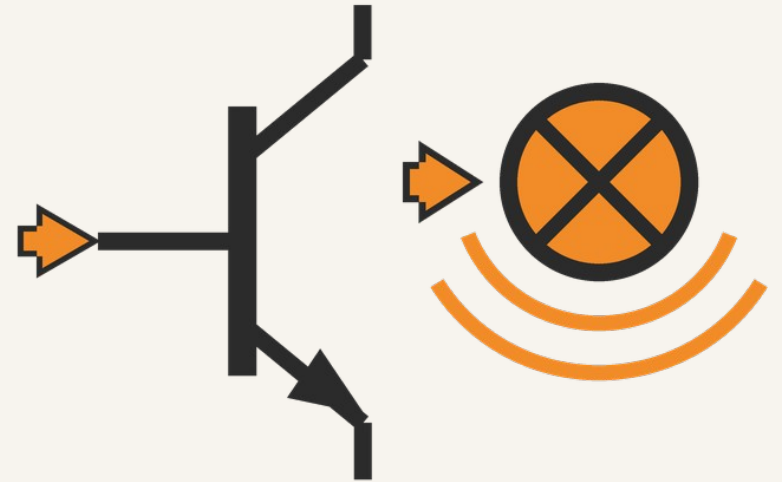


BOOKLET 3 • ELECTRONICS AND ANALOGUE
CONTROL

Transistors and Relays

A small voltage at the base, switching
something much bigger.

National 5 Engineering Science



Daily Review

Lesson 5 — Voltage Dividers and Sensors

- 1 Which resistor is V_2 taken across?
- 2 An LDR is R_2 and it gets darker. What happens to V_2 ?
- 3 $R_1 = 3 \text{ k}\Omega$, $R_2 = 1 \text{ k}\Omega$, $V_1 = 6 \text{ V}$. Find V_2 .
- 4 Name an output transducer that produces movement.
- 5 State the three steps for describing a sensor circuit.

PART 1

The Transistor as a Switch

The divider gives you a changing voltage. The transistor turns it into an on and an off.

By the end of this part...

- 1 I can describe the transistor as a switching device
- 2 I can describe how a small input voltage switches a larger output

What a transistor does

Booklet p.27

What it is

A fast, automatic electronic switch.

What it does

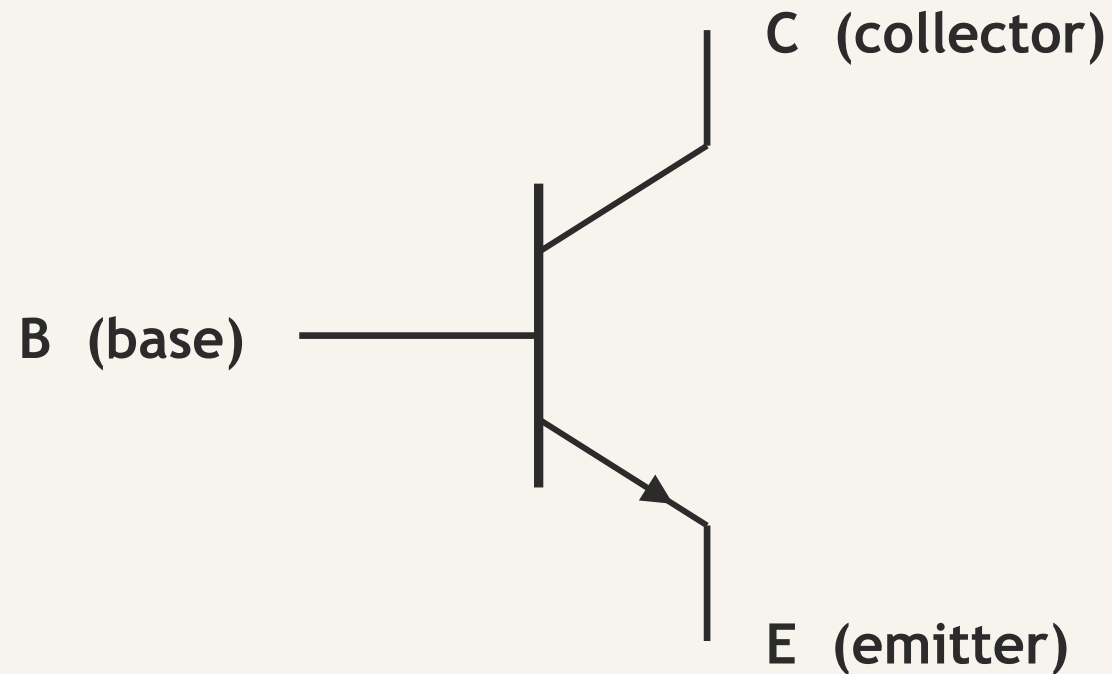
A small voltage at the base controls a much larger current.

