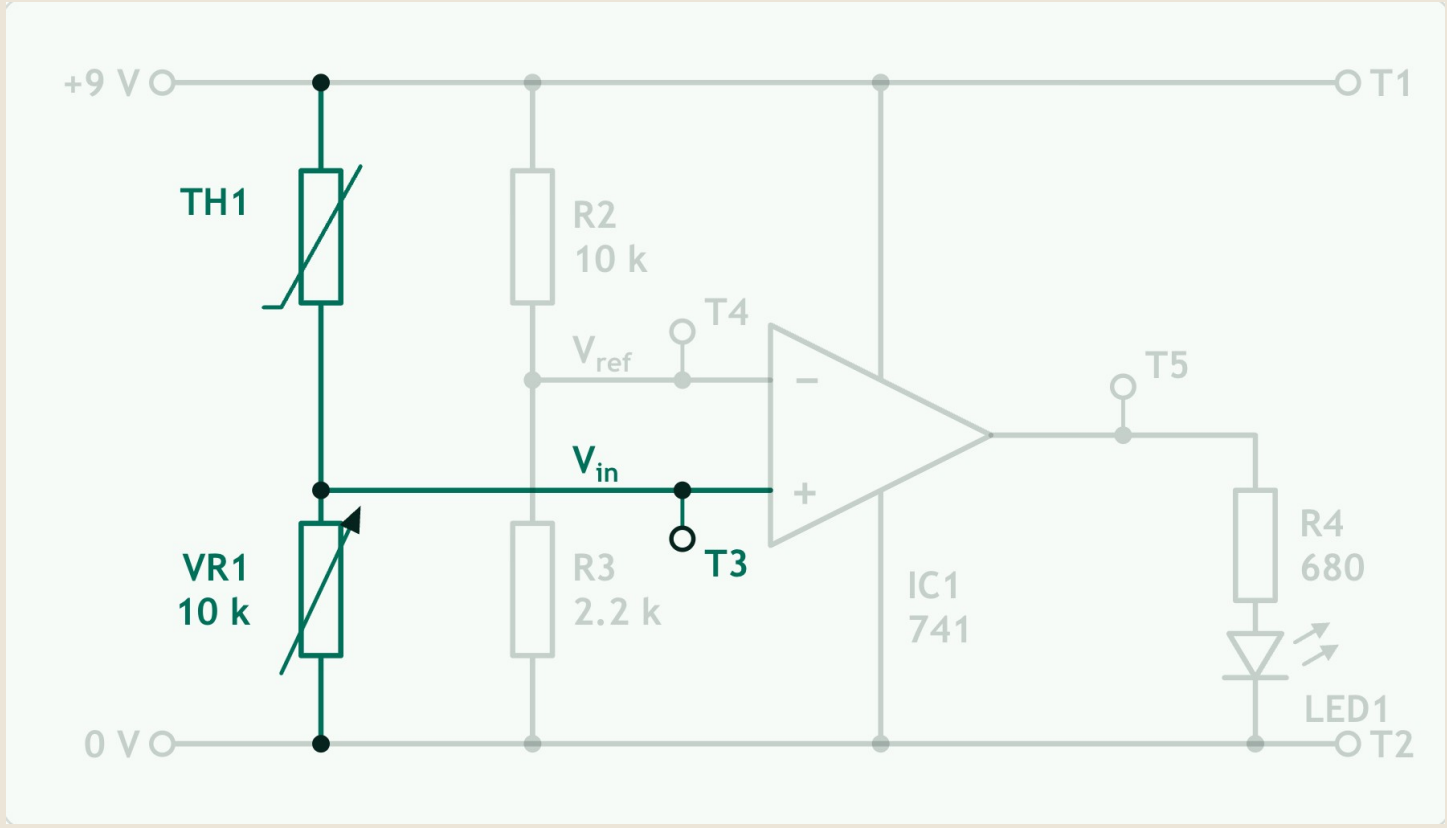


Setting the Switch Point

VR1 is part of the **input** divider.

Turn VR1: V_{in} **changes**.

VR1 **sets** the **temperature** at which LED1 comes on.



