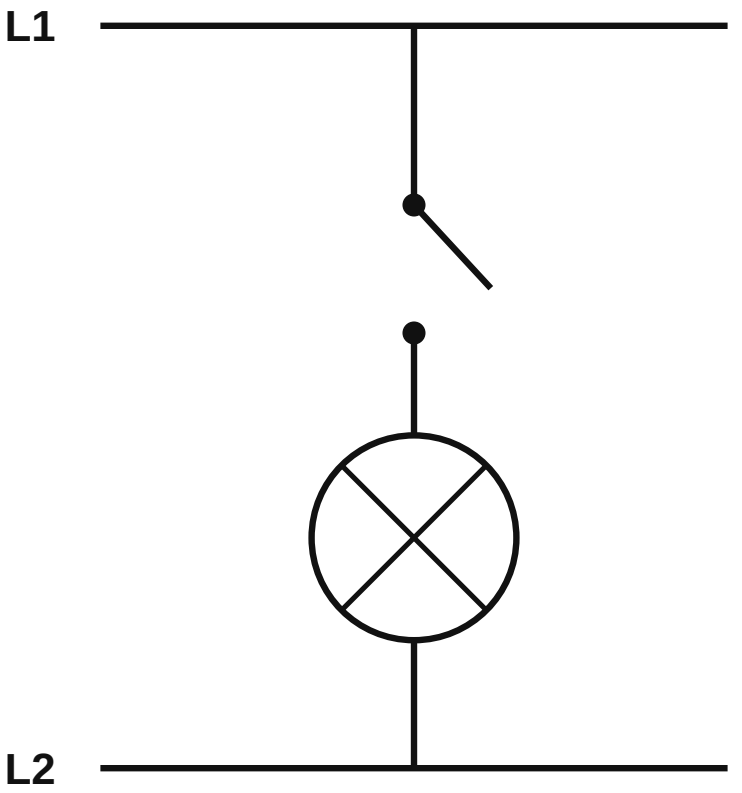
A PICKETTPANEL LITE COMPANION

PickettPanel

From Design to Concept



Learn control circuits by building them —
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First edition, 2026

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IMPORTANT — SAFETY NOTICE

This book teaches control circuit principles and fault-finding methods using PickettPanel Lite, a browser-based simulator. No exercise in this book requires or encourages work on live or energised electrical equipment. Electrical installation, maintenance and fault-finding on real equipment carries a risk of serious injury or death. Such work should only be carried out by competent persons, suitably trained and qualified, working in accordance with the applicable regulations for their jurisdiction — in Ireland and the UK, this includes the relevant national wiring rules and electrical safety legislation. The author and publisher accept no liability for any loss, damage or injury arising from the use or misuse of the information in this book. Circuit conventions in this book follow UK and Irish practice, using a 230V single-phase supply with rails labelled L1 and L2.

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About the Author VIII

A Note for Teachers 1

Getting Started with PickettPanel Lite 2

Chapter 1 — A Switch and a Lamp 3

1.1 The complete path 3

1.2 Building it 4

1.3 Reading the circuit with a meter 6

1.4 Your first faults 8

1.5 Half-splitting 10

Chapter 2 — Two Switches 12

2.1 Everything must be closed 12

2.2 Building it 14

2.3 Any one will do 14

2.4 Reading it with the meter 16

2.5 The fault that does not stop the circuit 17

2.6 Finding it 19

Chapter 3 — Normally Closed..... 22

3.1 A contact that starts closed 22

3.2 Building it 23

3.3 Why the stop button is the one that starts closed 25

3.4 Start and stop in one circuit 27

3.5 Chains 28

3.6 What the meter says 30

3.7 Faults 31

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Chapter 4 — The Relay 35
4.1 Two circuits that never touch 35
4.2 Building it 36
4.3 One coil, several contacts 39
4.4 What the meter says 40
4.5 Faults 41
Chapter 5 — The Seal-In 46
5.1 The idea 46
5.2 Building it 47
5.3 Where the seal must not go 48
Chapter 6 — Interlocks 55
6.1 Each circuit vetoes the other 55
6.2 Building it 56
6.3 Where the interlock must not go 60
6.4 Both buttons at once 60
6.5 What the meter says 62
6.6 Faults 64
Chapter 7 — Indication 69
7.1 A lamp is a sentence 69
7.2 Building it 70
72
7.3 The command or the result 72
7.4 Lamp test 74
7.5 Colour 77

