OHMSVILLE

SHOP NOTES

The Classroom Reader

Intro to Electronics: twelve lessons in five units, on paper.

OHMSVILLE.COM/MANUALS/CLASSROOM-READER

Contents

The Classroom Reader

Intro to Electronics: twelve lessons in five units, on paper.

The whole course on paper, in order, with the demonstrations as links you can open on the bench. Read it end to end or open it at the unit you are stuck on. The two questions at the foot of each lesson have no printed answers, on purpose: the shop teacher marks them live, against the board in front of you.

Charge and the loop

What electricity is · The loop

2 lessons, about 12 minutes.

What electricity is

CHARGE AND THE LOOP · ABOUT 6 MINUTES

Everything on this bench is made of atoms, and every atom carries charge: a positive core and negative electrons around it. In a copper wire the outermost electrons are barely held. They wander from atom to atom all the time, in every direction, going nowhere in particular. That is a wire with nothing happening in it.

Current is what you get when those electrons drift one way on purpose. We measure it in amperes, and one amp is a lot of electrons: about six billion billion passing a point every second. The kit works in thousandths of an amp, milliamps, written mA. A red LED wants about 20 mA. The pushbutton passes that easily; your finger does not.

Voltage is the push. A battery uses a chemical reaction to pile up extra electrons on one terminal and leave the other short of them, and the difference between the two is the voltage, measured in volts. Nine volts means each bit of charge that makes the trip from one terminal to the other gives up nine joules per coulomb of energy along the way, in the resistor as heat and in the LED as light.

The water analogy is the one every shop teacher reaches for, and it is good: voltage is pressure, current is the flow in litres per second, and a thin pipe is resistance. A pump is the battery. It gets you through the first half of this course.

Here is where it breaks. Cut a pipe and water pours out. Cut a wire and nothing pours out, because charge cannot leave the metal; the electrons just stop drifting. And a battery does not squirt electrons down an empty hose. The wire is already full of them, end to end, so

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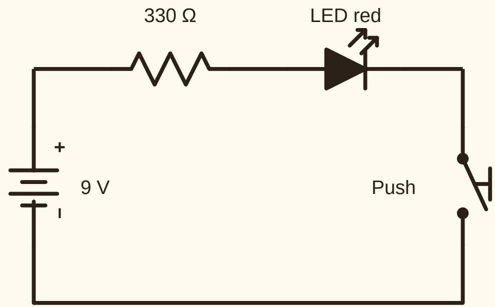

The loop

CHARGE AND THE LOOP · ABOUT 6 MINUTES

Current only flows around a complete loop. From the battery +, through every part in turn, and back to the battery −. Break the loop anywhere and the whole thing stops, not just the part after the break. The battery in experiment 1 is connected to the LED the whole time, and the LED stays dark until the button closes the gap.

That is what a switch is: a gap you can open and close. The pushbutton closes while you hold it. The slide switch stays where you put it. Neither one does anything clever; each is a bit of metal that either touches or does not.

A short circuit is a loop with nothing in it to slow the current down. Wire the battery + straight to the battery − and the full nine volts pushes through almost zero ohms. In a real kit the wire gets hot and the battery goes flat in minutes. Every resistor and lamp in a loop is there partly to keep that from happening.

Put two switches in the same loop, one after the other, and both have to be closed before anything flows. That is series. Give each switch its own path around the other and either one will do. That is parallel. Computers are built from millions of exactly this: series is AND, parallel is OR.

Get in the habit of tracing the loop with a finger before you wire it. Start at +, name each spring you pass through, and make sure you arrive at −. If you cannot trace it, the electrons cannot either.

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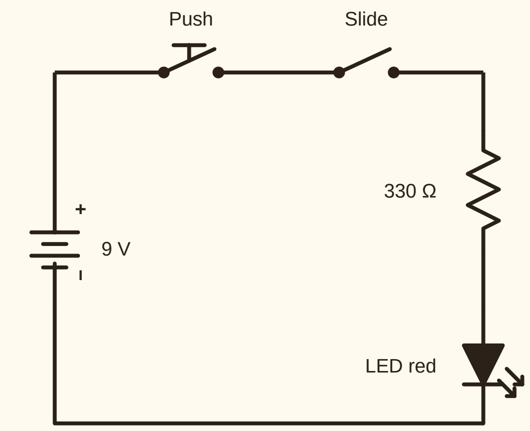

Ohm's law

Resistance and Ohm's law · Series and parallel

2 lessons, about 18 minutes.