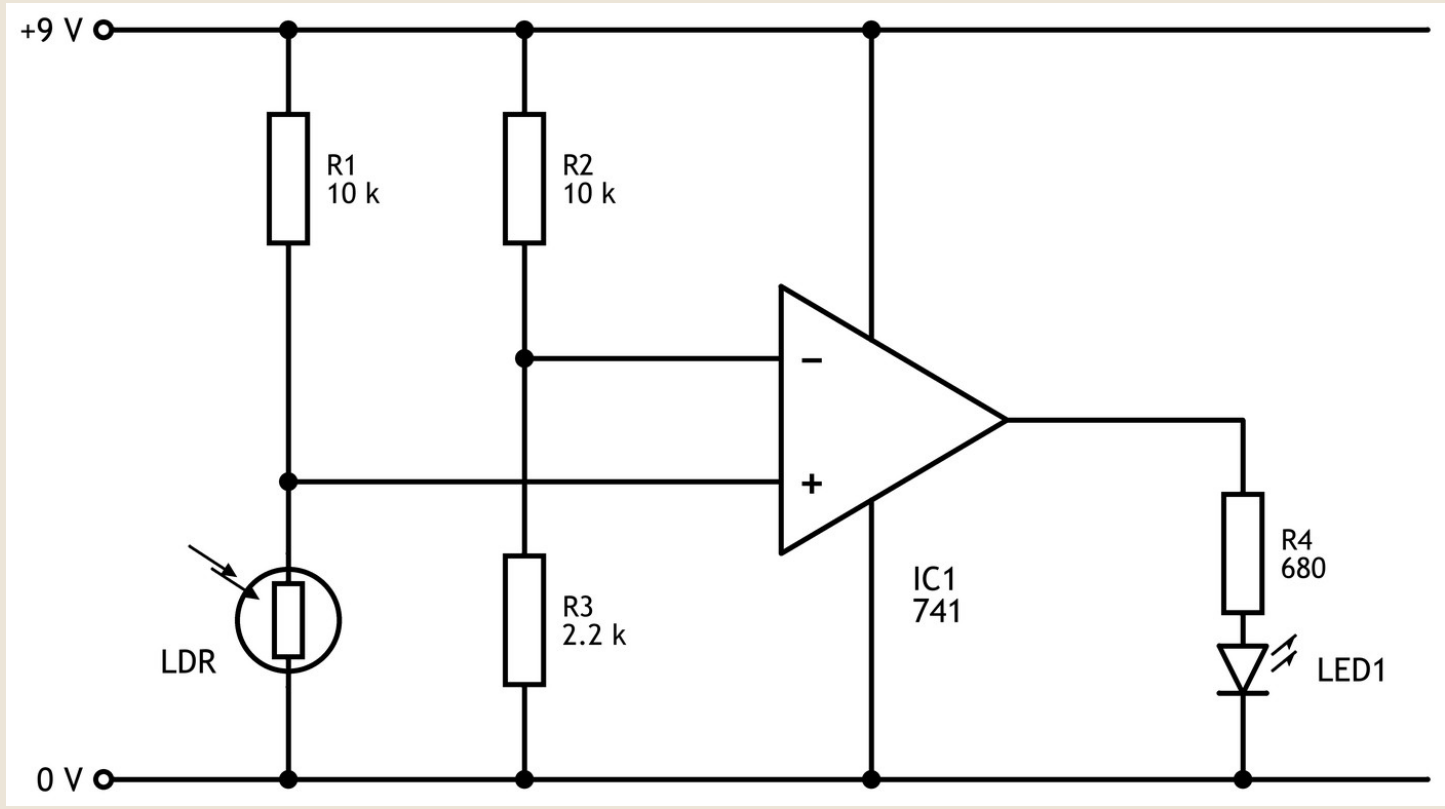
Another Way to Build It

TH1 becomes a **fixed resistor**.

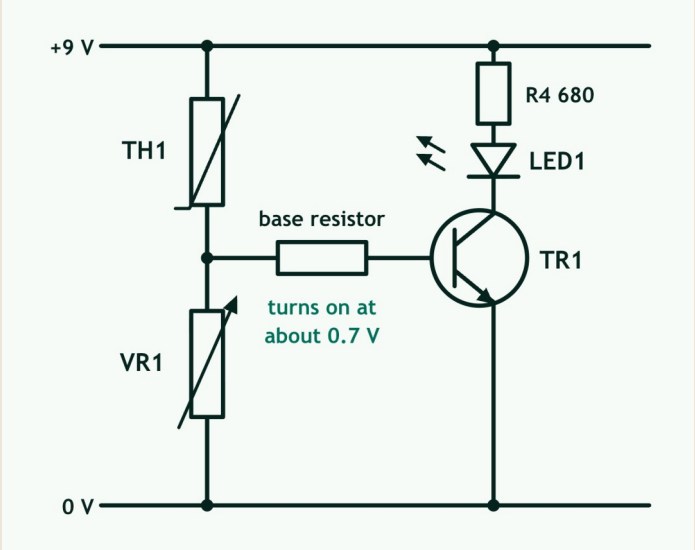
VR1 becomes an **LDR**.

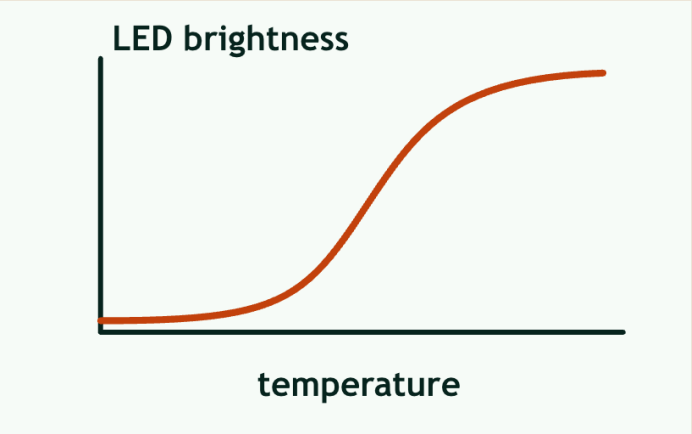
Dark: LDR resistance **rises**, V_{in} **rises**.

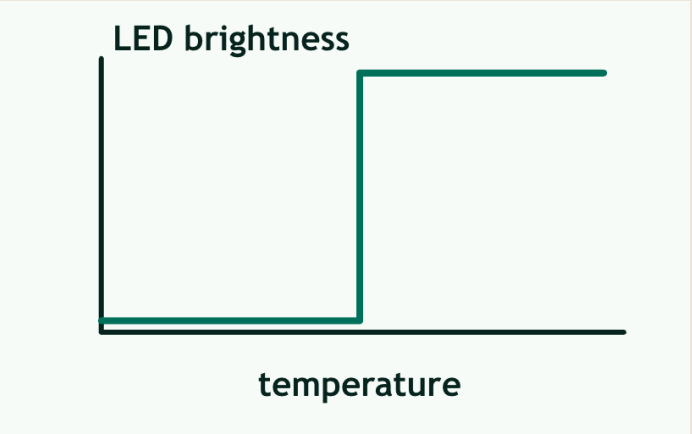
LED1 comes on in the **dark**.



Comparator or Transistor Switch?







Transistor switch

The same job, fewer parts.

Gradual

LED1 glows **dimly** near the switch point.

Sharp

LED1 is fully **on** or fully **off**.

