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FREE EBOOK

ROBOTICS AND ELECTRONICS

Breadboard Circuits

Fifteen experiments with batteries, LEDs, switches and sensors

INSIDE THIS BOOK

- Meet the breadboard
- Parts, symbols and safe power
- LEDs and resistors
- Switches, buzzers and motors
- The transistor: a small current controls a big one
- ...and 5 more chapters, practice questions and a glossary

Beginner

Students of class 5 to 10 and beginners

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Breadboard Circuits

Learn how a breadboard is joined inside, how to read a circuit diagram and how to turn it into a working circuit. Then build fifteen safe experiments on batteries of 9 V or less, from a first LED to a night lamp, a water level indicator, a 555 blinker, logic gates, alarms and a traffic light model, and learn how to find and fix faults.

WHO IT IS FOR	Students of class 5 to 10 and beginners
LEVEL	Beginner
SUBJECT AREA	Robotics and electronics
WHAT IS INSIDE	10 chapters, practice questions with answers, and a glossary

HOW TO USE IT

Read one chapter at a time and try the examples as you go: on a computer, at your workbench or in your notebook. The boxes give tips, safety points and short activities. When you finish, test yourself with the practice questions and check your answers at the end. Words you may not know are explained in the glossary.



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Meet the breadboard

A **breadboard** is a plastic board full of small holes. Under the holes are metal clips. When you push the leg of a part into a hole, a clip holds it and connects it to the other holes in the same strip. So you can build a circuit without **soldering** (joining metal with melted metal), then pull it apart and use the parts again.

How the holes are joined inside

A common half-size breadboard has about 30 numbered **rows** and ten lettered **columns**, a to j. A groove runs down the middle, between column e and column f. This groove is the **centre gap**.

Holes	Joined to
a, b, c, d, e in one row	each other (a strip of five)
f, g, h, i, j in one row	each other (another strip of five)
Column e and column f	nothing: the centre gap separates them

So each row has two separate strips of five holes.

The centre gap is made for **chips** (integrated circuits). A chip has two lines of legs. When it sits across the gap, every leg lands in its own strip, so no two legs are joined by mistake.

The power rails

Along each long edge are two lines of holes marked with a red line (+) and a blue or black line (-). These are the **power rails**. All the holes along one line are joined. The battery's positive wire goes into the red rail and its negative wire into the blue rail, so any part can reach + or - nearby.

On some long breadboards, each rail is broken into two halves in the middle. If you are not sure, test it with a multimeter on its continuity (beep) setting: touch one probe to a hole at each end of the rail. A beep means the rail is joined all the way.

REMEMBER

Every leg of a part must go into a different strip, unless you want those legs joined. Two legs of one LED in the same strip are shorted together, and the LED will never light.

Putting parts in neatly

1. Straighten each leg, then push it gently and straight down.
2. Use solid-core **jumper wires** (wires with stiff ends). Thick or bent legs damage the clips.
3. Use red wires for + and black or blue wires for -. This habit saves hours of fault finding.
4. When a wire needs cutting or stripping, use side cutters or a wire stripper with an adult's help, and point the cut end down at the table.

EXAMPLE

Arjun from Lucknow built his first circuit, but the LED stayed dark. Both legs of the LED were in row 12. He moved the short leg to row 14, added a wire from row 14 to the blue rail, and the LED lit.

TRY THIS

Draw a breadboard in your notebook, shading each strip of five holes in a different colour. Keep this map beside you for the first few experiments.

CHAPTER 2

Parts, symbols and safe power

Every experiment here runs on a 9 V battery (the rectangular kind) with a snap-on clip, or a holder of four AA cells, which gives 6 V. Nothing in this book uses more than 9 V.

SAFETY

Never connect any circuit in this book to a wall socket, an inverter or a cut adapter wire. Mains electricity can kill. A 9 V battery is safe to touch, but it gets hot and can leak if a bare wire joins its two terminals, so always connect a part between them.

Voltage, current and resistance

- **Voltage** (volts, V) is the push that makes electricity flow.
- **Current** (amperes, A) is how much flows. 1,000 **milliamperes** (mA) make 1 A.
- **Resistance** (ohms, Ω) is how hard a part makes it for current to flow.