Resistance and Ohm's law

OHM'S LAW · ABOUT 10 MINUTES

Resistance is how hard a part makes the current work to get through. We measure it in ohms, written Ω. Copper wire is a fraction of an ohm. A resistor is a part built to have a known resistance and nothing else: a little carbon or metal film sized so that 330 Ω is 330 Ω, give or take five percent.

Ohm's law ties the three together: volts equal amps times ohms, V = I × R. Turn it around and current is volts divided by ohms, I = V / R. Nine volts across 1 kΩ pushes 9 / 1000 = 0.009 A, which is 9 mA. Across 330 Ω it is about 27 mA. Across 10 kΩ under 1 mA. Same battery, three resistors, three brightnesses. That is the whole of the Ohm's law recipe.

When an LED sits in the loop it takes about 1.9 V for itself before the resistor sees the rest, so experiment 1 runs at (9 − 1.9) / 330, about 21 mA. You will do that subtraction a lot. It is the only wrinkle in an otherwise one-line law.

The stripes tell you the value. The first two bands are digits, the third is how many zeros to add, and the fourth is the tolerance. Black 0, brown 1, red 2, orange 3, yellow 4, green 5, blue 6, violet 7, grey 8, white 9. Orange orange brown is 3, 3, one zero: 330 Ω. Brown black red is 1, 0, two zeros: 1 kΩ. Brown black orange is 10 kΩ, brown black yellow is 100 kΩ. A gold fourth band means five percent, which is why the kit's second 330 Ω actually measures 336.

A resistor turns the energy it takes out of the current into heat, and the power is volts

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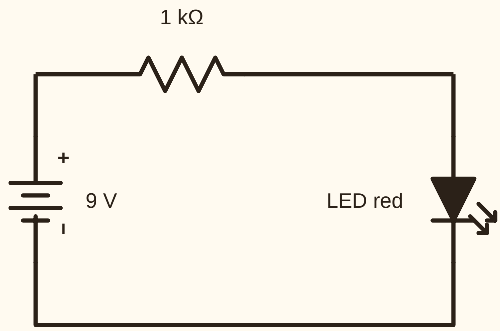

Series and parallel

OHM'S LAW · ABOUT 8 MINUTES

Two parts in series sit one after the other in the same loop, so the same current passes through both. There is nowhere else for it to go. The battery's volts get shared out between them, and the resistances simply add: 330 Ω after 1 kΩ is 1330 Ω.

That is why two LEDs in series through one 1 kΩ glow dimmer than one did. Each LED takes about 1.9 V, so the resistor is left with 9 − 3.8 = 5.2 V and passes about 5 mA instead of 7. Batteries in series work the same way in reverse: the second battery's + sits on top of the first's − and the loop sees 18 V. Twice the volts through the same ohms is twice the current, which is why experiment 11 uses the 1 kΩ and not the 330 Ω.

Two parts in parallel sit side by side between the same two points, so each sees the full voltage and each draws its own current. The currents add up at the battery. Two LEDs each on their own 330 Ω both run at full brightness, and the battery supplies about 42 mA instead of 21.

Resistors in parallel let more current through together than either would alone, so the combined resistance is lower than the smallest one: two 330 Ω side by side act like 165 Ω. Capacitors are the odd ones out. Side by side they add their farads, because you have simply made a bigger bucket. Experiment 14 uses that to drop a tone by a third.

Do not share one resistor between two parallel LEDs. It looks thrifty, but the two LEDs then split one current between them, and since no two LEDs are quite alike the one with the slightly lower forward voltage hogs most of it. One resistor per LED, every time.