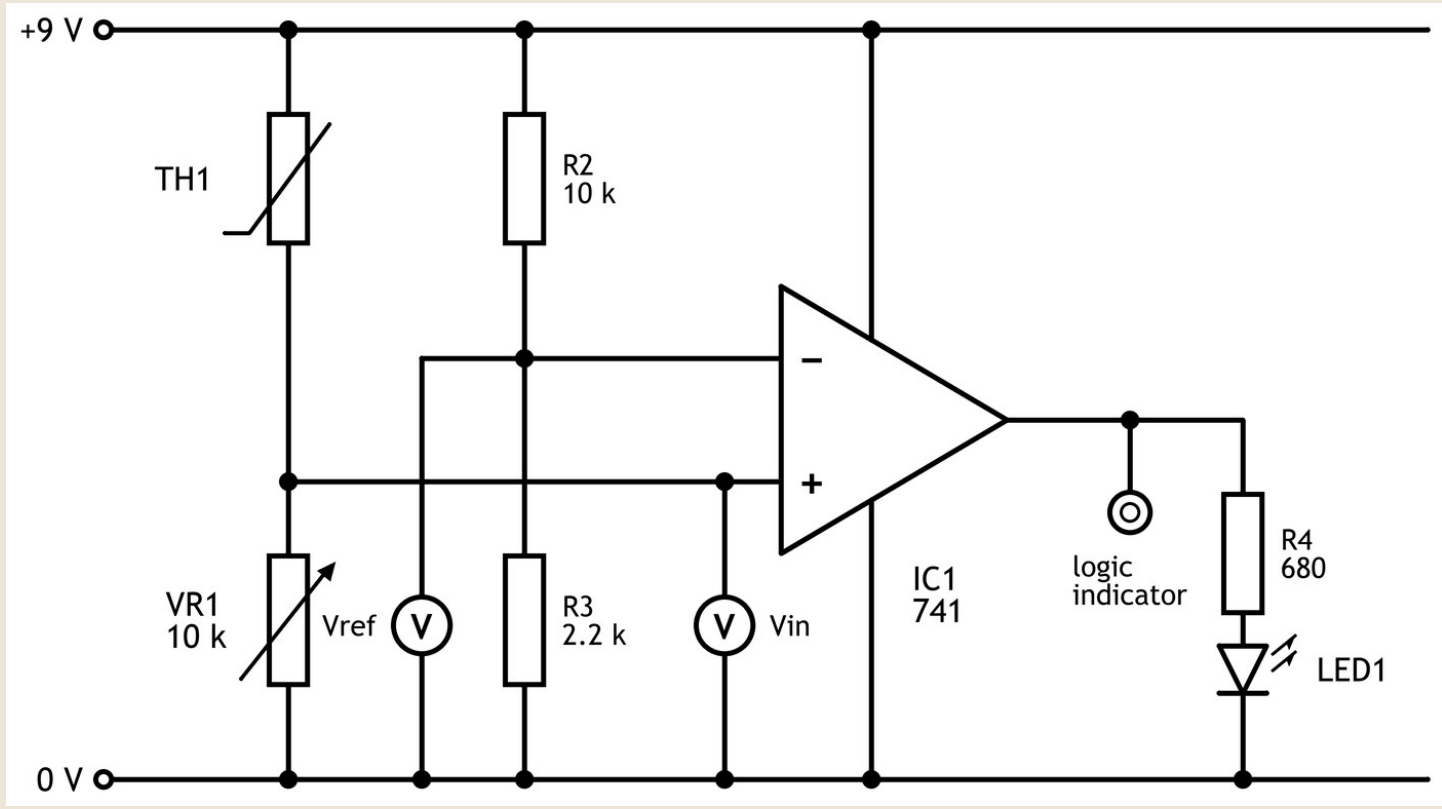
Test It in Yenka

Voltmeter: V_{in} to 0 V.

Voltmeter: V_{ref} to 0 V.

Logic indicator on the output.

Red: high. **White**: low.



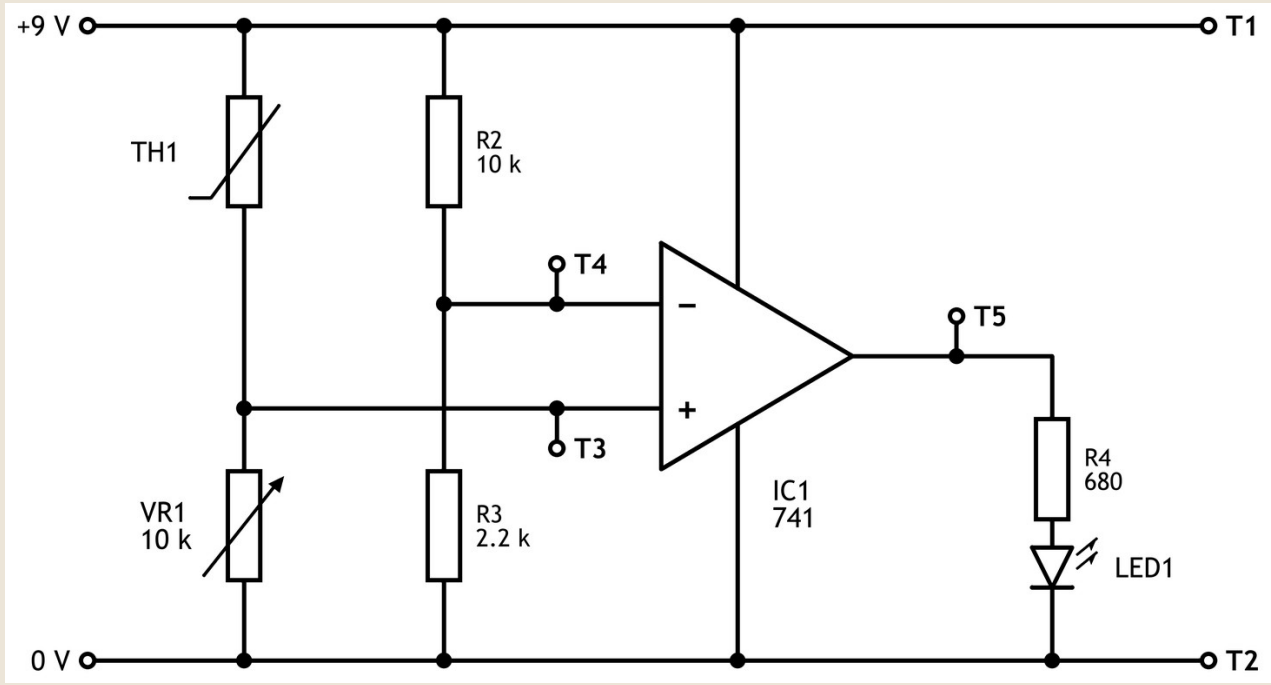
Before the Power Goes On

No short: +V to 0 V, no beep.

Supply: right voltage, right way round.

IC1 and **LED1** the right way round.

Resistors: right values, right places.



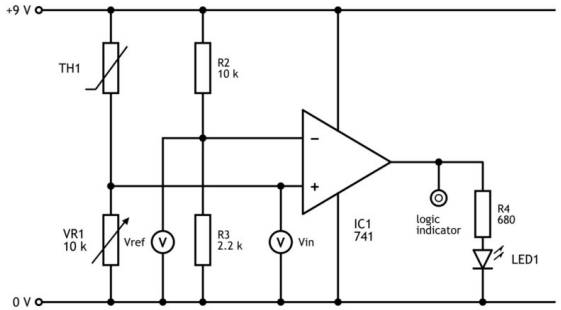
Your Turn: Yenka

Task 2 (B6-L2-p12)

Build the circuit in **Yenka**.
Record the readings at each temperature.

TASK 2 — Yenka: build and test

1. **Open** Yenka (Electronics). **Build** the circuit above.
2. Parts: 9 V supply, thermistor TH1, variable resistor VR1 (10 kΩ), R2 10 kΩ, R3 2.2 kΩ, a 741 op-amp, R4 680 Ω and LED1.
3. **Add** the two voltmeters and the logic indicator, as in the diagram below.
4. **Set** TH1 to each temperature in the table. **Record** the readings.



