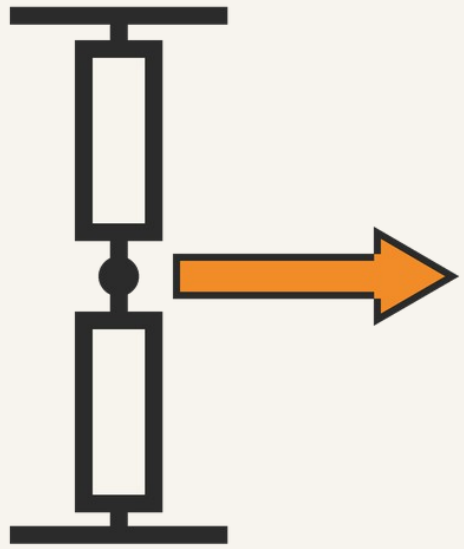
BOOKLET 3 · ELECTRONICS AND ANALOGUE CONTROL

Voltage Dividers and Sensors



Two resistors in series, and the voltage you take from between them.

National 5 Engineering Science

Daily Review

Lesson 4 — Input and Output Devices

1. State the rule for total resistance in series.

2. What does an LDR react to?

3. Describe how a thermistor's resistance changes as it gets hotter.

4. State Ohm's Law.

5. Name an output transducer that produces sound.

PART 1

The Voltage Divider

A supply gives one voltage. A divider gives you any smaller one you want.

By the end of this part…

1. I can describe how a voltage divider works
2. I can calculate a voltage in a fixed divider

Analogue signals

Booklet p.21

Analogue

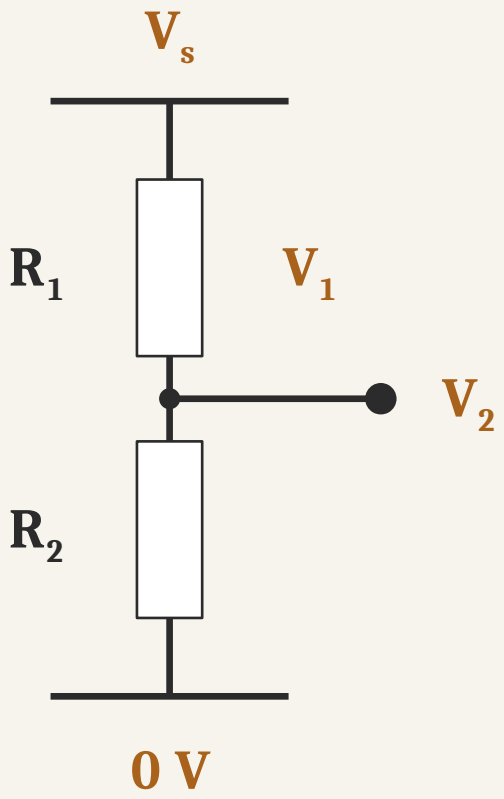
A signal that can take any value in a range, and changes smoothly.

The example

The voltage across an LDR divider as the light drops at sunset.

What a voltage divider is

Booklet p.21 — two resistors in series across the supply



The output V_2 is taken across the LOWER resistor, R_2.

The bigger resistance takes the bigger share

Booklet p.21

The rule

The supply is shared between the two resistors, in the same ratio as their resistances.

So

V_2 is always less than the supply voltage — some of it is always across R_1.

The voltage divider relationship

Booklet p.21 — on the data sheet

$$V_1/V_2 = R_1/R_2$$

V_1, V_2

the two voltages, in volts (V)

R_1, R_2

the two resistances, in ohms (Ω)

Worked example — find the output · p.21

In a voltage divider $R_1 = 3\ k\Omega$ and $R_2 = 1\ k\Omega$.

The voltage across R_1 is 9 V. Calculate V_2.

$V_1 = 9\ V$

$R_1 = 3000\ \Omega$

$R_2 = 1000\ \Omega$

$V_2 = ?$

$$V_1/V_2 = R_1/R_2$$

$$V_2 = (V_1 \times R_2)/R_1$$

$$V_2 = 9 \times 1000/3000$$

$$\underline{V_2 = 3\ V}$$

Worked example — work backwards · p.21

In a voltage divider R_1 = 5 kΩ and R_2 = 2 kΩ.
The voltage across R_2 is 2 V. Calculate V_1.