At National 5

You only need the NPN transistor.

The NPN symbol

Booklet p.27 – the symbol on the data sheet



The three connections

Booklet p.27

Connection	Letter	What it does
base	B	the input — a small signal here switches it
collector	C	connected to the output device
emitter	E	the path back to 0 V

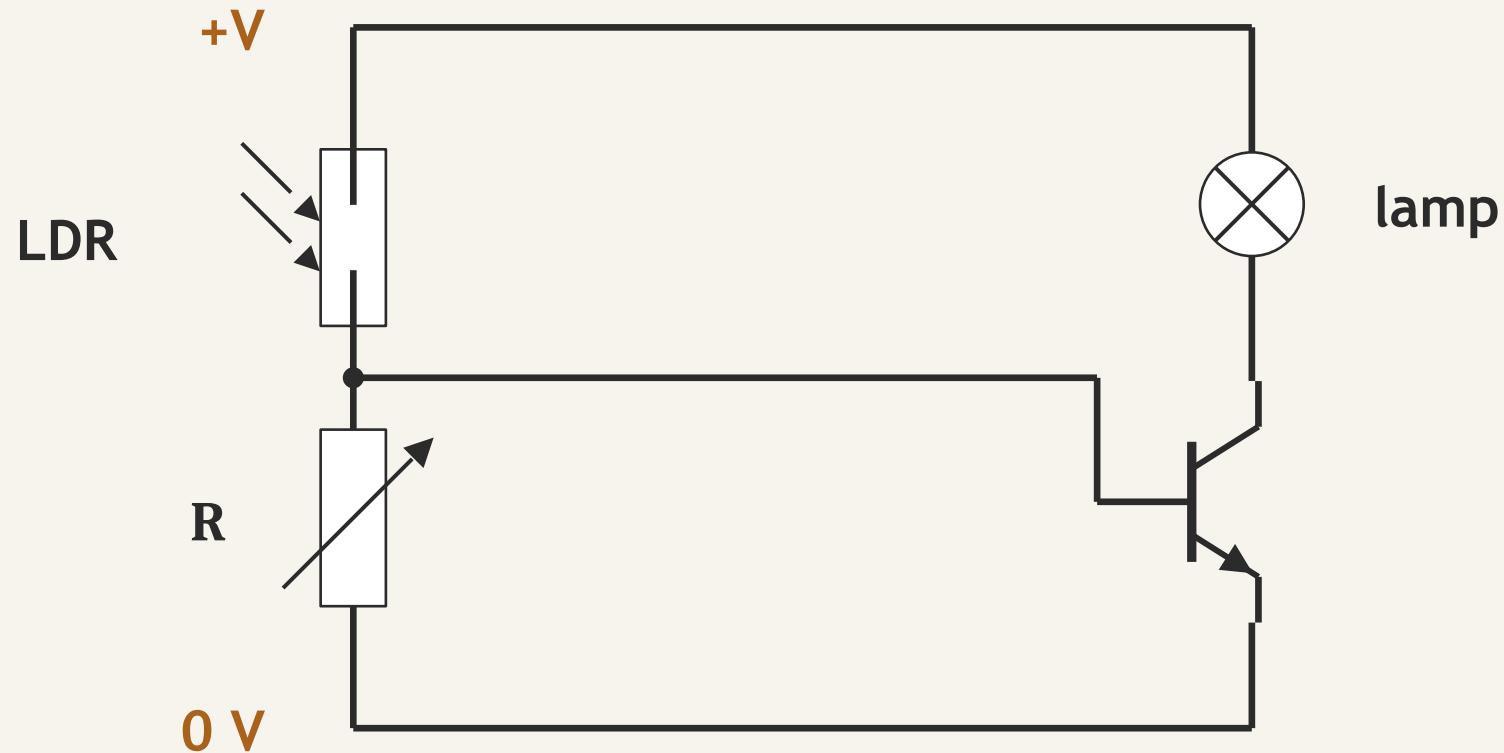
The switching voltage

Booklet p.27

- Below about 0.7 V at the base — the transistor is OFF.
- At about 0.7 V at the base — the transistor turns ON.
- Once it is on, the output device operates.