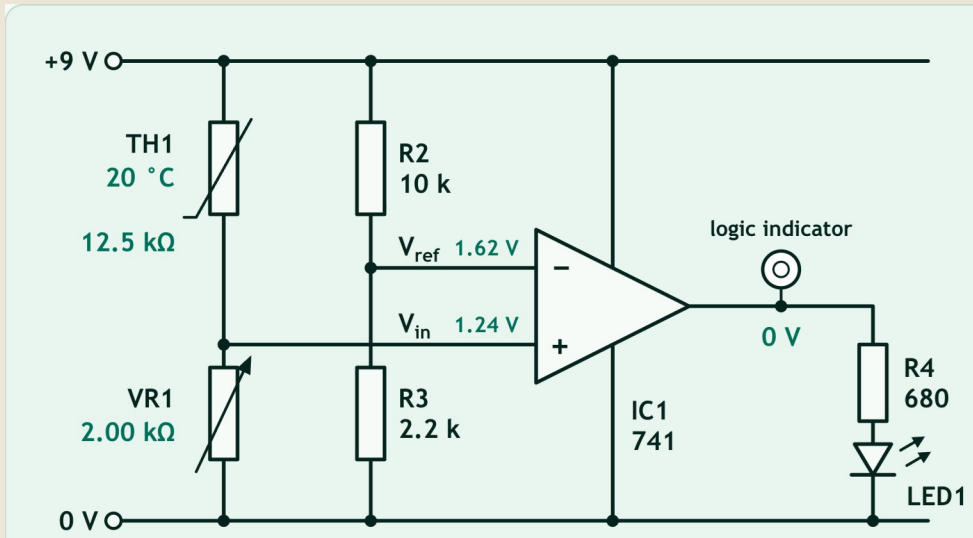
In Yenka the logic indicator is **red for high** and **white for low**.

TH1 (°C)	V_{in} (V)	V_{ref} (V)	$V_{in} > V_{ref}$?	Logic indicator (red or white)	LED1 on?
0					
10					
20					
30					
40					
50					

At what temperature does LED1 come on?

_____

Comparator Bench at 20 °C

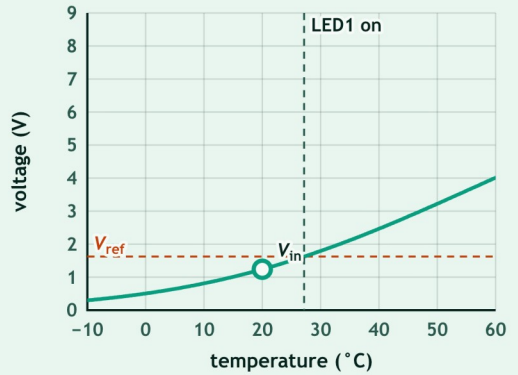


Logic indicator: red = high, white = low, as in Yenka.

TH1 resistance	V_{in} (T3)	V_{ref} (T4)	Output (T5)	LED1 comes on at
12.5 kΩ	1.24 V	1.62 V	low, white	about 27 °C

Temperature of TH1 (°C) 20

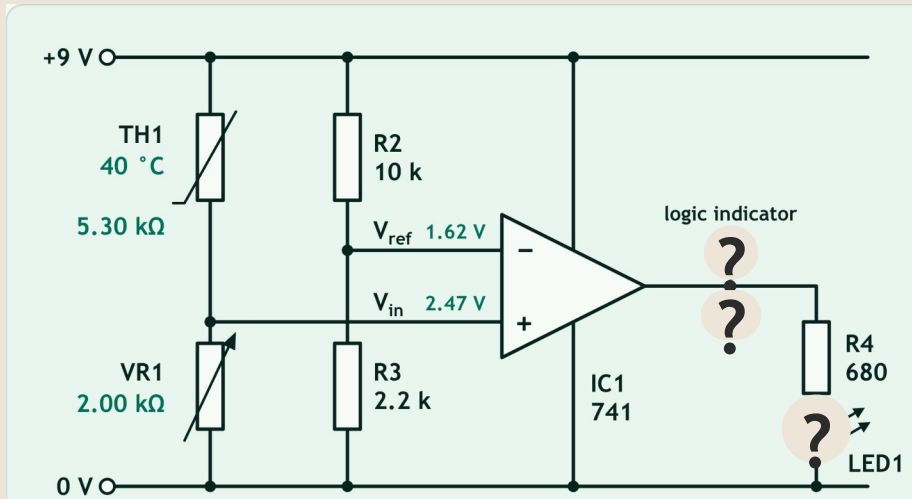
VR1 (kΩ) 2



Where the lines cross, LED1 switches.

20 °C: V_{in} 1.24 V is below V_{ref} 1.62 V. LED1 off.

TH1 is warmed to **40 °C**. **State** whether LED1 is **on** or **off**.

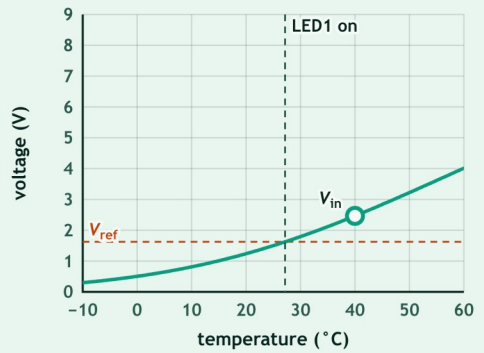


Logic indicator: red = high, white = low, as in Yenka.

TH1 resistance	V_{in} (T3)	V_{ref} (T4)		LED1 comes on at
5.30 kΩ	2.47 V	1.62 V	?	about 27 °C