$V_2 = 2\ V$

$R_1 = 5000\ \Omega$

$R_2 = 2000\ \Omega$

$V_1 = ?$

$$V_1/V_2 = R_1/R_2$$

$$V_1 = (V_2 \times R_1)/R_2$$

$$V_1 = 2 \times 5000/2000$$

$$\underline{V_1 = 5\ V}$$

Show me — divider calculations

SHOW ME BOARDS

1. $R_1 = 1\ k\Omega$, $R_2 = 1\ k\Omega$, $V_1 = 4\ V$. Find V_2.
2. $R_1 = 2\ k\Omega$, $R_2 = 4\ k\Omega$, $V_1 = 3\ V$. Find V_2.
3. $R_1 = 6\ k\Omega$, $R_2 = 2\ k\Omega$, $V_1 = 6\ V$. Find V_2.
4. $R_1 = 1\ k\Omega$, $R_2 = 3\ k\Omega$, $V_2 = 9\ V$. Find V_1.
5. The two resistors are equal. What fraction of the supply is V_2?

Show me — divider calculations

SHOW ME BOARDS

EXTRA PRACTICE

1. R_1 = 500 Ω, R_2 = 500 Ω, V_1 = 5 V. Find V_2.
2. R_1 = 3 kΩ, R_2 = 6 kΩ, V_1 = 2 V. Find V_2.
3. R_1 = 8 kΩ, R_2 = 2 kΩ, V_1 = 8 V. Find V_2.
4. R_1 = 2 kΩ, R_2 = 6 kΩ, V_2 = 12 V. Find V_1.
5. R_2 is three times R_1. What fraction of the supply is V_2?

Your turn — TRY THIS

Booklet p.21 — TRY THIS: Voltage Divider

Answer the three questions in your booklet.
3 marks each: relationship, substitution,
then the answer with its unit.
Question 3 asks for V_1, not V_2.

Booklet p.21 — TRY THIS: Voltage Divider

TRY THIS — Answers

ANSWERS

Booklet p.21 — Voltage Divider

Q	Working	Answer
1	$V_2 = (6 \times 1000) \div 2000$	3 V
2	$V_2 = (4 \times 940) \div 470$	8 V
3	$V_1 = (4 \times 1000) \div 2000$	2 V

In question 2, R_2 is the bigger resistor — so V_2 is the bigger voltage.

Checkpoint

1. What is a voltage divider made from?
2. Which resistor is the output voltage taken across?
3. Two equal resistors divide a 10 V supply. What is V_2, and why?

Daily Review

Part 1 — The Voltage Divider

1. What is the output of a voltage divider taken across?

2. $R_1 = 2\ k\Omega$, $R_2 = 2\ k\Omega$, $V_1 = 3\ V$. Find V_2.

3. Can V_2 ever be bigger than the supply voltage?

4. State the voltage divider relationship.

5. Which resistor has the bigger voltage across it?

PART 2

Sensors in the Divider

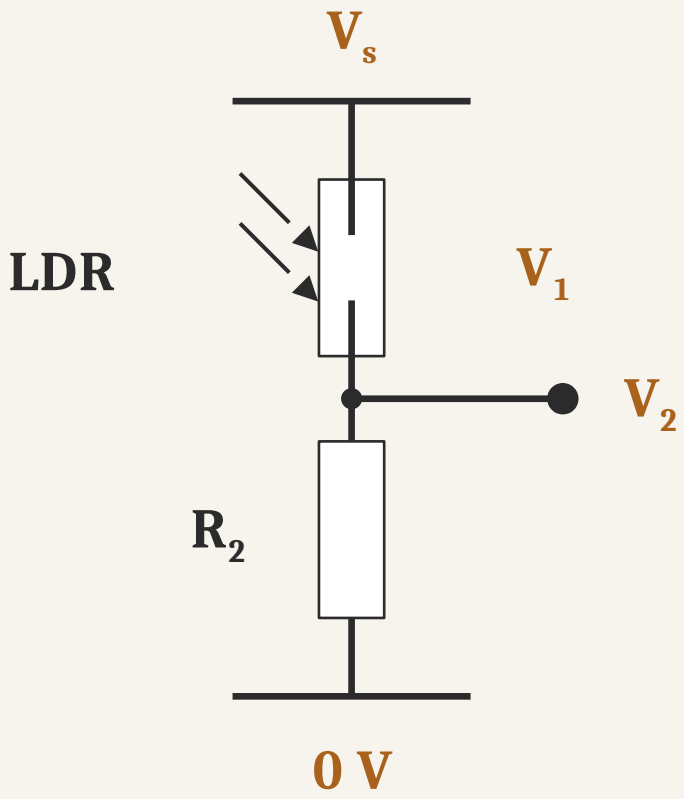
Replace one resistor with an LDR and the output voltage follows the light.