They are linked by **Ohm's law**: voltage = current $\times$ resistance, or $V = I \times R$.

EXAMPLE

A red LED needs about 2 V across it and is happy with about 15 mA (0.015 A). On a 9 V battery, the resistor must take the other 7 V. Resistance = $7 \div 0.015$ = about 467 Ω . The nearest common value is 470 Ω , so Meena uses a 470 Ω resistor.

Resistor colour bands

A resistor shows its value with coloured bands. Read from the end away from the gold band. Black is 0, brown 1, red 2, orange 3, yellow 4, green 5, blue 6, violet 7, grey 8 and white 9. The first two bands are digits; the third says how many zeros to add. A "k" means thousand, so 10 k Ω is 10,000 Ω .

Value	Bands
220 Ω	red, red, brown
330 Ω	orange, orange, brown
470 Ω	yellow, violet, brown
1 k Ω	brown, black, red
10 k Ω	brown, black, orange
22 k Ω	red, red, orange
100 k Ω	brown, black, yellow

Parts with a right way round

- **LED** (light-emitting diode): the longer leg is the **anode** (+). The shorter leg, on the side where the rim is flat, is the **cathode** (-).
- **Electrolytic capacitor**: a stripe with minus signs marks the negative leg.
- **Diode**: the silver or white band marks the cathode.
- **Buzzer**: the longer leg, or the leg near a "+" mark, is positive.

Circuit symbols

A **circuit diagram** draws each part as a simple symbol and each wire as a line.

Part	Symbol, in words
Battery	a long thin line (+) beside a short thick line (-)
Resistor	a zigzag line, or a small rectangle
Diode	a triangle pointing at a bar; current flows the way the triangle points
LED	a diode symbol with two small arrows coming out
Transistor	a circle with three lines; the emitter line has an arrow
Joined wires	a dot where lines meet

From diagram to breadboard

1. Every **dot** on the diagram, where wires meet, becomes one strip on the breadboard.
2. Follow the path from + to -, part by part, placing each one so its legs land in the right strips.
3. Tick each wire on the diagram with a pencil as you place it, and check everything once more.

TIP

Connect the battery last, and unsnap it before you change anything. Building with the power on is the easiest way to damage a part.

LEDs and resistors

The LED shows at once whether current is flowing. These two experiments teach the most important rule in electronics: an LED always needs a resistor.

Experiment 1: An LED with a resistor

You need: a breadboard, a 9 V battery and clip, a red LED, a $470\ \Omega$ resistor, a jumper wire.

Build it:

1. Push the clip's red wire into the + rail and the black wire into the - rail. Do not snap on the battery yet.
2. Put one leg of the $470\ \Omega$ resistor in the + rail and the other in row 10, column a.
3. Put the LED's long leg in row 10, column c, and its short leg in row 12, column c.
4. Add a jumper wire from row 12, column a, to the - rail.
5. Snap on the battery. The LED glows.
6. Unsnap the battery, turn the LED round, and try again. It stays dark.

What you learn: current flows from + through the resistor and the LED to -. A diode lets current pass only one way, so the LED must face the right way. Without the resistor, too much current would flow and the LED would burn out.

Experiment 2: LEDs in series and in parallel

You need: two red LEDs, one $330\ \Omega$ and two $470\ \Omega$ resistors, jumper wires.

Series first. In a **series** circuit, parts sit one after another in a single path, like children holding hands in a line.

1. Connect: + rail $\rightarrow$ $330\ \Omega$ resistor $\rightarrow$ LED 1 $\rightarrow$ LED 2 $\rightarrow$ - rail, each LED with its long leg towards +.
2. Snap on the battery. Both LEDs glow.
3. Pull out LED 1. Both go dark, because the only path is broken.

Two red LEDs take about 4 V, leaving 5 V for the resistor. Current = $5 \div 330$ = about 0.015 A, or 15 mA.

Now parallel. In a **parallel** circuit, each part has its own path between + and -.

1. Unsnap the battery and build two separate LED-and-470 Ω pairs, each running from the + rail to the - rail.
2. Snap on the battery. Pull out one LED. The other keeps glowing.

What you learn: in series, one break stops everything. In parallel, each path works on its own. Give each LED in parallel its own resistor; if they share one, the LED that conducts most easily takes most of the current.