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7.6 What the meter says 78

7.7 Faults 79

Chapter 8 — The Contactor 83

8.1 The same relay, grown up 84

8.2 Two circuits, and now one of them matters 86

8.3 Building the power circuit 86

8.4 Building the control circuit 88

8.5 The overload 90

8.6 What the meter says 92

8.7 Faults 92

Chapter 9 — Forward and Reverse 98

9.1 Two contactors, one motor 99

9.2 Building the power circuit 101

9.3 The control circuit 102

9.4 Electrical, mechanical, and the gap between them 106

9.5 Letting the simulator check it 107

9.6 What the meter says 107

9.7 Faults 110

Chapter 10 — Control Stations 116

10.1 Two places, one machine 116

10.2 Jog 118

10.3 Hand, Off, Auto 120

10.4 What the meter says 122

10.5 Faults 123

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Chapter 11 — Timing 127
11.1 A relay with a delay in it 127
11.2 The terminals, and the one that catches people 128
11.3 On-delay 129
11.4 Off-delay, and the trap 131
11.5 What the meter says 134
11.6 Faults 135
Chapter 12 — Sequencing 138
12.1 The conveyor problem 138
12.2 The permissive 139
12.3 Building the cascade 140
12.4 Starting in order, stopping in reverse 142
12.5 Adding time 143
12.6 What the meter says 145
12.7 Faults 145
Chapter 13 — The Drive 150
13.1 Two halves, again — but drawn differently 150
13.2 The control side is not 230V any more 152
13.3 Where the logic went 154
13.4 Relay outputs 154
13.5 Speed 156
13.6 What the meter says 156
13.7 Faults 157
Chapter 14 — Ladder Logic 161

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14.1 The same drawing, without the wire 162

14.2 A contact is not a contact 163

14.3 Building the seal-in 164

14.4 The trap: NC in the field, NO in the program 165

14.5 What the program must never be trusted with 166

14.6 The rest of the toolbar 167

14.7 Watching it run 168

14.8 Faults 169

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About the Author

I'm an electrical and electronics engineer and a software developer, and for years now everything I've built has pointed at the same thing: helping people actually learn this trade, rather than pass a test on it.

The work reaches different people in different forms — some of it for students, some for teachers, some for working maintenance staff brushing up mid-career — but the goal underneath has never changed. Teach the craft properly, to anyone willing to do the work.

If one thing has stuck with me from years in this field, it is that there is no substitute for getting it wrong. Every fault I have chased, every circuit that refused to behave the way I expected, taught me something no page ever did. Understanding comes from doing something wrong, watching it fail, and working out why — not from being handed the answer before you have earned it.

The trouble is that getting it wrong on a real panel is expensive. It costs time, it costs parts, and on a live machine it can cost a great deal more. So most people are taught the right answer first and never find out what the wrong one looks like.

That is what PickettPanel is for, and this book with it. You can wire a circuit wrong, watch it sit there doing nothing, and take it apart to find out why — as many times as you like, with nothing at stake but an afternoon. Then you meet the same fault on a real machine, and you have seen it before.

Whether you are teaching yourself at the kitchen table, sitting in a classroom, or sharpening something you already do every day: build them, break them, and go looking for the faults that do not announce themselves.

George Pickett Dublin

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A Note for Teachers

This book was written for someone learning without a classroom as much as for someone sitting in one, so nothing here assumes you have a licence, a login, or a lab booked. Every circuit runs in PickettPanel Lite, free, in a browser — which means every student in a class can build alongside the reading on their own device, at the same time, without queueing for a bench or splitting a licence seat.

A few ways this fits into a classroom or apprenticeship setting:

Assign a section as pre-reading, then use lesson time to build and break the circuit together rather than explain it from scratch.

Use the fault sections as group diagnostic exercises — have students reason through the meter readings before revealing the answer.

Let students build the "before chapter" preview exercise at the end of each chapter as a quick check of understanding before moving on.

The book stays intentionally scoped to what Lite can do, so nothing a student does here depends on a paid tier. A companion instructor edition — covering scenario libraries, scoring, and attempt tracking for PickettPanel Pro — is planned separately for programmes that want that layer on top.

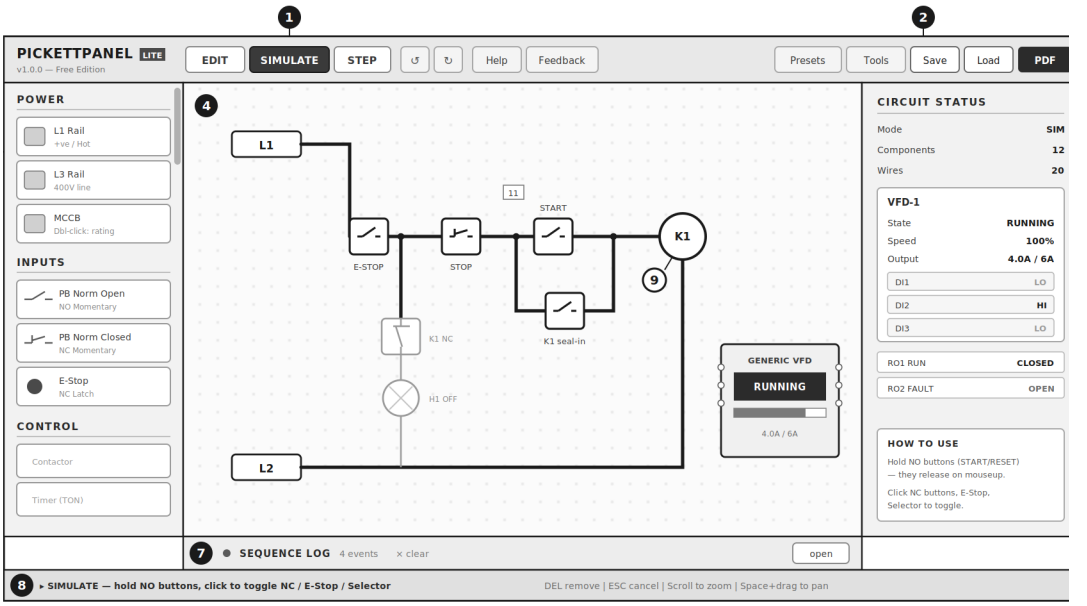
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Getting Started with PickettPanel Lite