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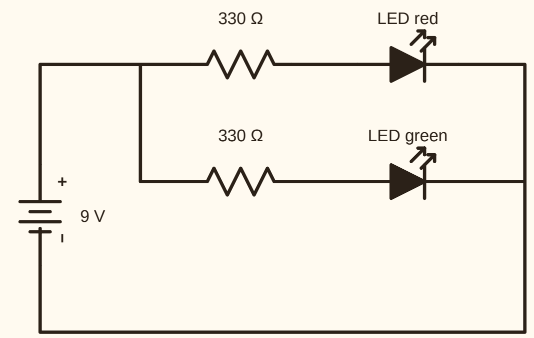

Parts that do something

Capacitors and time · Diodes and LEDs · Transistors as switches and amplifiers

3 lessons, about 25 minutes.

Capacitors and time

PARTS THAT DO SOMETHING · ABOUT 8 MINUTES

A capacitor is two metal plates very close together with an insulator between. Push charge onto one plate and it pulls the opposite charge onto the other, but nothing crosses the gap. It is a bucket for charge. Capacitance, in farads, is the size of the bucket: how much charge it holds per volt. A farad is enormous, so the kit's parts are in microfarads, µF. The 100 µF is a million times smaller than a farad and still the biggest bucket on the board.

Filling a bucket takes time, and the resistor in front of it is the width of the hose. Multiply the ohms by the farads and you get seconds: that is the time constant, R × C. In one time constant the capacitor charges to about 63 percent of the way, and it is essentially full after four or five. 10 kΩ × 100 µF is one second. 1 kΩ × 470 µF is about half a second. 10 kΩ × 0.1 µF is one thousandth of a second.

That one line explains half the kit. Experiment 9 fades an LED up over a couple of seconds because it charges 100 µF through 10 kΩ. Experiment 12 keeps an LED glowing for half a second after you let go, because the 470 µF empties out through 1 kΩ and the LED. Swap in 470 Ω and it empties twice as fast. Swap a 100 µF for a 0.1 µF and something that blinked now sings.

Once a capacitor is full, no more current flows into it. So a capacitor passes changes and blocks anything steady. That is why it can pass a click or a tone from one transistor to the next while keeping their steady voltages apart, and it is the trick behind every oscillator in Unit 4.

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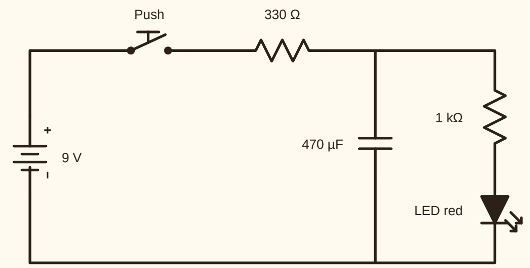

Diodes and LEDs

PARTS THAT DO SOMETHING · ABOUT 7 MINUTES

A diode is a one-way valve for current. Push the right way, from anode to cathode, and it conducts. Push the wrong way and it is a wall. Nothing moves, so nothing lights. Inside is a junction between two flavours of silicon, and the junction only lets charge across in one direction.

A diode is not a resistor. It does not take a share of the volts in proportion to the current. It takes a fixed bite, its forward voltage, and then lets almost anything through. For an ordinary silicon diode that bite is about 0.6 or 0.7 V. For the kit's red LED it is about 1.9 V, and for the green about 2 V. Above that the current climbs very steeply.

That steepness is why an LED must never go straight across a battery. Nine volts onto a part that only knows how to hold 1.9 leaves seven volts with nowhere to go, the current runs away, and the LED burns in a blink. The resistor in series soaks up the difference and sets the current: (9 − 1.9) / 330 Ω is about 21 mA, a comfortable glow. Brightness follows current, not volts, so the resistor is the dimmer.

The LED's light comes from the junction itself: electrons crossing it drop to a lower energy and the difference leaves as a photon. The colour is set by the semiconductor, not by the plastic, and a higher energy colour needs a bigger forward voltage. That is why the green takes a little more than the red.