REMEMBER

The lights and fans in your home are wired in parallel. That is why the tube light stays on when you switch off the fan.

TRY THIS

Three red LEDs in series take about 6 V, leaving 3 V. For about 15 mA: $3 \div 0.015 = 200 \Omega$, so build it with 220 Ω .

CHAPTER 4

Switches, buzzers and motors

A circuit becomes useful when you can control it. Here you will switch an LED, a buzzer and a motor.

Experiment 3: The push button

A **push button** joins its contacts only while you press it. The common small button has four legs, joined inside in two pairs. Pressing connects the pairs.

You need: the LED and 470 Ω resistor from Experiment 1, a four-leg push button.

Build it:

1. Place the button across the centre gap, with two legs on each side.
2. Connect the + rail to one leg. Take the circuit on from the leg **diagonally opposite** that one.

3. From that leg, connect the resistor, then the LED (long leg towards the resistor), then the - rail.
4. Snap on the battery and press. The LED lights only while you press.

What you learn: a switch is a gap that you can close. Diagonally opposite legs always give the switching action, even if you do not know how the legs are paired.

TIP

To find the pairs, set your multimeter to continuity and touch two legs. If it beeps without pressing, they are a pair.

Experiment 4: A buzzer alarm

An **active buzzer** has its own sound circuit inside, so it beeps as soon as it gets the right voltage. A **passive** buzzer needs a changing signal; you will use one with the 555 timer.

You need: an active buzzer, a push button, jumper wires. Check the buzzer's voltage on its label or shop listing. Many work from about 3 V to 12 V; if yours says 5 V, use a holder of three AA cells (4.5 V).

Build it: connect + rail → button → buzzer's + leg, and the buzzer's other leg to the - rail. Press the button and the buzzer sounds like a doorbell.

What you learn: this simple loop is the heart of every alarm: something closes a contact, and a buzzer sounds.

TRY THIS

Make a **pressure mat**: two foil-covered cards, foil sides facing, with a sponge between them that has a hole in its middle. Use the foils in place of the button. A footstep presses them together through the hole.

Experiment 5: Controlling a motor with a switch

You need: a small DC toy motor rated 3 V to 6 V, a holder for four AA cells (6 V), a slide switch, two crocodile-clip leads, and a paper flag taped to the shaft. A motor needs more current than a 9 V battery can give for long, so use the AA holder.

Build it:

1. Connect the holder to the rails and the switch's middle leg to the + rail.
2. Clip one motor wire to an end leg of the switch, and the other motor wire to the - rail.
3. Slide the switch. The flag spins. Slide it back. It stops.
4. Swap the two motor wires. The flag now spins the other way.

What you learn: a DC motor's direction depends on which way current flows through it.

A **DPDT** switch (double pole, double throw) can reverse a motor. It has six legs in two rows of three. Connect the motor to the middle pair and the battery to the pair at one end. Then join each leg at that end to the leg diagonally opposite it at the other end. One position now runs the motor forward, the other backward.

SAFETY

Keep fingers, hair and loose sleeves away from a spinning shaft. If a motor gets hot, switch it off and let it cool.

CHAPTER 5

The transistor: a small current controls a big one

A **transistor** is an electronic switch with no moving parts. A tiny current into one leg lets a much bigger current flow through the other two, so weak signals from sensors can switch on LEDs and buzzers.

Meet the BC547

The BC547 is a small **NPN transistor** used in thousands of school projects.

Leg	Name	Job
C	Collector	the big current comes in here
B	Base	the small control current goes in here

Leg	Name	Job
E	Emitter	both currents leave here, to the - rail

For most BC547s, hold the flat face towards you with the legs pointing down: the legs are C, B, E from left to right. Check the pack or the **datasheet** (the maker's information sheet), because some makers differ.

When about 0.7 V appears between base and emitter, a small current flows into the base and the transistor turns on. A current a hundred times bigger, or more, can then flow from collector to emitter.

REMEMBER

Never connect the base straight to the + rail. Always use a resistor, or the base current will be too large and will damage the transistor.

Two resistances in series share the battery's voltage; the bigger one takes the bigger share. This is a **voltage divider**. If one of the two is a sensor whose resistance changes, the voltage at the middle point changes too. Connect that point to a transistor's base, and the sensor controls the transistor.