Go to **pickettpanel.com** in any modern browser. It is free, there is nothing to install, and nothing you do in it can hurt you. It works on a laptop, a desktop, or a tablet.

- Drag components onto the canvas from the palette.
- Click a terminal, then click the terminal you want to join it to, to wire them together.
- Press **Simulate** to run the circuit.
- Use the meter to measure, and **Inject Fault** or **Random Fault** to break it on purpose.

The layout below is a reference, not a tour — you will be inside the real thing within a minute of opening it.



1. **Mode toolbar**
   Edit, Simulate and Step, plus undo / redo.
2. **File and output tools**
   Presets, Tools, Save, Load, Export PDF.
3. **Component sidebar**
   Devices grouped by Power, Inputs, Control and Loads. Drag one onto the canvas to place it.
4. **Circuit canvas**
   Where the circuit is drawn and run. Heavy lines
5. **Circuit status panel**
   Live mode, component and wire counts, drive state, digital inputs and relay outputs.
6. **Context help**
   Changes with the selected mode.
7. **Sequence log**
   Time-ordered record of every switching event.
8. **Status and shortcut bar**
   Current mode hint and keyboard shortcuts

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Chapter 1 — A Switch and a Lamp

Before you start

If you have picked up this book because circuit diagrams have always looked like a foreign language, you are in the right place. There is nothing clever happening in a control circuit. There is a path, and either electricity can get round it or it cannot. Everything else in this book is built on that one idea.

You do not need a lab, a toolbox, or a college enrolment. You need a computer or a tablet, a browser, and **pickettpanel.com**. It is free, there is nothing to install, and nothing you do in it can hurt you.

Work through this chapter with the simulator open beside you. Reading about a circuit teaches you very little. Building one, watching it work, then breaking it on purpose — that is where it starts to stick.

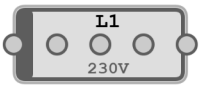
1.1 The complete path

Electricity will not flow into a component and stop there. It has to go somewhere and come back. If there is a complete path out from the supply, through whatever you are trying to operate, and back to the supply, current flows. Break that path anywhere at all and everything on it stops.

That is the whole of chapter 1. Everything from here is detail.

In a UK control panel the two sides of that path are usually labelled **L1** and **L2**. L1 is the live side, sitting at 230 volts. L2 is the return, sitting at 0 volts. Think of L1 as the top of a hill and L2 as the bottom. Current will run downhill through anything you put between them.

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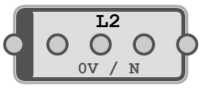


FIG 1.1

The two supply rails. L1 sits at 230V, L2 at 0V. Every circuit in this book is built between these two.

Put a lamp between the two rails and it lights. There is a path: out of L1, through the lamp, back to L2. Nothing is deciding anything — the path exists, so current flows.

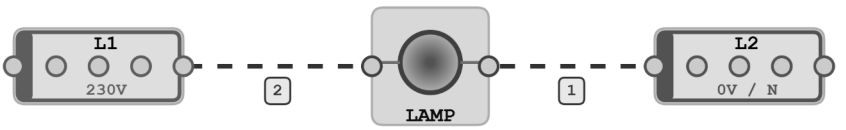


FIG 1.2

A lamp connected directly across the rails. The path is complete, so the lamp is on and stays on.

That circuit works, but it is useless. The lamp is on and there is no way to turn it off. To control something, you need to be able to break the path on purpose. That is all a switch is: a deliberate gap you can open and close.

1.2 Building it

Open PickettPanel and start with an empty canvas. You are going to build the first real circuit in this book: **L1 → switch → lamp → L2.**

Step 1 — place the rails. From the component palette, place an **L1** near the top left and an L2 near the bottom left. These are your supply.

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Step 2 — place the switch. Place a **selector switch (SEL)** in the middle of the canvas. A selector is a maintained switch — click it once and it stays where you put it, like a light switch on a wall.

Step 3 — place the lamp. Place a **white lamp (LAMP_W)** to the right of the switch.

Step 4 — wire it. Click a terminal, then click the terminal you want to join it to. Wire L1 to the top of the switch. Wire the bottom of the switch to one side of the lamp. Wire the other side of the lamp back to L2.