Temperature of TH1 (°C) 40

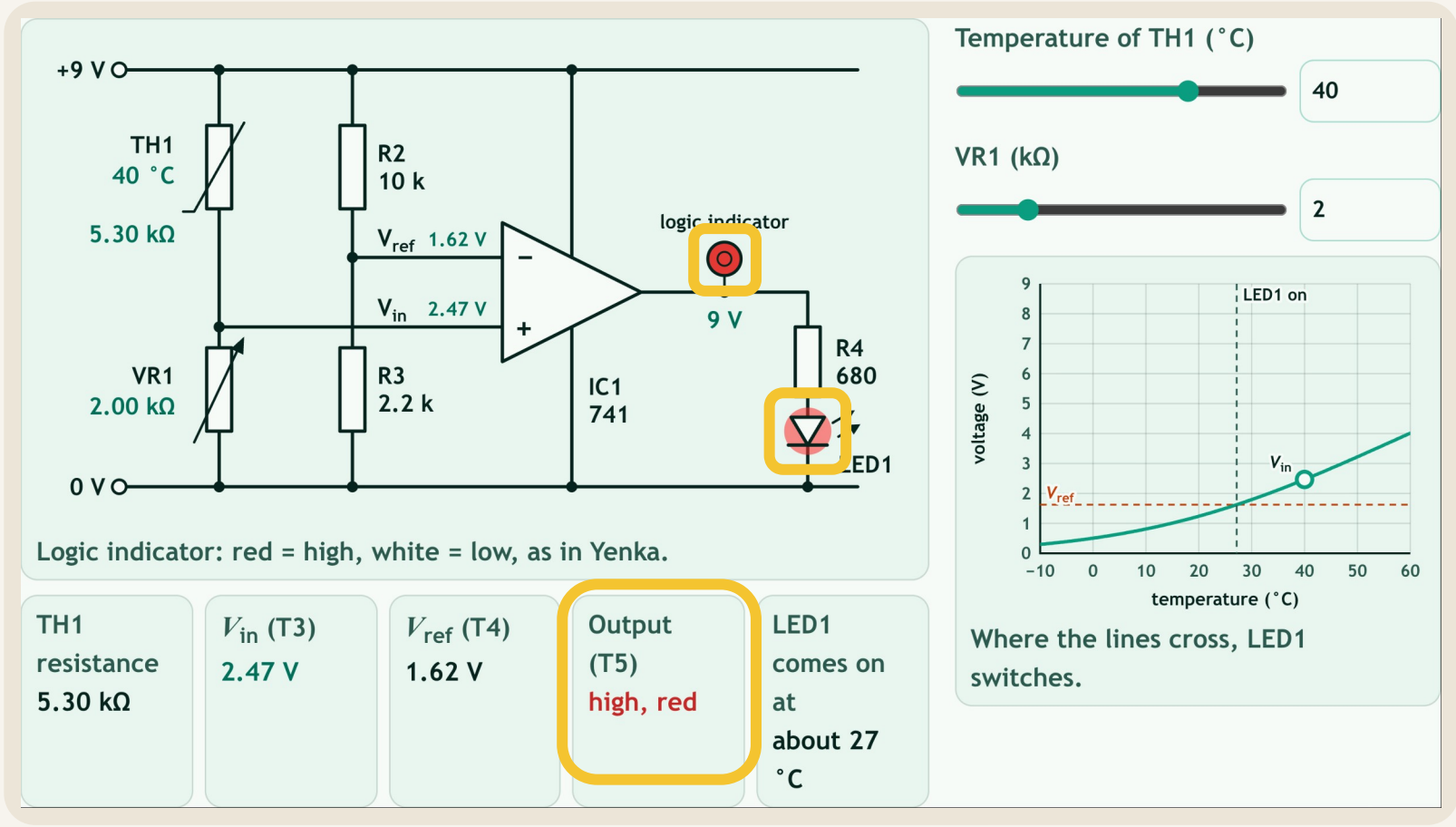
VR1 (kΩ) 2



Where the lines cross, LED1 switches.