A transistor switching a lamp

Booklet p.27



The divider sets the base voltage. Everything else follows from it.

Show me – the transistor

SHOW ME BOARDS

- 1 What does a transistor do in a control circuit?
- 2 Name the three connections of an NPN transistor.
- 3 What is the approximate switching voltage?
- 4 The base is at 0.3 V. Is the transistor on or off?
- 5 Which connection carries the current to the output device?

Show me – the transistor

SHOW ME BOARDS

EXTRA PRACTICE

- 1 Why is a transistor called a switch and not an amplifier here?
- 2 Which connection is the input?
- 3 The base is at 0.9 V. Is the transistor on or off?
- 4 Which connection is the path back to 0 V?
- 5 What sets the base voltage in a sensor circuit?

Checkpoint

- 1 State the function of a transistor in a control circuit.
- 2 Name the three connections and say what each is for.
- 3 A sensor circuit never gets the base above 0.4 V. What happens to the output, and why?

Daily Review

Part 1 — The Transistor as a Switch

- 1 What is the switching voltage of an NPN transistor?
- 2 Which connection is the input?
- 3 What does a transistor do in a control circuit?
- 4 The base is at 0.2 V. Is the output on or off?
- 5 What sets the base voltage?

PART 2

Relays and the Protection Diode

A transistor cannot switch a mains motor. A relay can — and it needs protecting.

By the end of this part...

- 1** I can describe the function of a relay in a control circuit
- 2** I can describe the function of a protection diode
- 3** I can interpret a full sensor control circuit
- 4** I can simulate a transistor switching circuit with a sensor input

What a relay is

Booklet p.28

An electromagnetic switch

A small current in the coil closes a separate set of contacts.

Two circuits

The coil circuit and the switched circuit are electrically separate.

Why engineers use a relay

Booklet p.28

The problem

A transistor circuit is low-voltage. It cannot carry a 230 V mains current.

The answer

So a small electronic circuit switches the coil, and the contacts switch the big circuit.

The protection diode

Booklet p.28

The problem

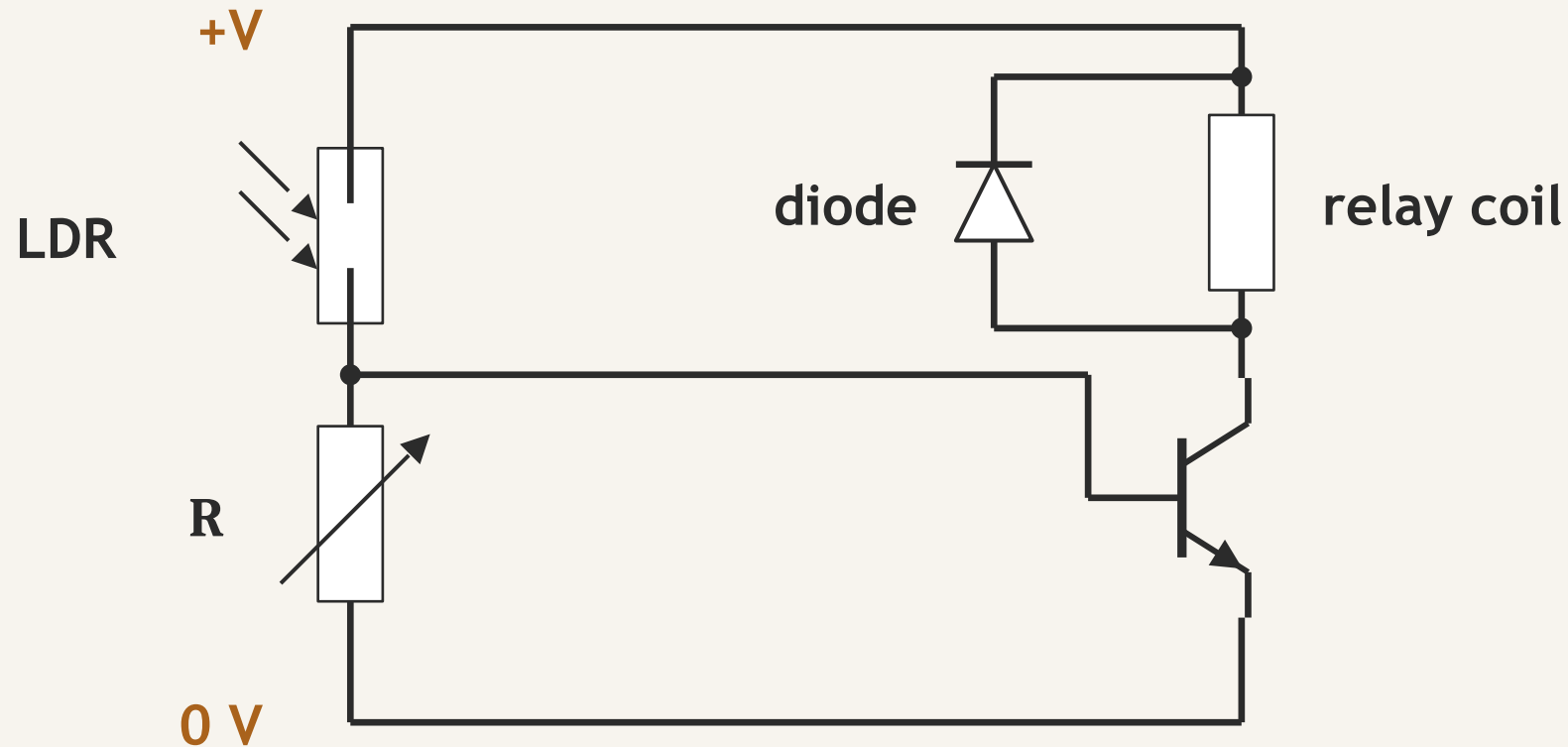
Switching the coil off makes a voltage spike that can damage the transistor.