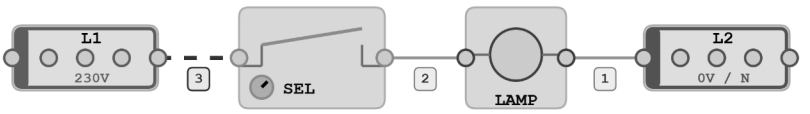


FIG 1.3

The finished circuit: L1 through the switch, through the lamp, back to L2. Switch open, lamp off.

Step 5 — run it. Press **Simulate.** Nothing happens yet, because the switch is open — there is a gap in the path.

Now click the switch. The path closes, the wires light up to show current flowing, and the lamp comes on.

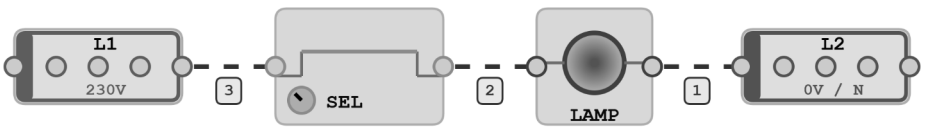


FIG 1.4

The same circuit with the switch closed. The energised path is shown as a heavy line; the lamp is on.

Click the switch again and it goes out.

That is your first control circuit. It is not a toy version of a real one — it is exactly the circuit behind every light switch in your house. The simulator draws it as labelled components so it is easy to follow while you are learning; on a real draw-

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ing the same circuit appears as standard symbols, which you can switch to at any time and which the last chapter comes back to.

Try this before moving on

Delete the wire between the lamp and L2, then run the simulation and close the switch. Nothing happens. The switch is closed, the lamp is fine, the supply is on — but the path is not complete, so nothing works. Put the wire back. This is the single most common fault you will ever chase, and you have just created it deliberately.

1.3 Reading the circuit with a meter

Knowing a circuit does not work is easy. Knowing where it does not work is the job. That is what a multimeter is for, and you are going to start using one now, on a circuit with two components, while it is still impossible to get lost.

Switch the meter into **voltage** mode. You get two probes, A and B. A meter reads the **difference** between wherever you put those two probes. That word matters — a meter never tells you what is happening at one point, only what is happening between two.

Put probe A on L1 and probe B on L2. You read **230V**. That is your supply, present and correct.

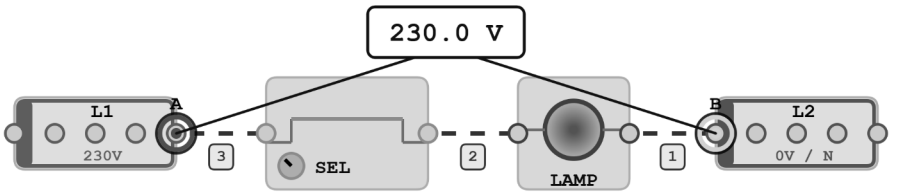


FIG 1.5

Probes across the supply rails reading 230V. Always start here — prove the supply before chasing anything else.

Now leave the switch open, and put your probes across the switch itself — one on each side.

You read **230V.**

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That surprises people, so it is worth sitting with. The switch is off. Nothing is working. And yet there is a full 230 volts across it. Here is why: with the switch open, the entire circuit is broken at that one point. L1's 230V reaches one side of the switch and stops. The other side of the switch connects through the lamp to L2, so it sits at 0V. The difference across the gap is the full supply.

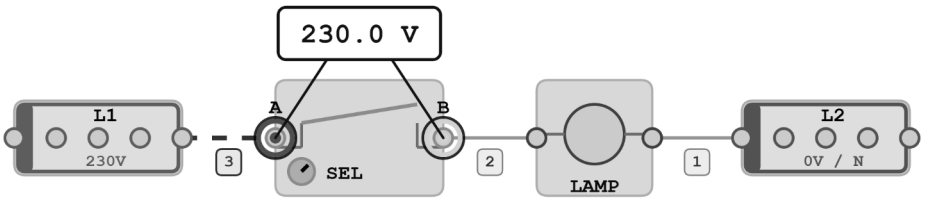


FIG 1.6

Probes either side of the open switch, reading 230V. Voltage appears across the break.

Now close the switch and measure across it again. **0V.**

There is your rule, and it is the one you will use for the rest of your working life:

> ### Voltage appears across a break.
>
> **A component that is doing its job has little or no voltage across it. A gap that should not be there has the full supply across it.**

Close the switch and measure across the lamp instead. You read 230V — because the lamp is the component doing the work, and the whole supply is being dropped across it. That is a healthy reading. The lamp is meant to have 230V across it.

So: 230V across a lamp that is lit is normal. 230V across a switch that is closed is a fault. Same reading, opposite meaning. The reading only means something when you know what the circuit is trying to do.

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1.4 Your first faults

Now break it on purpose. In PickettPanel, use **Inject Fault**, click a component or wire, and choose the fault you want.

Fault 1 — a broken wire

Inject **Broken (open conductor)** into the wire between the lamp and L2. Run the simulation and close the switch.

Nothing. The lamp stays dark.

Find it with the meter. Probes across the supply: 230V, so the supply is healthy. Probes across the switch: 0V, so the switch is closed and doing its job. Probes across the lamp: 0V — and that is your clue. A working lamp should have the full supply across it. If it has nothing, current is not reaching it.

