Fixed voltage dividers

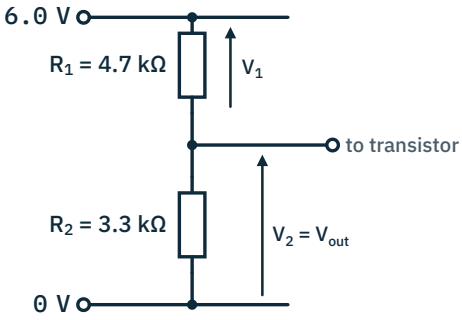
LEARNING INTENTION

We are learning how a fixed voltage divider shares the supply voltage.

SUCCESS CRITERIA — I CAN

- ☐ spot a voltage divider in a circuit diagram
- ☐ calculate V_{out} using the Data Booklet
- ☐ explain what happens to V_{out} when a resistor changes

Sharing the supply



A fixed voltage divider

A **voltage divider** is two resistors in series across a supply. The supply voltage is shared between them.

This is Kirchhoff's 2nd law: $V_s = V_1 + V_2$.

The bigger resistor takes the bigger share.

The voltage across R_2 is the output, V_{out}. It feeds the transistor, so exam papers often call it V_{in}.

DATASHEET · VOLTAGE DIVIDER

01 Two resistors in series between the supply and 0 V.

02 The **same current** flows through both.

03 Bigger resistance → bigger share of V_s. Equal resistors → half each.

04 V_{out} is measured across R_2, from the middle to 0 V.

DATA BOOKLET page 5

$V = IR$ — Ohm's law

$R_t = R_1 + R_2$ — resistors in series

$V_t = V_1 + V_2$ — Kirchhoff's 2nd law

$V_1/V_2 = R_1/R_2$ — voltage divider

WORKED EXAMPLE Eilean Corr lighthouse battery monitor

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 6.0 V R_1 = 4.7 kΩ R_2 = 3.3 kΩ	V_{out} (= V_2)	$R_t = R_1 + R_2$ $V = IR \rightarrow I = V/R$ $V_2 = I \times R_2$	R_t = 4.7 + 3.3 = 8.0 kΩ I = 6.0 ÷ 8.0 = 0.75 mA V_2 = 0.75 × 3.3	**V_{out} = 2.48 V** (2.475 V)

Check with Kirchhoff: $V_1 = 0.75 \times 4.7 = 3.525$ V, and 3.525 V + 2.475 V = 6.0 V ✓

Fixed voltage dividers

SHORT CIRCUIT

× WHAT EXAMINERS SAW

Mixed units: I = 0.00075 A, then 0.00075 × 3.3 = 0.0025 V. R_2 was still in kΩ, so the answer is 1000 times too small.

✓ THE FIX

Keep kΩ with mA, or Ω with A. Check the final unit suits the values used. Sense check: V_{out} can never be bigger than V_s.

Course reports 2025–26: the final unit must suit the values used.

Method 2: use the ratio

WORKED EXAMPLE The ratio method

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 9.0 V R_1 = 10 kΩ R_2 = 20 kΩ	V_1 and V_2	$V_1/V_2 = R_1/R_2$ $V_s = V_1 + V_2$	10 : 20 = 1 : 2 1 + 2 = 3 parts 1 part = 9.0 ÷ 3 = 3.0 V	**V_2 = 6.0 V** V_1 = 3.0 V

Fastest when the values divide neatly. Check: I = 9.0 ÷ 30 = 0.3 mA, and 0.3 × 20 = 6.0 V ✓

What if a resistor changes?

Change either resistor and the shares change. Use these rules.

R_2 ↑ → V_{out} ↑

R_2 takes a bigger share of the supply.

R_1 ↑ → V_{out} ↓

R_1 takes a bigger share, so less is left for R_2.

Any R ↑ → I ↓

The total resistance goes up, so the current goes down.

Change (V_s = 6.0 V)	R_t	Current I	V_1	V_{out} (V_2)
Start: R_1 = 4.7 kΩ, R_2 = 3.3 kΩ	8.0 kΩ	0.75 mA	3.53 V	2.47 V
R_2 made bigger (4.7 kΩ)	9.4 kΩ ↑	0.64 mA ↓	3.00 V ↓	**3.00 V ↑**
R_1 made bigger (10 kΩ)	13.3 kΩ ↑	0.45 mA ↓	4.51 V ↑	**1.49 V ↓**

SHORT CIRCUIT

× WHAT EXAMINERS SAW

"Explain the effect on V_{out} if R_1 increases." Answer seen: "V_{out} goes down. The current goes down." Two separate points, no cause.

✓ THE FIX

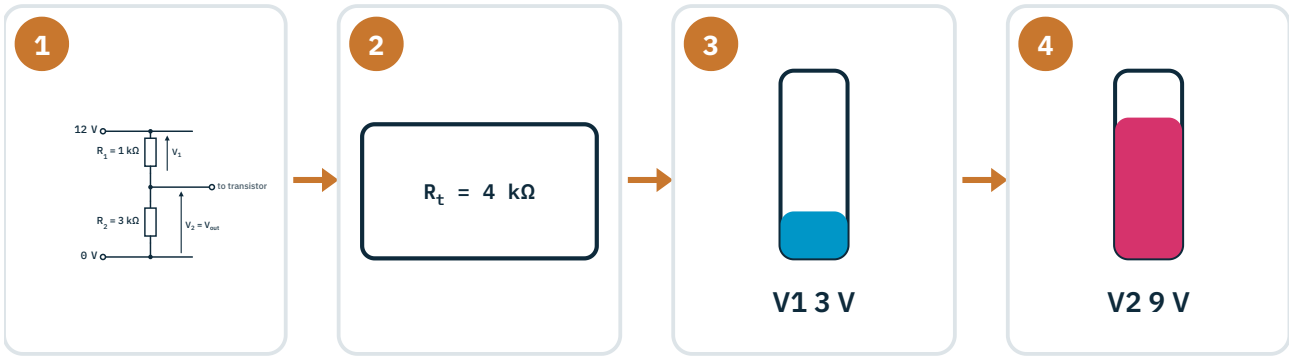
Give one cause and its linked effect, joined with so or because: "R_1 takes a bigger share of the supply voltage, so V_{out} decreases."