Experiment 6: An automatic night lamp with an LDR

An **LDR** (light-dependent resistor) has high resistance in the dark and low resistance in bright light.

You need: a BC547, an LDR, a 10 k Ω resistor, a 100 k Ω preset (a small adjustable resistor), an LED, a 470 Ω resistor.

Build it:

1. Place the BC547 with each leg in its own row. Connect the emitter to the - rail.
2. Connect the LDR from the base row to the - rail.
3. Connect the 10 k Ω resistor from the + rail to one end leg of the preset, and the preset's middle leg to the base row.
4. Connect + rail $\rightarrow$ 470 Ω $\rightarrow$ LED $\rightarrow$ collector.
5. Snap on the battery. Cover the LDR with your hand: the LED lights. Uncover it: the LED goes off.
6. Turn the preset to choose how dark it must get before the lamp comes on.

How it works: in light, the LDR's resistance is low, so the base stays below 0.7 V and the transistor is off. In the dark, the LDR's resistance rises, the base voltage rises, and the transistor turns on.

TIP

The 10 k Ω resistor stays in the circuit even when the preset is turned to zero, so the base current can never become too large.

Experiment 7: A touch switch

Your skin conducts electricity a little. With two transistors joined together, the tiny current through a fingertip can light an LED.

You need: two BC547s, a 10 k Ω resistor, an LED, a 470 Ω resistor, two short wires with bare ends as touch contacts.

The circuit: the first transistor's emitter connects to the second transistor's base. Both collectors are joined, and the LED with its 470 Ω resistor runs from the + rail to them. The second emitter goes to the - rail. One touch wire connects to the first transistor's base; the other connects through the 10 k Ω resistor to the + rail. Leave the bare ends about 3 mm apart.

Touch both bare ends with one fingertip and the LED glows. Lift your finger and it goes out.

How it works: a few millionths of an ampere flow through your skin into the first transistor. It multiplies that current, and the second multiplies it again. Two transistors joined this way are a **Darlington pair**.

SAFETY

This is safe only because the battery is 9 V. Never touch any wire connected to mains, an inverter or a charger.

Water, rain and heat

Tap water conducts electricity a little, because of the salts dissolved in it. A thermistor changes its resistance with temperature. Both make good sensors for the transistor switch.

Experiment 8: A water level indicator

You need: a BC547, a 1 k Ω resistor, an LED, a 470 Ω resistor, two long wires with bare ends (the probes), a plastic cup and water.

The circuit: probe A connects to the + rail. Probe B connects through the 1 k Ω resistor to the base. The emitter goes to the - rail. The LED and 470 Ω resistor run from the + rail to the collector.

Build it:

1. Tape both probes inside the empty cup, bare ends at the same height, about 1 cm apart. Keep the breadboard and battery on a dry table.
2. Snap on the battery and slowly pour in water. When the water reaches the probe ends, the LED lights.

How it works: the water joins the probes, a small current flows into the base, and the transistor switches the LED on. The 1 k Ω resistor protects the base if the probes ever touch.

EXAMPLE

Kavya in Jaipur built three copies of this circuit, with probes at one-quarter, half and full height and a shared + probe at the bottom. Three LEDs show how full her test bucket is.

DID YOU KNOW

After some days, the probe ends turn dull or green, because the tiny current slowly eats the metal. This is normal.

Experiment 9: A rain alarm

You need: two BC547s, a 1 k Ω resistor, an active buzzer, and a rain pad. Buy a ready rain sensor pad, or make one: wind two bare wires side by side, about 2 mm apart, around a strip of plastic, so they never touch.

The circuit: use the Darlington pair from Experiment 7, because rainwater conducts less than tap water. One pad wire goes to the + rail. The other goes through the 1 k Ω resistor to the first transistor's base. The buzzer replaces the LED and its resistor: + leg to the + rail, other leg to the joined collectors.

Sprinkle a few drops on the pad and the buzzer sounds. Dry it and it stops.

SAFETY

Only the pad goes outdoors, on a long pair of wires. Keep the battery and breadboard indoors and dry.

Experiment 10: A temperature-sensitive circuit

A **thermistor** is a resistor that changes with heat. The common **NTC** type has less resistance when it is warmer. A "10 k Ω NTC" has 10 k Ω at 25 °C.