Now put your probes across the faulty wire itself: **230V**. Voltage across a break. That is the fault, and you have found it in four measurements.

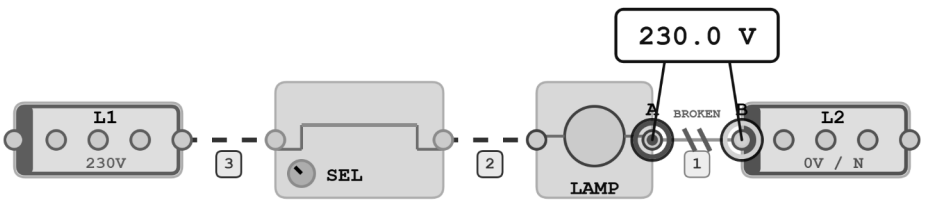


FIG 1.7

A broken wire in the return path. The meter reads 230V across the break while everything else reads normally.

Fault 2 — a burnt-out lamp

Clear the first fault, then use **Inject Fault** on the lamp and choose Burnt out (open filament).

The symptom looks identical: switch closed, nothing happens. But the meter tells a different story. Probes across the lamp now read 230V — full supply, lamp not lit. The current is arriving and the lamp cannot use it. The break is inside the lamp itself.

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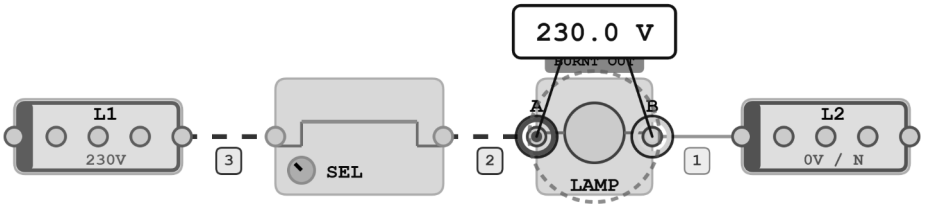


FIG 1.8

Failed lamp. Full supply present across it, but no light — the break is inside the component.

Notice what just happened. Two faults, one symptom, and the meter separated them in seconds. You did not guess, and you did not start pulling things apart. You measured.

Fault 3 — find it yourself

Use **Random Fault**. The simulator hides a fault somewhere in the circuit and gives you the symptom, but not the location.

Work it the same way every time:

- Prove the supply. Probes across L1 and L2.
- Work along the path from L1 towards L2, one component at a time.
- The first place you find voltage where there should be none is your fault.

On a two-component circuit that takes about thirty seconds. The reason to practise it here, where it feels almost too easy, is that the method does not change when the circuit gets bigger. In chapter 12 you will use the exact same four steps on a motor starter with twenty components in it. The circuit grows. The method does not.

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1.5 Half-splitting

One refinement, and then you are done with chapter 1.

Working from L1 towards L2 one component at a time is fine on a small circuit. On a large one it is slow. Instead, put a probe roughly **halfway** along the path. You have now proved half the circuit with one measurement — the fault is either before your probe or after it, and you have thrown away half the possibilities.

Do it again on whichever half is faulty. Then again. Twenty components takes about five measurements instead of twenty.

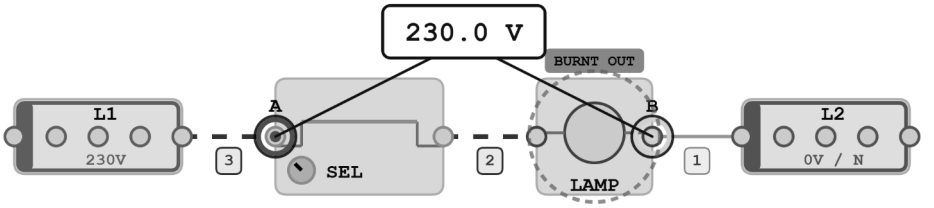


FIG 1.9

Half-splitting: one measurement at the mid-point eliminates half the circuit.

This is called **half-splitting**, and it is the difference between an apprentice who finds faults and one who wanders around a panel hoping.

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What you have learned

- Current needs a complete path. Break it anywhere and everything stops.
- L1 is the live side, L2 is the return. Circuits are built between them.
- A switch is a deliberate gap you can open and close.
- A meter reads the difference between two probes, never a single point.
- Voltage appears across a break.
- A component doing its job drops voltage. A gap that should not exist also drops voltage. Knowing which is which is the whole skill.
- Prove the supply first. Then half-split.

Before chapter 2

Build the switch-and-lamp circuit once more from an empty canvas, without looking back at the steps. It should take you under a minute.

Then add a second switch **in series** with the first — one after the other in the same path — and work out, before you run it, what will have to be true for the lamp to light.

That is chapter 2.

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Chapter 2 — Two Switches

Before you start

In chapter 1 you built one path with one gap in it. That is as simple as a control circuit gets, and almost nothing in a real panel is that simple.