By the end of this part…

1. I can use a variable voltage divider to provide an input signal
2. I can link a change in sensor resistance to a change in output voltage

Swap a resistor for a sensor

Booklet p.23 — the LDR takes the place of R_1



As the LDR's resistance changes, so does V_2.

LDR in the top position

Booklet p.23 — the LDR is R_1

In bright light

The LDR's resistance is LOW, so it takes little of the supply — V_2 is HIGH.

In darkness

The LDR's resistance is HIGH, so it takes most of the supply — V_2 is LOW.

LDR in the bottom position

Booklet p.23 — the LDR is R_2

In bright light

The LDR's resistance is LOW, so little of the supply is across it — V_2 is LOW.

In darkness

The LDR's resistance is HIGH, so most of the supply is across it — V_2 is HIGH.

How to describe a sensor circuit

Booklet p.31 — the routine

- First, what happens to the SENSOR'S RESISTANCE.
- Then, what happens to the OUTPUT VOLTAGE V_2.
- Then, what the output device does.
- Never jump from the light level straight to the lamp.

Worked example — an LDR divider · p.23

In normal light an LDR (R_1) is 8 kΩ and R_2 is 2 kΩ.

The voltage across the LDR is 8 V. Calculate V_2.

$V_1 = 8\ V$

$R_1 = 8000\ \Omega$

$R_2 = 2000\ \Omega$

$V_2 = ?$

$$V_1/V_2 = R_1/R_2$$

$$V_2 = (V_1 \times R_2)/R_1$$

$$V_2 = 8 \times 2000/8000$$

$$\underline{V_2 = 2\ V}$$

Show me — which way does V_2 go?

SHOW ME BOARDS

1. The LDR is R_1. It gets darker. What happens to V_2?
2. The LDR is R_2. It gets darker. What happens to V_2?
3. A thermistor is R_2. It gets hotter. What happens to V_2?
4. A thermistor is R_1. It gets colder. What happens to V_2?
5. You want V_2 to rise as a room warms. Where does the thermistor go?

Show me — which way does V_2 go?

SHOW ME BOARDS

EXTRA PRACTICE

1. The LDR is R_1. It gets brighter. What happens to V_2?
2. The LDR is R_2. It gets brighter. What happens to V_2?
3. A thermistor is R_2. It gets colder. What happens to V_2?
4. A thermistor is R_1. It gets hotter. What happens to V_2?
5. You want V_2 to rise as it gets dark. Where does the LDR go?

Your turn — TRY THIS

Booklet p.23 — TRY THIS: Sensor Voltage Divider

Answer the three questions in your booklet.
Read carefully which component is R_1
and which is R_2 — it changes the answer.

Booklet p.23 — TRY THIS: Sensor Divider

TRY THIS — Answers

ANSWERS

Booklet p.23 — Sensor Voltage Divider

Q	Working	Answer
1	$V_2 = (4 \times 3000) \div 2000$	6 V
2	$V_2 = (2 \times 20\,000) \div 10\,000$	4 V
3	$V_2 = (3 \times 6000) \div 2000$	9 V

Every one has the bigger resistance taking the bigger voltage.

Simulate it — the LDR divider

Yenka · success criterion 4.5

Build the divider with a 10 kΩ resistor.
PREDICT what happens to V_2 as it gets dark.
Then cover the LDR and read the meter.
Swap the LDR and the resistor over, and predict again.

Yenka — LDR voltage divider

What the simulation shows

ANSWERS

Yenka · success criterion 4.5

LDR position	Cover the LDR	Why
upper (R_1)	V_2 falls	the LDR takes more, so R_2 gets less
lower (R_2)	V_2 rises	the LDR takes more, and V_2 is across it

Same sensor, same change — opposite output. The position is the design decision.

Daily Review

Part 2 — Sensors in the Divider

1. The LDR is R_2 and it gets darker. What happens to V_2?

2. Which resistor is V_2 taken across?

3. $R_1 = 4\ k\Omega$, $R_2 = 2\ k\Omega$, $V_1 = 8\ V$. Find V_2.