On a real LED the longer leg is the anode, and the flat edge on the rim marks the cathode. On the board the springs are labelled A and K. Wire it backwards and the LED simply

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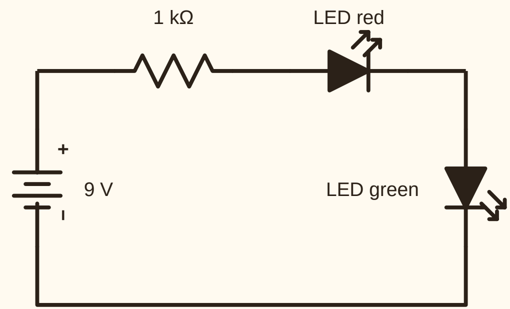

Transistors as switches and amplifiers

PARTS THAT DO SOMETHING · ABOUT 10 MINUTES

The transistor is the part that made everything else possible. The kit's Q1 and Q2 are NPN transistors with three legs: base, collector, and emitter. A small current into the base lets a much larger current flow from collector to emitter. Take the base current away and the collector current stops. A little current controls a big one.

How much bigger is a number called beta, or hFE, and for the kit's transistors it is around 100. In the Tiny current recipe the 100 kΩ lets about 83 µA into the base, and the LED lights with about 8 mA: a hundred times more. Hover both and check the ratio yourself.

The base to emitter path behaves like a diode, and it needs about 0.6 or 0.7 V before it opens. Below that the transistor is off. That is why there is always a resistor in front of the base: without it the base would be an LED across a battery all over again.

Used as a switch, you give the base either nothing or plenty. Nothing, and the transistor is an open gap. Plenty, and it is closed as far as it can go, saturated, with the collector current set by the load and not by the base at all. The night light in Unit 4 works this way: the photocell decides whether the base gets enough, and the LED is either on or off.

Used as an amplifier, you keep the base in between, where the collector current follows the base current up and down. Experiment 8 does this: the pot sets a voltage, a tiny current trickles through 100 kΩ into the base, and the LED dims smoothly as the collector current follows. The knob never carries the LED's current. It only steers it. Every volume

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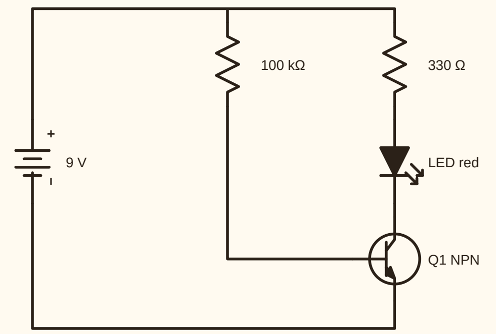

Circuits that move

Oscillators · Sensors

2 lessons, about 15 minutes.

Oscillators

CIRCUITS THAT MOVE · ABOUT 8 MINUTES

Everything so far sits still once you wire it. An oscillator does not. It flips back and forth on its own, and the kit's flasher, tone, siren, metronome, and theremin are all the same oscillator with different parts in it.

It is called an astable multivibrator, and it is two transistors that take turns. When Q1 switches on, its collector drops, and a capacitor carries that drop to Q2's base and turns Q2 off. Q2's capacitor then slowly charges back up through a 10 kΩ until Q2's base reaches 0.7 V and Q2 switches on. That drops its collector, the other capacitor kicks Q1 off, and the whole thing flips the other way. Neither side can stay put, so it never stops.

Each half of the cycle lasts about 0.7 × R × C, so the whole period is about 1.4 × R × C. With 10 kΩ and 100 µF that is about 1.4 seconds per cycle, a blink of 0.7 Hz: the flasher. With 10 kΩ and 0.1 µF the capacitors are a thousand times smaller, so it flips a thousand times faster: about 700 Hz, too fast to see, so we put a speaker on it and listen. The flasher and the tone are the same circuit.

A speaker only makes sound when the current through it changes. A steady 27 mA is silent; the jump from zero to 27 mA is a click. Seven hundred jumps a second is a tone, and this circuit gives a square wave: fully on, fully off. That is why it sounds a little buzzy.