Real circuits have several things that can break the path, and several things that can complete it. A machine will not start unless the guard is closed and the isolator is on and the overload has not tripped. A light comes on if the door switch is made or the manual button is pressed. Every control circuit you will ever meet is built from those two ideas, stacked up.

This chapter covers both. By the end of it you will have built them, broken them, and — the part that matters — met a fault that does not stop the circuit working.

Have the simulator open. Build as you read.

2.1 Everything must be closed

Take the circuit from chapter 1 and put a second switch in the same path, one after the other, so current has to get through both of them to reach the lamp.

Before you run it, work out what has to be true for the lamp to light.

There is only one answer. Both switches must be closed. The path runs L1 → switch 1 → switch 2 → lamp → L2, and a gap anywhere on it stops everything. Open either switch and the lamp goes out. Open both and the lamp goes out. There is no combination where one switch alone will do it.

Components arranged one after the other in the same path are **in series**. The rule is worth learning in the words you will use on site:

> **In series, everything must be closed.**
>
> **One open contact anywhere in a series path stops the whole path, no matter how many closed ones sit either side of it.**

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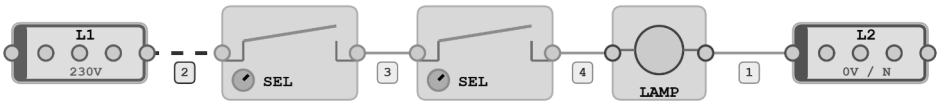


FIG 2.1

Two switches in series, both open. No path, lamp off.

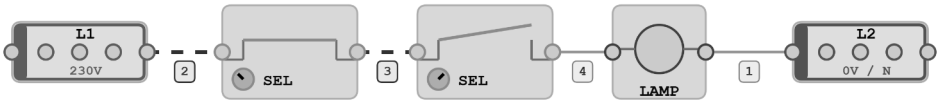


FIG 2.2

Switch 1 closed, switch 2 open. Still no path — one gap is enough.

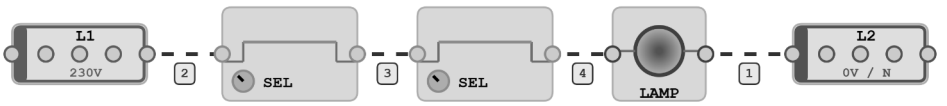


FIG 2.3

Both switches closed. The path is complete and the lamp is on.

If you have come across logic before, this is an **AND:** lamp on = switch 1 AND switch 2. You do not need that word to wire a panel, but it will come back in the last chapter of this book when the same circuit gets written as ladder logic for a PLC. It is the same idea in a different notation.

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2.2 Building it

Start from an empty canvas rather than editing chapter 1's circuit. Building it again from nothing is worth the extra minute.

Step 1 — place the rails. An **L1** near the top left, an **L2** near the bottom left.

Step 2 — place two switches. Two **selector switches (SEL)**, one above the other, in the middle of the canvas.

Step 3 — place the lamp. A **white lamp (LAMP_W)** below them.

Step 4 — wire the path in order. L1 to the top of switch 1. Bottom of switch 1 to the top of switch 2. Bottom of switch 2 to one side of the lamp. Other side of the lamp back to L2.

Notice what you just did. You wired it as a single line, in the order the current travels. That is the habit to build now, because it is exactly how you will read a real drawing: start at L1, follow the path, end at L2.

Step 5 — run it. Press **Simulate**, then work through all four combinations: both open, switch 1 only, switch 2 only, both closed. Only the last one lights the lamp.

Try this before moving on

Add a third switch in series, then a fourth. Run it again. Nothing about the rule changes — every one of them has to be closed. A series path with twelve contacts in it behaves exactly like this one, which is why it is worth being sure of it now.

Then delete them back down to two.

2.3 Any one will do

Now the other arrangement.

Instead of putting the second switch after the first, put it **alongside** — both switches connected between the same two points, so current arriving at the top has a choice of two ways down.

Build it: L1 to the top of both switches. Bottom of both switches to the lamp. Lamp to L2.

Run it and try the four combinations again. This time the lamp lights on three of them. Switch 1 alone, switch 2 alone, or both together — any of those gives current a complete route through. Only when both are open is there no path at all.

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Components arranged side by side like this are **in parallel**, and each route through is called a **branch**.

In parallel, any one closed path is enough.

Current does not need every branch. It needs one.

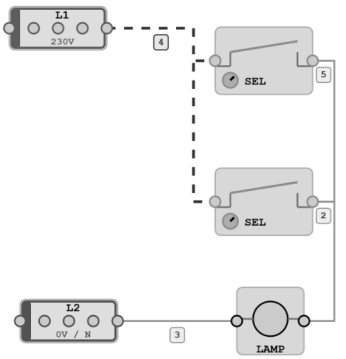


FIG 2.4

Two switches in parallel, both open. Neither branch is complete, so the lamp is off.