4. State the three steps for describing a sensor circuit.

5. What is an analogue signal?

PART 3

Reading a Sensor Circuit

The exam gives you a circuit and a data table. Both have to be read the same way.

By the end of this part…

1. I can interpret data tables for an LDR or thermistor
2. I can calculate a voltage in a fixed voltage divider

Reading a data table

Booklet p.23

Step 1

Find the sensor's resistance at the condition the question names.

Step 2

Put that resistance into the divider relationship with the fixed resistor.

Watch out

THE MISTAKE

- Assuming the sensor is always R_1
- Reading V_2 across the top resistor
- An answer bigger than the supply

THE CORRECT ANSWER

- Read the circuit — it can be either
- V_2 is across the LOWER resistor
- V_2 is always less than the supply

Your turn — the practice questions

Booklet p.25–26 — PRACTICE: Voltage Dividers and Sensors

Answer questions 1 to 10 in your booklet.
The marks are printed beside each question.
Questions 4, 5 and 10 want a description — resistance first, then V_2.

Booklet p.25–26 — PRACTICE, Q1–10

PRACTICE — Answers, Q1–3

ANSWERS

Booklet p.25–26 — Voltage Dividers and Sensors

Q	The answer	Marks
1	a signal that can take any value in a range, and changes smoothly	1
2	to produce a smaller voltage from the supply voltage	1
3	$V_2 = (3 \times 440) \div 220 = 6$ V	3

PRACTICE — Answers, Q4–6

ANSWERS

Booklet p.25–26 — Voltage Dividers and Sensors

Q	The answer	Marks
4	the LDR's resistance increases, so it takes more of the supply and V_2 decreases	2
5	the thermistor's resistance decreases, so V_2 across it decreases	2
6	$V_2 = (2 \times 3000) \div 2000 = 3$ V	3

PRACTICE — Answers, Q7-8

ANSWERS

Booklet p.25-26 — Voltage Dividers and Sensors

Q	The answer	Marks
7	the two resistors share the supply, so some is always across R_1 — V_2 must be less	2
8	$V_1 = (8 \times 1000) \div 4000 = 2$ V	3

PRACTICE — Answers, Q9-10

ANSWERS

Booklet p.25-26 — Voltage Dividers and Sensors

Q	The answer	Marks
9	an adjustable input signal — a volume control, a dimmer, or setting a trigger point	2
10	in the lower position, as R_2, so V_2 rises as the light falls	1

Exam practice

National 5 Engineering Science 2024 Q10 — a kettle sensing circuit

Part	What it asks	Marks
10(b)	the name of this type of series circuit	1
10(c)	the resistance R, from 5.0 V, 4.8 kΩ and V_{in} = 1.4 V	4

Four marks: relationship, missing voltage, substitution, answer.

LOOKING AHEAD

Transistors and Relays

Turning a changing voltage into a switch.

Plenary

1. What is a voltage divider made from?
2. Which resistor is V_2 taken across?
3. R_1 = 2 kΩ, R_2 = 4 kΩ, V_1 = 5 V. Find V_2.
4. An LDR is R_1. Describe what happens to V_2 as it gets darker.
5. Why can V_2 never be bigger than the supply voltage?

Plenary

EXTRA PRACTICE

1. What is an analogue signal?
2. Which resistor has the larger voltage across it?
3. R_1 = 5 kΩ, R_2 = 1 kΩ, V_1 = 10 V. Find V_2.
4. A thermistor is R_2. Describe what happens to V_2 as it gets hotter.
5. Give one engineering use of a variable voltage divider.

Extension

1. A divider has a 1 kΩ and a 1 MΩ resistor. Almost all the supply is across one of them. Which, and why?
2. An LDR divider drives a lamp that must come on at dusk. Where does the LDR go, and why not the other way?
3. Why is a voltage divider a better sensor circuit than measuring the sensor's resistance directly?

Extension

EXTRA PRACTICE

1. A divider has two 1 MΩ resistors. What is V_2 as a fraction of the supply, and does the size of the resistors change that?
2. A thermistor divider drives a fan that must come on when a machine overheats. Where does the thermistor go, and why?
3. A designer wants the trigger point to be adjustable. What would you put in the divider, and where?