The answer

The diode goes across the coil, in reverse to the supply, giving the spike a safe path.

The full control circuit

Booklet p.28



Sensor, divider, transistor, coil – and the diode across the coil.

The four blocks of it

Booklet p.28

- An input transducer — an LDR, a thermistor or a switch.
- A voltage divider that turns its resistance into a voltage.
- A transistor that switches when that voltage is big enough.
- An output device, or a relay to switch a separate circuit.

Light- and dark-sensing

Booklet p.28

Circuit	Position of LDR	Output switches on when...
Light-sensing	LDR as R_1 (top)	the light level is high
Dark-sensing	LDR as R_2 (bottom)	the light level is low

Hot and cold sensing

Booklet p.28

Circuit	Position of thermistor	Switches on when...
High temperature	thermistor as R_1 (top)	the temperature is high
Low temperature	thermistor as R_2 (bottom)	the temperature is low

Describing it — the routine

Booklet p.31 — Knowledge Organiser

- First, what happens to the SENSOR'S RESISTANCE.
- Then, what happens to V_{out} .
- Then, whether the TRANSISTOR switches on.
- Then, what the OUTPUT does.

Watch out

THE MISTAKE

- Transistor legs the wrong way round
- No protection diode, or fitted backwards
- The sensor in the wrong half of the divider

THE CORRECT ANSWER

- Identify B, C and E from the flat face
- The banded end goes to the positive side
- Decide first: on for MORE, or for LESS?

Show me — describe the circuit

SHOW ME BOARDS

- 1 A dark-sensing lamp. Describe what happens as it gets dark.
- 2 Where does the LDR go in a dark-sensing circuit?
- 3 What happens at the base when V_2 reaches 0.7 V?
- 4 Why is there a diode across the relay coil?
- 5 Why not connect the mains lamp straight to the collector?

Show me – describe the circuit

SHOW ME BOARDS

EXTRA PRACTICE

- 1 A cooling fan on a hot machine. Describe what happens as it heats up.
- 2 Where does the thermistor go in that circuit?
- 3 What happens at the base when V_2 falls to 0.4 V?
- 4 Which way round does the protection diode go?
- 5 Name one thing the relay's contacts could switch.

Simulate it — the dark-sensing circuit

Yenka · success criterion 5.6

Build the dark-sensing circuit in Yenka.
PREDICT the base voltage in the light.
Then darken the LDR and watch the output.
Adjust R to change the switching level.