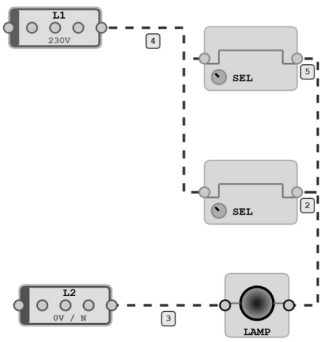


FIG 2.5

One branch closed. The lamp is on — the second switch makes no difference at all.

This is the **OR** arrangement, and it is how you get two start buttons at opposite ends of a machine, or a light that can be operated from either end of a corridor.

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2.4 Reading it with the meter

The meter rule from chapter 1 has not changed, and it does not change for the rest of the book: **voltage appears across a break**. What is new is that there are now more places for a break to be.

Build the series circuit again. Close switch 1, leave switch 2 open, and run it.

Prove the supply first. Probes across L1 and L2: **230V**.

Now work along. Probes across switch 1 (closed): **0V** — it is doing its job. Probes across switch 2 (open): **230V** — there is your gap. Probes across the lamp: **0V**, because no current is reaching it.

Nothing here is new. You are running the same method on a longer path.

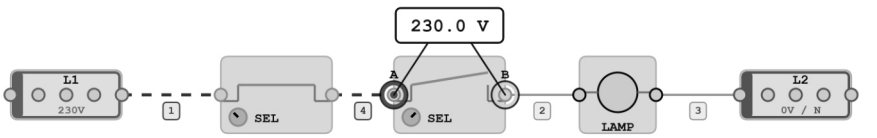


FIG 2.6

Series circuit with switch 2 open. The full supply appears across the open contact; everything else reads zero.

Now close switch 2 as well. Across switch 1: 0V. Across switch 2: 0V. Across the lamp: **230V**, and the lamp is lit.

Sit with that for a second, because it is the whole of series circuit measurement in one sentence: the supply has to be dropped somewhere, and in a healthy circuit it is dropped across the thing doing the work. Contacts that are closed take almost none of it. Contacts that are open take all of it.

Add the third and fourth switch back in if you deleted them, close them all, and measure across each in turn. Still 0V on every one, still 230V across the lamp. The length of the path does not change the arithmetic.

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2.5 The fault that does not stop the circuit

Save your parallel circuit before this next part. **Save** downloads the circuit as a file, so you can load it back and get a known-good version whenever you have broken something past the point of untangling it. Get in the habit now — chapter 1's circuit took a minute to build, and by chapter 10 they will not.

Build the parallel circuit. Close switch 1 only. The lamp is on.

Now use **Inject Fault** on switch 2 — the switch in the branch that is currently doing nothing — and choose Stuck open.

Run it.

The lamp is still on. Nothing looks wrong. Nothing is wrong, yet.

Now open switch 1.

The lamp goes out — and stays out, no matter what you do with switch 2. The circuit that worked perfectly a moment ago now has no way of working at all, and nothing about the way you were operating it changed.

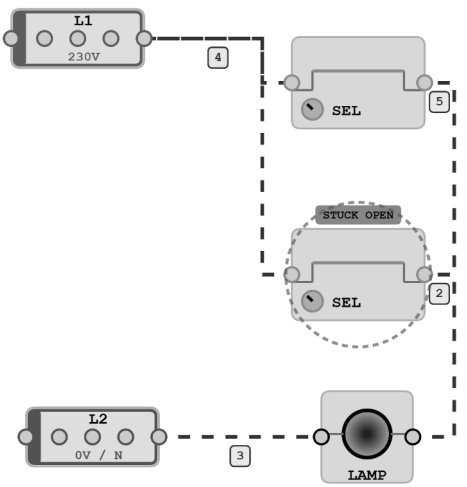


FIG 2.7

Switch 2 stuck open in the unused parallel branch.The lamp is lit from the other branch and the fault is completely invisible.

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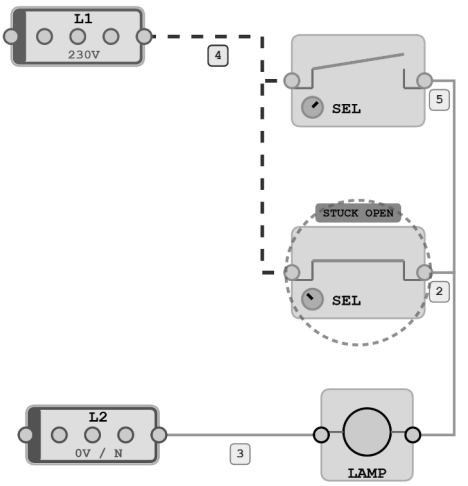


FIG 2.8

The same fault with the healthy branch opened. Now there is no path at all.

This is the most important thing in the chapter, and it is worth saying plainly. **A parallel branch can fail without anything appearing to be wrong**. The circuit carries on working on its remaining branch, and the fault sits there unnoticed until the day someone uses the other one.

This is why a machine "suddenly" fails to start from the second control station, or why an emergency stop at the far end of a line turns out to do nothing when somebody finally hits it. The fault was there for months. There was just nothing to reveal it.

The lesson for you: when a circuit has parallel branches, **working is not the same as healthy**. Testing means proving every branch, one at a time, not proving that the lamp comes on.