You need: a BC547, a 10 k Ω NTC thermistor, a 1 k Ω preset, an LED, a 470 Ω resistor.

The circuit: the thermistor runs from the + rail to the base. The preset runs from the base to the - rail. The emitter goes to the - rail. The LED and 470 Ω resistor run from the + rail to the collector.

Build it:

1. Connect everything and snap on the battery.
2. Set the preset so the LED is just dark: if it glows, turn until it goes out; if it is dark, turn until it starts to glow, then back a little.
3. Hold the thermistor between your fingers. As it warms, the LED begins to glow, and grows brighter. Let go, and as it cools, the LED fades.

How it works: warming lowers the thermistor's resistance, so more voltage reaches the base and the transistor turns on. The LED fades in gradually, because this simple circuit has no sharp switching point.

SAFETY

Warm the thermistor only with your fingers or warm breath. Never use a flame or a soldering iron.

TRY THIS

Measure the thermistor's resistance with a multimeter at room temperature, then again while you hold it for a minute. Write down both values. Which is lower, and why?

CHAPTER 7

The 555 timer

The **555** is a small chip with eight legs that can make an LED blink, a buzzer sing or a delay happen. The common version, the NE555, works from about 4.5 V to 16 V, so a 9 V battery suits it.

Find the notch or dot at one end of the chip. With the notch on your left, leg 1 is bottom left, and the legs are counted anticlockwise, so leg 8 is top left. Always place the chip across the centre gap.

Leg	Name	In our circuits
1	Ground	- rail
2	Trigger	joined to leg 6
3	Output	drives the LED or buzzer
4	Reset	+ rail (keeps the chip running)
5	Control	a 10 nF capacitor to the - rail
6	Threshold	joined to leg 2
7	Discharge	between the two timing resistors
8	Supply	+ rail

How the blinker works

In the **astable** circuit (one that never stays still), a capacitor charges through two resistors, R1 and R2, then discharges through R2 alone, again and again. The output is high while it charges and low while it discharges.

- Time on = $0.693 \times (R1 + R2) \times C$
- Time off = $0.693 \times R2 \times C$
- Frequency (times per second) = $1.44 \div ((R1 + 2 \times R2) \times C)$

Use ohms and farads. 10 μF (microfarads) is 0.00001 F, and 100 nF (nanofarads) is 0.0000001 F.

EXAMPLE

With $R1 = 10 \text{ k}\Omega$, $R2 = 47 \text{ k}\Omega$ and $C = 10 \text{ }\mu\text{F}$: time on = $0.693 \times 57,000 \times 0.00001 =$ about 0.40 s. Time off = $0.693 \times 47,000 \times 0.00001 =$ about 0.33 s. The LED blinks a little more than once a second.

Experiment 11: A blinking LED

You need: an NE555, 10 $\text{k}\Omega$ and 47 $\text{k}\Omega$ resistors, a 10 μF electrolytic capacitor, a 10 nF capacitor, an LED, a 470 Ω resistor.

Build it:

1. Connect leg 8 and leg 4 to the + rail, and leg 1 to the - rail.
2. Connect R1 (10 $\text{k}\Omega$) from the + rail to leg 7, and R2 (47 $\text{k}\Omega$) from leg 7 to leg 6.
3. Join leg 6 to leg 2 with a short wire.
4. Connect the 10 μF capacitor from leg 2 to the - rail, negative stripe towards the - rail.
5. Connect the 10 nF capacitor from leg 5 to the - rail.
6. Connect leg 3 $\rightarrow$ 470 $\Omega \rightarrow$ LED $\rightarrow$ - rail.
7. Snap on the battery. The LED blinks.

What you learn: a capacitor and resistors can measure time. Bigger values make slower blinks.

TRY THIS

Add a second LED and $470\ \Omega$ resistor from the + rail to leg 3, with the LED's short leg towards leg 3. It lights when the output is low, so the two LEDs take turns, like a railway crossing light.

Experiment 12: A tone generator

Make the capacitor much smaller and the blinking becomes so fast that you hear it as a sound.