Yenka — transistor switching circuit

What the simulation shows

ANSWERS

Yenka · success criterion 5.6

Light level	LDR resistance	V_2	Output
bright	low	low	off
dim	rising	rising	off
dark	high	above 0.7 V	on

Turning R changes the light level it switches at — that is what R is for.

Assignment link

Booklet p.28 — see Booklet 8

- Write a test procedure before you build.
- Record results that name each component's function.
- "The thermistor's resistance fell, so V_{out} rose..."
- Check battery orientation before you run the simulation.

Daily Review

Part 2 — Relays and the Protection Diode

- 1 What does a relay do?
- 2 Why is a protection diode needed?
- 3 Where does the LDR go in a dark-sensing circuit?
- 4 What is the transistor's switching voltage?
- 5 Name the four blocks of a control circuit.

PART 3

Putting It All Together

Ten questions that use everything in this booklet.

By the end of this part...

- 1 I can interpret a control circuit using a divider, transistor, relay and output
- 2 I can describe the function of a relay and a protection diode

Your turn – the practice questions

Booklet p.29-30 – PRACTICE: Transistor Switching and Relays

Answer questions 1 to 10 in your booklet.
The marks are printed beside each question.
Questions 7 and 9 want the full description –
resistance, then V_2 , then the transistor.

Booklet p.29-30 – PRACTICE, Q1-10

PRACTICE – Answers, Q1-3

ANSWERS

Booklet p.29-30 – Transistor Switching and Relays

Q	The answer	Marks
1	a fast electronic switch – a small input voltage switches a much larger output current	1
2	base, collector and emitter	1
3	about 0.7 V	1

PRACTICE – Answers, Q4-5

ANSWERS

Booklet p.29-30 – Transistor Switching and Relays

Q	The answer	Marks
4	an electromagnetic switch – a small coil current closes a separate set of contacts	2
5	switching the coil off makes a voltage spike; the diode across it, in reverse, gives it a safe path	2

Q4 also wants: so a small circuit can switch a much larger one.

PRACTICE — Answers, Q6-8

ANSWERS

Booklet p.29-30 — Transistor Switching and Relays

Q	The answer	Marks
6	in the lower position, as R_2	1
7	as it darkens the LDR's resistance rises, so V_2 rises; at about 0.7 V the transistor switches the lamp on	3
8	the transistor circuit cannot carry a mains current; the relay's contacts switch it, and keep it separate	2

PRACTICE — Answers, Q9-10

ANSWERS

Booklet p.29-30 — Transistor Switching and Relays

Q	The answer	Marks
9	thermistor in the upper position; as it heats, its resistance falls, so V_2 rises and the fan switches on	3
10	any two, with fixes — transistor legs reversed · diode missing or backwards · sensor in the wrong half	4

Q10 is 2 + 2: each mistake earns a mark, each fix earns another.

Exam practice

National 5 Engineering Science 2023 Q7 – a child's night light

Part	What it asks	Marks
7(a)	add the symbol for the lamp to the circuit	1
7(b)	the full name of component Y	1
7(c)	where an ammeter reads the base current	1
7(d)	the component that protects the transistor	1

© Qualifications Scotland (SQA)

LOOKING AHEAD

Logic and Digital Control

Booklet 4a — when a signal is only ever on or off.

Plenary

- 1 State the function of a transistor in a control circuit.
- 2 Name the three connections of an NPN transistor.
- 3 Describe the function of a relay.
- 4 Describe the function of a protection diode.
- 5 Describe a dark-sensing circuit from the LDR to the lamp.

- 1 What is the switching voltage of an NPN transistor?
- 2 Which connection of the transistor is the input?
- 3 Why can a relay switch a mains circuit when a transistor cannot?
- 4 Which way round does the protection diode go, and why?
- 5 Describe a cooling-fan circuit from the thermistor to the motor.

Extension

- 1 A dark-sensing circuit switches on too early in the evening. What would you change, and why?
- 2 Why does the relay coil need a diode but the lamp does not?
- 3 The variable resistor is replaced by a fixed one. What does the circuit lose?

- 1 A cooling fan switches on too late. What would you change, and why?
- 2 Could you swap the LDR and the fixed resistor and get the same circuit back by turning R? Explain.
- 3 Why is the transistor drawn between the output device and 0 V, rather than between +V and the output device?