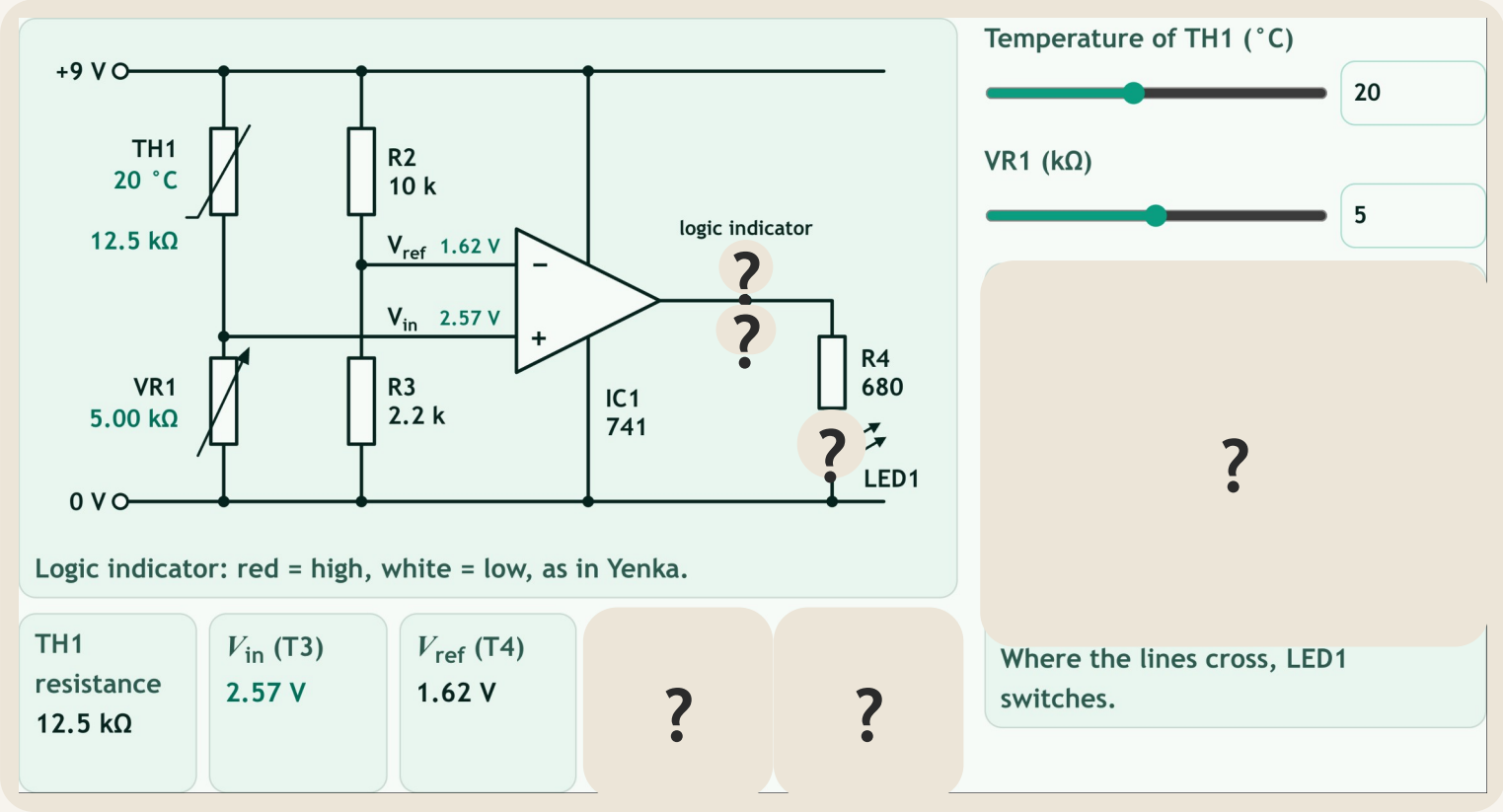
On: V_{in} is now bigger than V_{ref}

Reveal: 40 °C



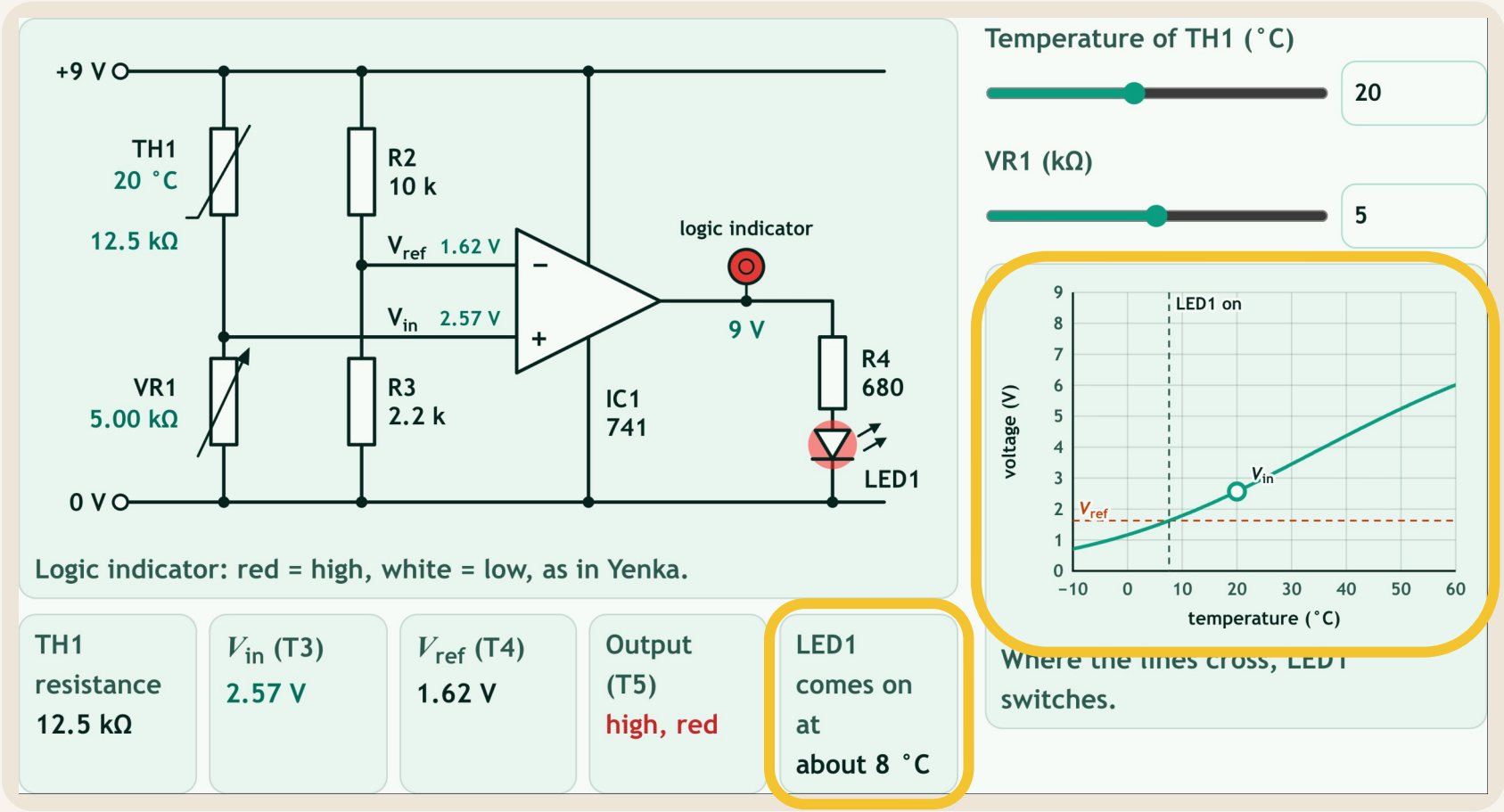
V_{in} **2.47 V** is **bigger** than V_{ref}. Output **high**: LED1 **on.**

Back to 20 °C. VR1 is turned **up** to **5 kΩ**. Does LED1 now come on **hotter** or **colder**?



Colder: about 8 °C

Reveal: VR1 at 5 kΩ



VR1 **bigger**: V_{in} **bigger**. LED1 comes on **colder**, at about 8 °C.

Your Turn: Threshold Hunter

Task 3 (B6-L2-p13)

Set VR1 so LED1 comes on at **30 °C**.
Then the **Threshold Hunter**: 4 of 5 for the **badge**.

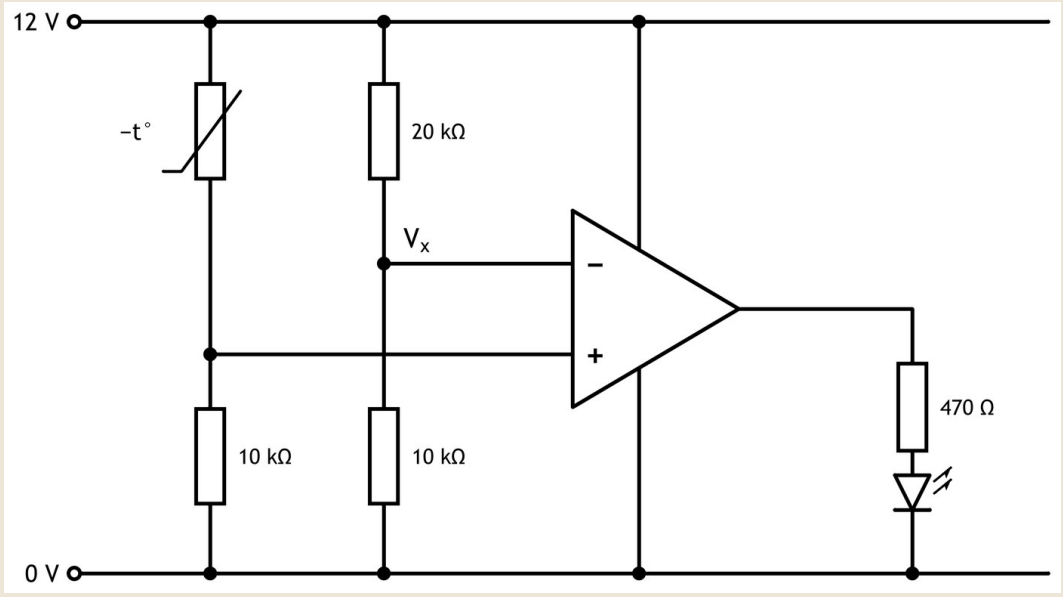
Scan me

Worked Example 2

The heat alarm from Worked Example 1. V_x = 4 V.