Change the R or the C in either half and the pitch follows. The siren knob puts a 100 kΩ pot in series with one 10 kΩ: more ohms, slower charge, lower note. Experiment 14 adds

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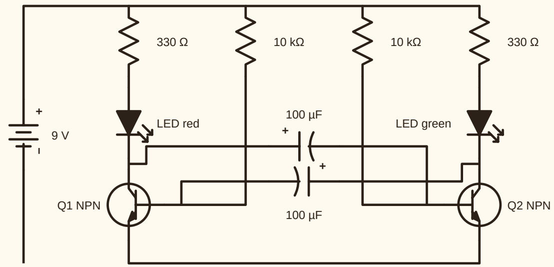

Sensors

CIRCUITS THAT MOVE · ABOUT 7 MINUTES

A sensor is something physical turned into ohms, or volts, so a circuit can act on it. The kit has two. The pot turns a position into ohms: from one end to the wiper you get anywhere from 0 to 10 kΩ depending where the knob sits. The CdS photocell turns light into ohms: about 1 kΩ in bright light and hundreds of kΩ in the dark.

The simplest use is to put the sensor straight in the loop as a variable resistor. The Light meter recipe is the photocell in series with an LED: more light, fewer ohms, more current, brighter glow. It is a dimmer that light turns. Experiment 2 is the same idea with the pot.

The second use is to put the sensor where a timing resistor was. In experiment 5 the photocell replaces one of the tone circuit's 10 kΩ, so the light level sets how fast one half of the cycle charges, and the pitch follows your hand.

The most useful trick is the voltage divider. Two resistances in a row split the battery voltage in proportion: a big one on top and a small one below puts most of the volts across the big one, and the point between them sits low. Swap their sizes and it sits high. The Voltage divider recipe shows the pot doing exactly this, sliding its wiper from 9 V to 0.

The night light is a divider with a transistor listening at the middle. The 100 kΩ pulls Q1's base up; the photocell pulls it down. In light the photocell is about 1 kΩ, it wins easily, the base sits near 0 V and Q1 stays off. In the dark the photocell lets go, the base rises

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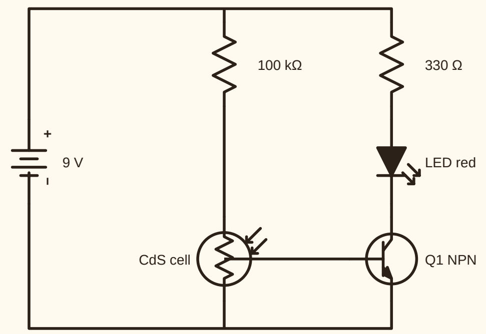


The shop

Reading schematics · Measuring · Safety and real parts

3 lessons, about 20 minutes.

Reading schematics

THE SHOP · ABOUT 7 MINUTES

A schematic is a map of the loops, not a picture of the board. It shows which terminal joins which, and nothing about where the parts sit or how long the wires are. The same schematic can be wired a dozen ways on the springs and every one of them is the same circuit. That is why the teacher grades the outcome and not your wiring.

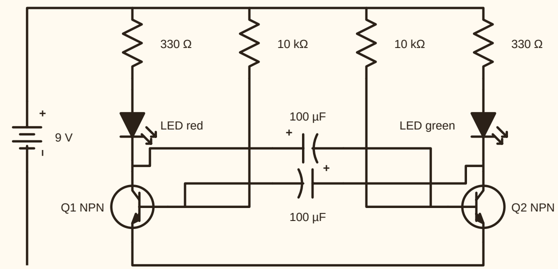
Learn the symbols and you can read any manual from 1978 or today. Battery: a stack of long and short lines, long is +. Resistor: a zigzag. Capacitor: two parallel plates; if one plate is curved the part is electrolytic and the curved plate is −. LED: a triangle pointing the way current flows, a bar across the point for the cathode, two little arrows for the light. Switch: a gap with a hinged bar. Speaker: a box with a cone. Photocell: a resistor in a circle with light arrows landing on it. Pot: a resistor with an arrow for the wiper.

The transistor is a circle with three legs. The flat bar inside is the base. The leg with the arrow is the emitter, and the arrow points out for NPN, the way current leaves. The remaining leg is the collector.

Wires that meet are joined; in these drawings a corner or a junction is a connection. Two lines that merely cross without joining are not. Labels beside each symbol match the labels printed on the board, so 330 Ω on paper is the spring pair marked 330 Ω in front of you.