Course reports 2024–25: 'explain' needs a single cause and a related effect. 2024 Q8(c).

Fixed voltage dividers

Sharing the supply in pictures

A DIVIDER SHARES THE SUPPLY



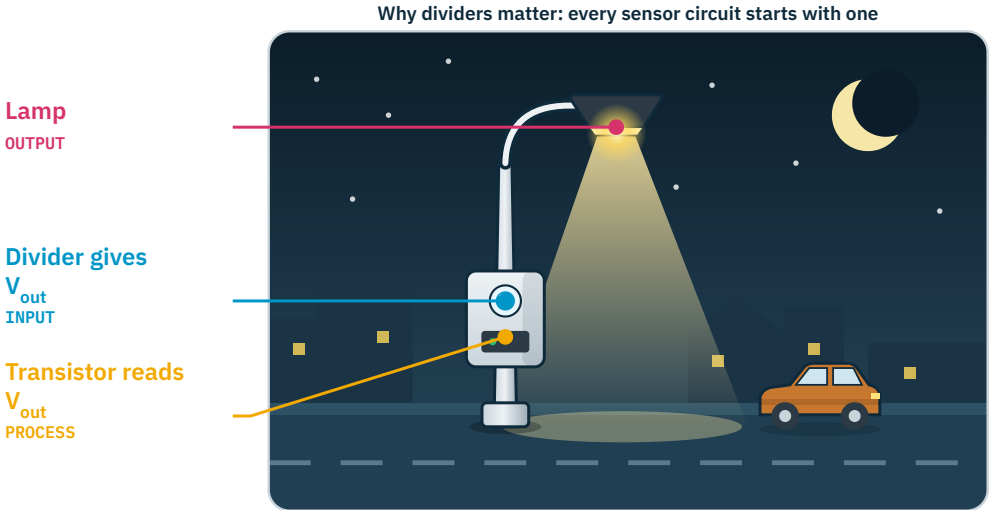
12 V across two resistors in series

Total resistance

1 kΩ takes 1/4

3 kΩ takes 3/4

Why dividers matter: every sensor circuit starts with one



WORKED EXAMPLE V_{out} by the ratio method

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
V_s = 12 V R_1 = 1 kΩ (top), R_2 = 3 kΩ (bottom)	V_{out} (across R_2)	$V_2/V_s = R_2/(R_1 + R_2)$	$V_2 = 12 \times 3/4$	9 V

Bigger resistor → bigger share of the voltage.

Fixed voltage dividers

WORKED EXAMPLE Missing resistor from V_{out}

1 GIVEN	2 FIND	3 FORMULA	4 SUBSTITUTE	5 ANSWER + UNIT
$V_s = 9$ V $R_1 = 6$ kΩ $V_{out} = 3$ V across R_2	R_2	$V_1 = V_s - V_2$ $R_2/R_1 = V_2/V_1$	$V_1 = 6$ V $R_2 = 6 \times 3/6$	**3 kΩ**

WRONG

$$V_2 = 12 \times 1/4 = 3 \text{ V}$$

Wrong resistor on top: this is V_1, not V_{out}.

RIGHT

$$V_2 = 12 \times 3/4 = 9 \text{ V}$$

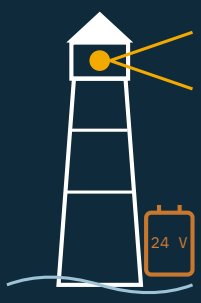
Use the resistor you want the voltage across on top of the fraction.

REAL ENGINEERING · EILEAN CORR LIGHTHOUSE

Eilean Corr (fictional) is a remote, automated lighthouse. Its lamp runs from a 24 V battery bank charged by solar panels.

Engineers at **Northlight Monitoring Ltd** (fictional) fitted a microcontroller to report the battery voltage by radio.

The microcontroller input can only take up to 5 V. A fixed voltage divider scales 24 V down to about 4.3 V.



SIGNAL CHAIN

INPUT · CONDITION	INPUT · SENSOR	PROCESS · V_{in}	PROCESS · TRANSISTOR	PROCESS · RELAY	OUTPUT
It gets dark	LDR resistance rises	V_{in} rises	Switches on	Coil energised, contacts close	Lamp switches on

Where V_{out} goes next. You will build this chain in units E4 and E5.

Fixed voltage dividers

PROBE · QUICK CHECKS

1. Two 10 kΩ resistors are in series across 9 V. What is V_{out}? _____
2. R_2 is made bigger. Does V_{out} go up or down? _____
3. Which law says $V_s = V_1 + V_2$? _____

EXAM READY · 10 MARKS

1 A circuit has two resistors in series between a supply and 0 V. **State** the name of this circuit. **[1]**

2 At Eilean Corr, V_s = 24 V, R_1 = 15 kΩ and R_2 = 3.3 kΩ. **Calculate** V_{out}. **[3]**

3 R_1 is replaced with a larger resistor. **Explain** the effect on V_{out}. **[2]**

4 R_2 is replaced with a larger resistor. **State** the effect on the current in the circuit. **[1]**

5 The engineers want V_{out} = 4.0 V from the 24 V supply. R_1 stays at 15 kΩ. **Calculate** the value of R_2 needed. **[3]**