(a) **State** the resistance of the thermistor when the voltage across the 10 kΩ resistor is equal to V_x. **1**

(b) **Describe** how this circuit works. **3**



Marking: Worked Example 2 (a)

Question	Expected response	Max mark	Additional guidance
(a)	20 kΩ OR 20 000 Ω OR 20K	1	Must have unit or be in R notation

Marking: Worked Example 2 (b)

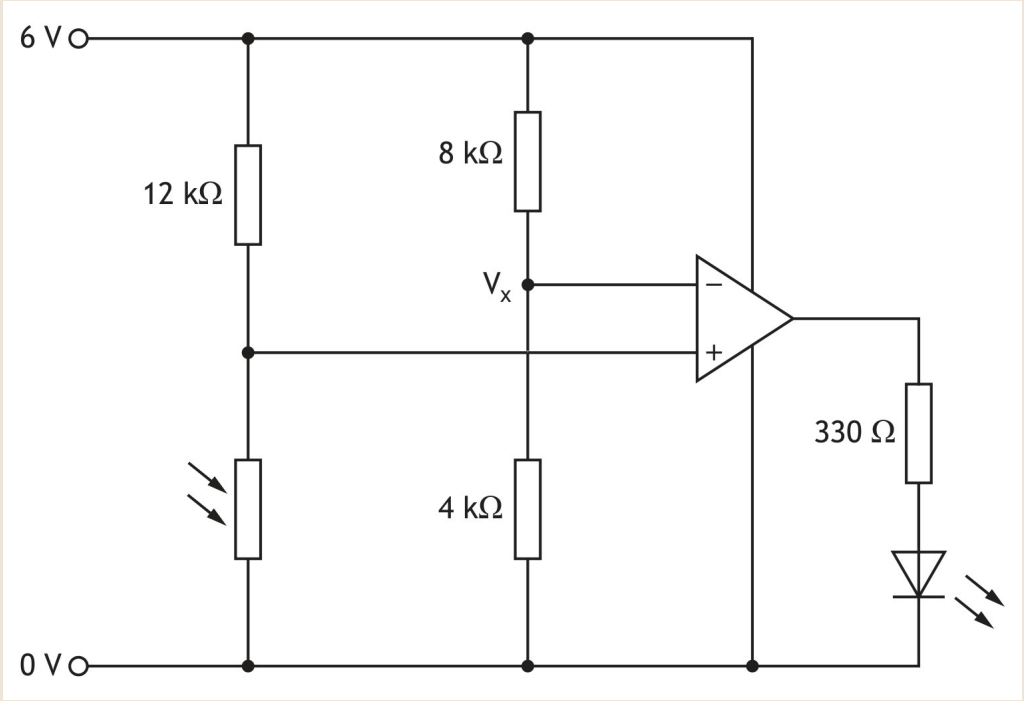
Question	Expected response	Max mark	Additional guidance
(b)	As temperature increases thermistor resistance decreases (1 mark) Voltage across the 10 kΩ resistor increases (1 mark) When it = V_x the comparator output switches on and the LED lights (1 mark)	3	Accept marks independently Accept V_{ref} = V_x = switch on voltage Do not accept arrow symbols

2024 Question 9 (a) and (b)

9. A child's LED night light is controlled using a LM741 comparator circuit as shown below.

(a) Calculate the reference voltage V_x. **3**

(b) State the resistance of the light dependent resistor when the voltage across it is equal to the reference voltage V_x. **1**



Marking: 2024 Question 9 (a)

Question	Expected response	Max mark	Additional guidance
9. (a)	$V_x = R_2 / (R_1 + R_2) \times V_S$ (1 mark) $V_x = 4000 / (8000 + 4000) \times 6$ (1 mark) $V_x = 2$ V (1 mark)	3	Accept (4/12) × 6 1 mark for Ohm's Law anywhere. 1 mark for both substitutions. 1 mark for final answer including unit If correct answer with unit and no working award 3 marks

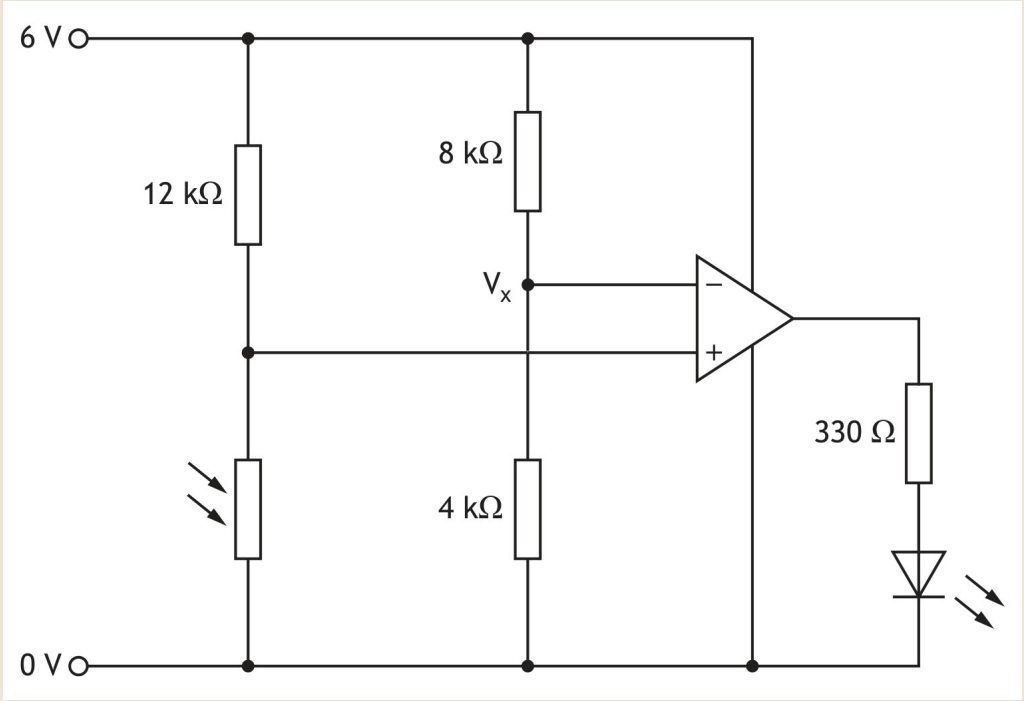
Marking: 2024 Question 9 (b)