Read a schematic the way you trace a loop: find the battery, put your finger on +, and follow the wire through each part to −. Then look for the side loops. In the flasher you

SCHEMATIC



Measuring

THE SHOP · ABOUT 7 MINUTES

On this bench you hover a part and read its volts and milliamps off the card. A real meter makes you choose, and the choice teaches you something.

Voltage is a difference between two points, so a voltmeter goes across a part: one probe on each end, in parallel with it, while the circuit runs. A voltmeter has a very high resistance, millions of ohms, so it takes almost no current and does not disturb the loop. Clip it across the LED in experiment 1 and hold the button: about 1.9 V.

Current is a flow through a point, so an ammeter goes in the loop: you break the wire and let the current pass through the meter on its way. An ammeter has almost no resistance, so it does not slow the current it is counting. That is exactly why you must never clip it across a part like a voltmeter: a near-zero-ohm meter across a battery is a short circuit, and the meter's fuse, if it has one, is the only thing that goes.

An ohmmeter puts a little current of its own through a part and works out the resistance. Use it on a part that is out of the circuit and powered down. Measure a resistor while the battery is still driving current through it and you get nonsense, or a dead meter.

Two rules let you check any reading. Go once around a loop and the volts across the parts add up to the battery's volts: in the Ohm's law recipe about 7.1 V across the 1 kΩ plus 1.9 V across the LED is 9 V. And current going into a junction equals current coming out: in experiment 7 the battery's 42 mA is two 21 mA branches rejoining. If your readings do not obey those two, one of the readings is wrong.

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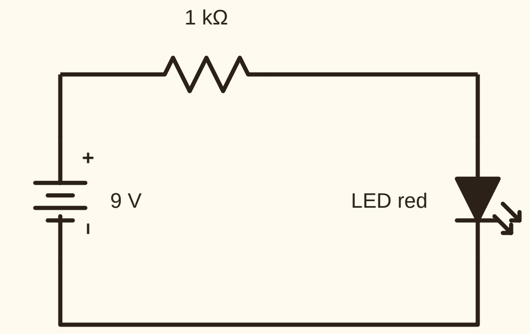

Safety and real parts

THE SHOP · ABOUT 6 MINUTES

You can hold a 9 V battery's terminals in your fingers all day. Dry skin is around 100 kΩ or more, so 9 V pushes well under a tenth of a milliamp through you, far below anything you can feel. Touch it to your tongue and you will feel it, because a wet tongue is a few kΩ, but that is a tingle, not a danger.

Mains is different in kind, not just degree. A wall outlet is 120 or 240 V, and a few tens of milliamps across the chest is enough to stop a heart. Ohm's law says 240 V through even 10 kΩ of damp skin is 24 mA. Never open, probe, or wire anything that plugs into the wall while it is plugged in, and until you have been taught how, do not work on the mains side at all. The low-voltage side of a wall adapter is fine. The adapter's insides are not.

Heat is the everyday hazard. A quarter-watt resistor asked for a watt gets hot enough to burn a fingertip in seconds before it smokes. A shorted 9 V battery gets hot and goes flat; a shorted lithium cell can catch fire. When something in a real circuit is hotter than it should be, take the battery out first and think second.

Polarity matters on three parts: the battery, every LED, and every electrolytic capacitor. The LED backwards is harmless. The electrolytic backwards heats, swells, and can burst, so check the stripe before you connect it. The battery backwards into a circuit with transistors and electrolytics can wreck several parts at once.

Real parts are not the numbers printed on them. Five percent tolerance means the kit's second 330 Ω is really 336, the second 10 kΩ is 9.7, and a 100 µF can be anywhere from

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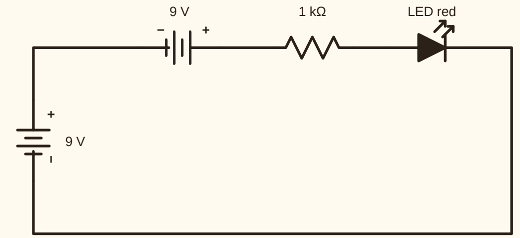

Colophon

Generated from the modules the bench runs on: every circuit in this booklet is the circuit the simulator solves, and every word beside it is the word the manual panel prints.

Built 2026-09-15 from commit 953a47e.