You need: the same circuit with $R1 = 1\ \text{k}\Omega$; for $R2$, a $1\ \text{k}\Omega$ resistor in series with a $100\ \text{k}\Omega$ potentiometer; $C = 100\ \text{nF}$; and a passive buzzer or piezo disc.

Build it:

1. Change $R1$ to $1\ \text{k}\Omega$. Between leg 7 and leg 6, put the $1\ \text{k}\Omega$ resistor in series with the potentiometer (its middle leg and one end leg).
2. Change the $10\ \mu\text{F}$ capacitor to $100\ \text{nF}$. Small capacitors like this have no + or - leg.
3. Connect the passive buzzer from leg 3 to the - rail.
4. Snap on the battery and turn the knob. The pitch slides up and down.

With the knob at zero, $R2 = 1\ \text{k}\Omega$: frequency = $1.44 \div (3,000 \times 0.0000001) =$ about 4,800 per second, a high whistle. With the knob at the far end, $R2 = 101\ \text{k}\Omega$ and the sound drops to about 71 per second, a low hum.

TIP

For a louder sound, use a small $8\ \Omega$ speaker, joined through a $10\ \mu\text{F}$ capacitor (+ towards leg 3) and a $100\ \Omega$ resistor. The resistor keeps the current safe for the chip.

CHAPTER 8

Logic gates

Every computer and phone is built from tiny switches called **logic gates**. A gate looks at its inputs and decides its output. We write 1 for "on" (a button pressed, an LED lit) and 0 for "off". A table that lists every input and its output is a **truth table**.

Experiment 13: OR, AND and NOT gates

You need: two push buttons, two 1N4148 diodes, two BC547s, two 10 k Ω and two 100 k Ω resistors, a 1 k Ω resistor, an LED, a 470 Ω resistor.

The OR gate, with diodes. Each button connects the + rail to the anode of its own diode. The two cathodes (banded ends) are joined in one strip. From that strip, the 470 Ω resistor and LED go to the - rail. Press either button, or both, and the LED lights. The diodes stop current from one button flowing back into the other.

The AND gate, with transistors. Stack the two transistors. The LED and 470 Ω resistor run from the + rail to the collector of transistor 1. Its emitter goes to the collector of transistor 2, whose emitter goes to the - rail. Each base connects through a 10 k Ω resistor to its own button, and each button to the + rail. A 100 k Ω resistor from each base to the - rail keeps that transistor firmly off when its button is up. Current can flow only when both transistors are on, so the LED lights only when you press both buttons.

A	B	OR	AND
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1

The NOT gate, with one transistor. The 1 k Ω resistor runs from the + rail to the collector. The LED runs from the collector to the - rail, long leg towards the collector. The emitter goes to the - rail. The base connects through 10 k Ω to a button, and the button to the + rail, with 100 k Ω from base to the - rail.

With the button up, current flows through the 1 k Ω resistor and the LED, so it lights. Press the button: the transistor turns on and pulls the collector almost to 0 V, so the LED goes out. Input 0 gives 1, and input 1 gives 0.

DID YOU KNOW

A modern phone's main chip holds billions of transistors, each far smaller than a speck of dust. Your breadboard gates do the same job, slowly and in a large size.

REMEMBER

OR needs any one input, AND needs all of them, and NOT turns the input upside down.

CHAPTER 9

Two projects: a burglar alarm and a traffic light

Experiment 14: A burglar alarm with a wire loop

A thin wire is stretched across a door or a cupboard opening. If anyone opens it, the wire breaks or pulls out, and the alarm sounds.

You need: a BC547, a 22 k Ω resistor, an active buzzer, a slide switch, and a long piece of very thin wire (a single strand from an old wire works well).

The circuit: the 22 k Ω resistor runs from the + rail to the base. The thin wire loop runs from the base to the - rail. The emitter goes to the - rail. The buzzer runs from the + rail to the collector. Put the slide switch in the battery's red wire.

Switch on. While the loop is whole, it holds the base at 0 V, so the buzzer is silent. Break or unplug the loop: the 22 k Ω resistor pulls the base up, the transistor turns on, and the buzzer sounds.

What you learn: this circuit stays "armed" by keeping a transistor off. While armed, about 0.4 mA flows through the resistor and the loop all the time, so switch it off when you are not testing it.