Question	Expected response	Max mark	Additional guidance
9. (b)	6 kΩ OR 6000 Ω OR 6K	1	Must have unit or be in R notation Accept answer consistent with V_x calculated in 9(a)

2024 Question 9 (c)

9. A child's LED night light is controlled using a LM741 comparator circuit as shown below.

(c) Describe how this circuit works. **3**



Marking: 2024 Question 9 (c)

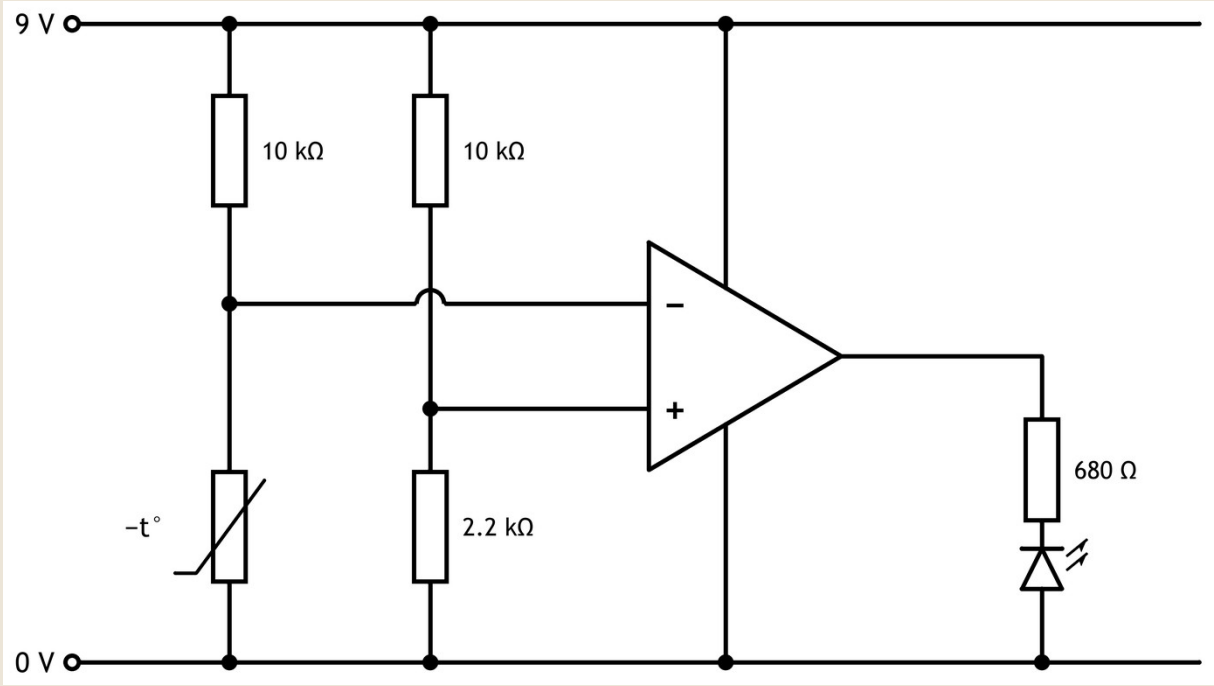
Questi	Expected response	Max mark	Additional guidance
9. (c)	As light level reduces LDR resistance increases (1 mark) As LDR resistance increases the voltage across LDR increases (1 mark) When voltage across the LDR = V_x then LM741/comparator/IC/op amp output switches on, powering the LED (1 mark)	3	Accept V ref = V_x = trigger voltage = switch on voltage Accept marks independently Accept LED lights up Accept alternatives to = Do not accept arrow symbols as alternatives to increase and decrease

Worked Example 3

A student simulates a night light: the LED should come on when it gets dark. The simulation does not work as specified.

Identify three errors in the student's simulation.

3



Marking: Worked Example 3

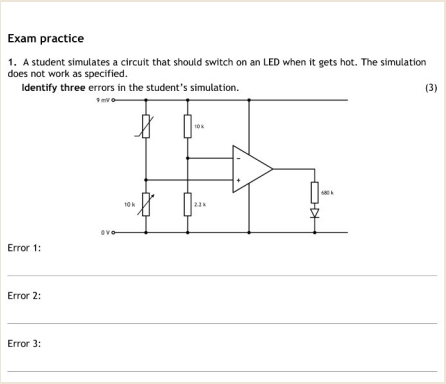
Question	Expected response	Max mark	Additional guidance
	A thermistor is used, not an LDR (1 mark) The sensor goes to the − input, not the + input (1 mark) The LED is the wrong way round (1 mark)	3	Errors can be listed in any order Accept + and − inputs swapped Accept LED reversed

Your Turn: Exam Practice

Exam practice (B6-L2-p14-16)

Answer questions **1** to **3**.

Then **complete** the **key words**.



Exam practice

1. A student simulates a circuit that should switch on an LED when it gets hot. The simulation does not work as specified.

Identify three errors in the student's simulation. (3)

Error 1:

Error 2:

Error 3:

Look back — by the end of this part…



1. I can **describe** how the circuit **works**
2. I can **test** it in Yenka with **voltmeters** and a **logic indicator**

Course Specification — 1 of 2

Content and concepts; circuit simulation and design

- Use appropriate relationships to determine voltage or resistance in a voltage divider circuit. (eg calculate the switch over voltage of an op-amp used in comparator mode).
- Describe the operation of a number of simple circuits: a transistor analogue switching circuit, bi-stable switching circuit, half-adder circuit, 741 comparator.
- Compile a pre-power up checklist for a given simulation printout, layout diagram or circuit diagram.

Course Specification — 2 of 2

Circuit construction

- Identify and draw the circuit symbols for, and describe the function of, the following components (using American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC) symbols):
  - op-amp circuits (741 op-amp comparator mode only)

Credits

Drawings: Circuit drawings, 741 pinout and booklet pages: Block 6 booklet, R Stewart.

Daily Reviews: © Qualifications Scotland (SQA). N5 Practical Electronics 2024 Q1(a), Q1(b)(i), Q3(a)(i), Q5(a); 2025 Q1(b)(ii), Q2, Q7(a)(i), Q7(b)(ii); 2026 Q7(a).

Screenshots and page figures: mrstewartphysics.co.uk, Lesson 2 The Op-amp Comparator page, R Stewart.

2024 Question 9: © Qualifications Scotland (SQA). N5 Practical Electronics 2024 Q9: question, figure and marking instructions.

Course specification: © Qualifications Scotland (SQA). N5 Electronics course specification v3.1, pp.5-7

R Stewart - October 2026