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2.6 Finding it

Go back to the injected fault, with the lamp lit from switch 1. Close switch 2 and put your probes across it. On a healthy branch that would read 0V — and so does this one. Switch 1 is holding both ends of switch 2 at the same potential, so the meter cannot see the fault at all. While another branch is carrying the load, a dead branch hides from the meter as well as from the lamp.

Now open switch 1, so switch 2 is the only way through. The lamp goes out, and across switch 2 you read **230V** — voltage across a break, in a switch that is supposedly closed.

That is the tell, and it is also the method: to test a branch, take away every other path first.

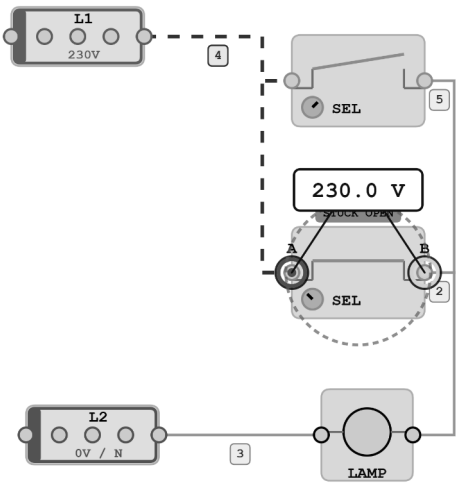


FIG 2.9

Switch 1 opened so switch 2 is the only path. 230V across a closed switch: the branch is dead.

Fault 2 — the series version

Clear that fault, build the series circuit, and inject Broken (open conductor) into the wire between the two switches.

Close both switches and run it. Nothing.

Prove the supply: 230V. Now half-split — probes from L1 to the point between the two switches. If you read 230V there, the break is in the first half. If you read nothing, it is in the second.

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On a four-component path that saves you one measurement. It is not worth much yet. Practise it here anyway, because the circuit in chapter 12 has twenty components in it and the method will be identical.

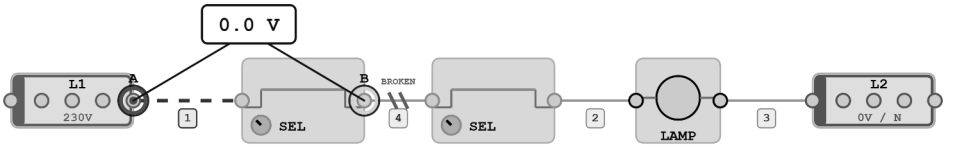


FIG 2.10

A broken wire between the two series switches, located by half-splitting from L1.

Fault 3 — find it yourself

Use **Random Fault** on the parallel circuit and work it properly:

- Prove the supply.
- Prove **each branch separately** — operate one branch at a time and check the lamp responds.
- On the branch that fails, follow the path and find the point where voltage appears across something that should be closed.

The second step is the new one. In chapter 1 there was only one path, so proving it was the same as proving the circuit. From here on it is not.

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What you have learned

- **In series, everything must be closed**. One open contact stops the whole path.
- **In parallel, any one closed path is enough**. Current needs one branch, not all of them.
- Series is AND. Parallel is OR. The same two ideas build every circuit in this book.
- In a healthy series path, closed contacts drop nothing and the load drops everything.
- A parallel branch can fail invisibly. The circuit keeps working and the fault waits.
- Testing a circuit with branches means proving every branch, not proving the lamp comes on.
- Save before you start breaking things.

Before chapter 3

Build a circuit with two switches in series controlling one lamp, and a third switch in parallel across one of them. Before you run it, work out which combinations light the lamp.

Then answer this, on paper, before you touch the simulator: is there any way to wire two switches so the lamp lights when **neither** of them is operated, and goes out when either one is?

With what you have so far, there is not. Every switch you have used closes when you operate it. Chapter 3 gives you the other kind — a contact that is closed until something acts on it — and with it, everything that a control circuit needs to protect a machine rather than just run one.

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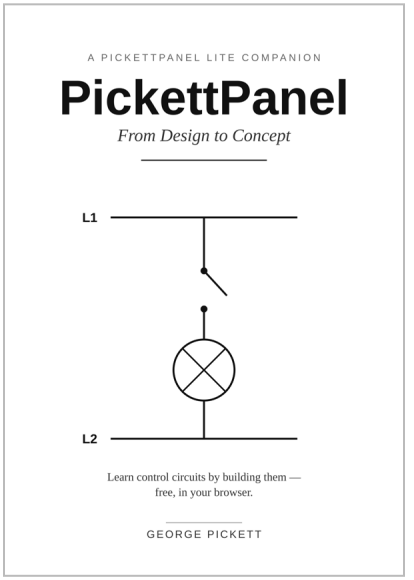
END OF FREE SAMPLE

That is the foundation.

Chapter 3 opens with the question chapter 2 left you:

can you wire two switches so the lamp is on when neither is operated, and goes out when either one is?

From there: relays, seal-ins, interlocks, motor starters, timing, sequencing, drives and PLC ladder logic — with real faults to find in every chapter.



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