EXAMPLE

Rohan in Pune ran the loop across his science-fair cupboard door. When his sister opened it, the strand slipped out and the buzzer sounded.

DID YOU KNOW

This buzzer stops if the wire is joined again. Real alarms keep ringing once triggered. One way uses a part called an **SCR** (thyristor), which stays on after it is triggered until its power is cut.

Experiment 15: A traffic light model

In this model the order is red, then green, then yellow as a warning, then red again. The 555 makes a steady tick, about once a second, and a counting chip lights the colours in turn.

You need: the 555 blinker with R2 changed to 68 k Ω (blue, grey, orange), a **CD4017** decade counter chip, ten 1N4148 diodes, red, yellow and green LEDs, and three 1 k Ω resistors.

Meet the CD4017. It has ten outputs, Q0 to Q9. Each tick at its clock leg moves the "on" output along by one: Q0, then Q1, up to Q9, and back to Q0.

CD4017 leg	Name	Connect to
16	Supply	+ rail
8	Ground	- rail
14	Clock	555 leg 3
13	Clock inhibit	- rail
15	Reset	- rail
3, 2, 4, 7	Q0 to Q3	red group
10, 1, 5, 6	Q4 to Q7	green group
9, 11	Q8, Q9	yellow group

Build it:

1. Build the 555 blinker with R2 = 68 k Ω . Each tick now lasts about one second.
2. Place the CD4017 across the gap and connect its supply, ground, clock, inhibit and reset legs.
3. For the red group, connect a diode from each of legs 3, 2, 4 and 7, with every banded end in one shared strip. From that strip, connect a 1 k Ω resistor and the red LED to the - rail.
4. Do the same for green (legs 10, 1, 5 and 6) and yellow (legs 9 and 11).
5. Snap on the battery. Red glows for four ticks, green for four, yellow for two, and the cycle repeats.

What you learn: the diodes form an OR gate for each colour. The LEDs glow fairly dimly, because the CD4017's outputs give only a small current. For bright lights, let each colour switch a BC547 that drives its LED.

TIP

Build and test the 555 first: an LED on leg 3 should blink about once a second. Then add the counter.

CHAPTER 10

When a circuit does not work

Every builder meets circuits that do not work. The skill is finding the fault calmly, step by step. Unsnap the battery before you move any part.

A checking order

- 1. Power.** Is the clip on firmly? Measure the battery on the multimeter's DC volts setting. A 9 V battery reading much lower than 9 V is getting weak.
- 2. Rails.** Are the battery wires in the correct rails? Is the rail broken in the middle?
- 3. Direction.** Are the LEDs, diodes, buzzer and electrolytic capacitor the right way round?
- 4. Strips.** Is every leg in its strip? Is any part sitting in one strip with both legs?
- 5. Chips, transistors, values.** Is the chip's notch where it should be? Are C, B and E right? Read every resistor's bands again: 47 kΩ and 470 Ω look alike at a glance.

Common faults

What you see	Likely cause	What to do
Nothing works	flat battery or loose clip	measure the battery; press the clip on firmly
One LED dark	LED reversed or burnt out	turn it round; test it in Experiment 1
555 LED always on or off	legs 2 and 6 not joined, or capacitor missing	follow the timing wires again

What you see	Likely cause	What to do
Transistor never switches	legs in the wrong order	check C, B, E against the pack
Battery gets warm	a short circuit between + and -	unsnap at once; look for touching wires

Measuring voltages

With the battery connected, put the multimeter's black probe on the - rail and touch the red probe to points in the circuit. At a transistor's base, below about 0.6 V means off and around 0.7 V means on. If the base never changes when you cover the LDR, the fault is in the divider.

EXAMPLE

Simran's night lamp in Chandigarh stayed on in daylight, and its base read 0.75 V. The LDR's leg had slipped out, so nothing pulled the base down. She pushed it back and the lamp worked.

TIP

Keep a project notebook. Draw each circuit, note the values and write what happened. Such notes are worth gold next month.

REMEMBER

You now know the building blocks: resistors, LEDs, switches, transistors, sensors, the 555 timer, gates and a counter. A microcontroller such as an Arduino does many of these jobs with code, but the safety habits stay the same.

CHECK YOURSELF

Practice questions

1. Which holes in one row of a breadboard are joined together?
2. Why do chips sit across the centre gap?

3. Work out the resistor for one red LED on a 9 V battery at about 15 mA.
4. In a series string of LEDs, what happens when one LED is removed, and why?
5. Why should each LED in parallel have its own resistor?
6. Which legs of a four-leg push button should you use if you do not know how they are paired?
7. What is the difference between an active and a passive buzzer?
8. Name the three legs of a BC547 and say what each does.
9. Why must a transistor's base never be connected straight to the + rail?
10. In the night lamp, why does the LED light up in the dark?
11. What is a Darlington pair, and why is it used in the touch switch and the rain alarm?
12. What does "NTC" mean for a thermistor?
13. A 555 blinker has $R1 = 10\text{ k}\Omega$, $R2 = 47\text{ k}\Omega$ and $C = 10\text{ }\mu\text{F}$. About how long is the LED on in each blink?
14. In the tone generator, what happens to the pitch when the potentiometer's resistance increases?
15. Write the truth table of an AND gate.
16. Why does the burglar alarm stay silent while the wire loop is whole?
17. In the traffic light model, why are diodes used between the CD4017 and each LED?
18. Your circuit's battery gets warm. What should you do first, and what is the likely fault?

Answers

1. Holes a to e form one joined strip, and holes f to j form another, not joined to the first.
2. So that each leg lands in its own strip and no two legs are joined by mistake.
3. The resistor takes $9 - 2 = 7$ V. Resistance = $7 \div 0.015 = \text{about } 467 \, \Omega$, so use $470 \, \Omega$.
4. All of them go out, because a series circuit has only one path.
5. LEDs differ slightly. With one shared resistor, the LED that conducts most easily takes most of the current and may burn out.
6. Two diagonally opposite legs, which are always in different pairs.
7. An active buzzer beeps on plain battery voltage. A passive buzzer needs a changing signal, such as a 555 output.
8. Collector (the large current comes in), base (the small control current goes in) and emitter (both currents leave to the - rail).
9. The base current would be far too large and would damage the transistor. A resistor limits it.
10. In the dark the LDR's resistance rises, so the base voltage rises to about 0.7 V and the transistor turns on.
11. Two transistors with the first one's emitter feeding the second one's base. Their gains multiply, so a tiny current through skin or rainwater can switch the load.
12. Negative temperature coefficient: its resistance falls as it gets warmer.
13. Time on = $0.693 \times (10,000 + 47,000) \times 0.00001 = \text{about } 0.40$ seconds.
14. The capacitor charges and discharges more slowly, so the frequency falls and the pitch becomes lower.
15. 0 and 0 give 0; 0 and 1 give 0; 1 and 0 give 0; only 1 and 1 give 1.
16. The loop connects the base to the - rail, holding it at 0 V, so the transistor stays off.
17. They form an OR gate, so several outputs can light one LED without feeding current into each other.
18. Unsnap the battery at once. The likely fault is a short circuit: + and - joined by a wire or by touching legs.

Glossary

Anode

the positive leg of a diode or LED.

Astable

a circuit that keeps switching on and off by itself, such as the 555 blinker.

Breadboard

a plastic board with joined metal clips under its holes, for building circuits without solder.

Capacitor

a part that stores a small electric charge; with a resistor it can measure time.

Cathode

the negative leg of a diode or LED, marked by a band or a flat rim.

Darlington pair

two transistors joined so their gains multiply, for very sensitive switching.

Diode

a part that lets current flow in one direction only.

LDR

light-dependent resistor; its resistance falls in bright light.

LED

light-emitting diode; a diode that gives out light.

Logic gate

a circuit whose output follows a fixed rule, such as AND, OR or NOT.

Ohm's law

voltage equals current multiplied by resistance.

Parallel

parts side by side, each with its own path between + and -.

Power rails

the long joined lines of holes along a breadboard's edges.

Resistor

a part that limits current; its value is shown by coloured bands.

Series

parts connected one after another in a single path.

Short circuit

an unwanted direct path between + and -.

Thermistor

a resistor whose resistance changes with temperature.

Transistor

a part in which a small base current controls a much larger current.

Truth table

a table of every input combination and the output each gives.

Voltage divider

two resistances in series that share a voltage between them.



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