

Circuits: Line & Load, Switch Types, Opens & Shorts

YES Electric • Arc Workforce Academy HVAC Apprenticeship

Draft 1 (October 2026). This lesson is under review. Videos are made by other companies, not YES Electric; follow this lesson and your journeyman where they differ. Boxes marked "Shop photo coming" will get real photos from our shop in a later version.

Unit 3 • Electrical for HVAC I • Appendix A Competency 6 (applied) Class time: ~4 hrs (1 video + 3 training board)

1. What you'll be able to do

- Split any circuit into its three roles — **source, switches (control), load (work)** — and say which side of the load is "line" and which is the return.
- Identify switch architectures by name and on sight: **SPST, SPDT, DPST, DPDT** — and match each to its HVAC job.
- Distinguish the two great failures with meter evidence: **OPEN** (loop broken — nothing runs) vs **SHORT** (loop bypassed the load — fuse/breaker blows).
- Read and draw a simple **ladder diagram** — the format every furnace door sticker uses (full diagram fluency is 3.7).

2. Tools & materials

- Training board (24 V section): transformer, assorted switches, relay, lamp loads, fuse holder with sacrificial fuses
- Dead-component bin: every switch type, a float switch, a high-limit, a pressure switch
- Whiteboard ladders; meters

3. Watch first

Order	Video	Channel	Length	Why
1	Electrical Circuit Basics Part 1 — Line & Load	HVAC School	4:59	The two halves of every circuit
2	Electrical Circuit Basics Part 2 — Intro to Ladder Diagrams	HVAC School	9:38	The drawing format that organizes everything
3	Electrical Circuit Basics Part 3 — Resistance and Loads	HVAC School	10:47	Why the load IS the resistance
4	Switch Types Explained: SPST → DPDT	AC Service Tech	5:29	The naming system, decoded
5	Electrical Basics — Switches and Contacts	HVAC School	4:03	NO/NC contacts
6	Open and Short Circuits Class · Diagnosing Open & Short Circuits	HVAC School	8:38 / 8:41	The two failure modes, with meters

4. The idea

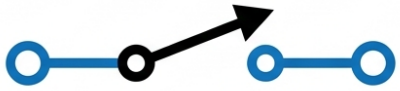
Every circuit is the same sentence

SOURCE → (switches in series) → LOAD → back to source.

- **Switches decide IF.** They're supposed to read ~0 V across when closed; they drop nothing, they just permit.
- **The load does the work** — and the load IS the designed resistance (Lesson 2.4). All the source voltage belongs across the load when everything's healthy.
- **Line side / load side:** "line" = toward the source, "load" = toward the work. Components are labeled this way (contactor L1/L2 vs T1/T2) and so is your diagnosis language.

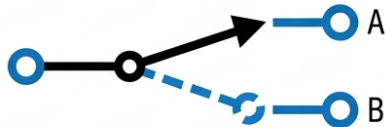
SWITCH TAXONOMY — POLES × THROWS

SPST — single pole, single throw



on/off — door switch, float switch, limit

SPDT — single pole, double throw

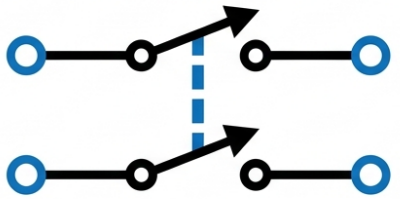


chooses A or B — fan relay, O/B logic

SIDE NOTE

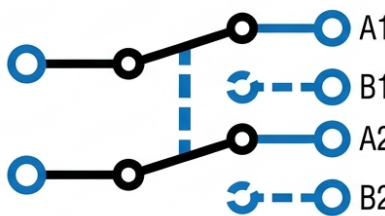
- **POLES** = how many circuits
- **THROWS** = how many positions
- **NO** = closes when actuated
- **NC** = opens when actuated
- **NORMAL** = de-energized

DPST — double pole, single throw



two circuits, one handle — the contactor

DPDT — double pole, double throw



two circuits, each chooses A or B

- **Poles** = how many separate circuits the handle moves. **Throws** = how many positions connect somewhere.
- **SPST** — one circuit, on/off. Door switch, float switch, limit. The workhorse.
- **SPDT** — one in, two outs (A or B). Fan-center relays, O/B reversing logic, zone dampers.
- **DPST** — two circuits, one handle. The contactor! Both legs of 240 broken together (mostly — many residential contactors are actually SP making one leg always-hot: the famous "one side is still live" trap, 3.6).
- **DPDT** — two circuits, each choosing A or B. Reversing applications.
- **NO/NC**: Normally Open closes when actuated; Normally Closed opens. "Normal" = de-energized/at rest. Safeties are mostly NC (closed when happy, open to call for help) — which is why a failed-open safety and a legitimately tripped one look identical until you ask WHY (Unit 7's pressure-switch lesson lives on this).

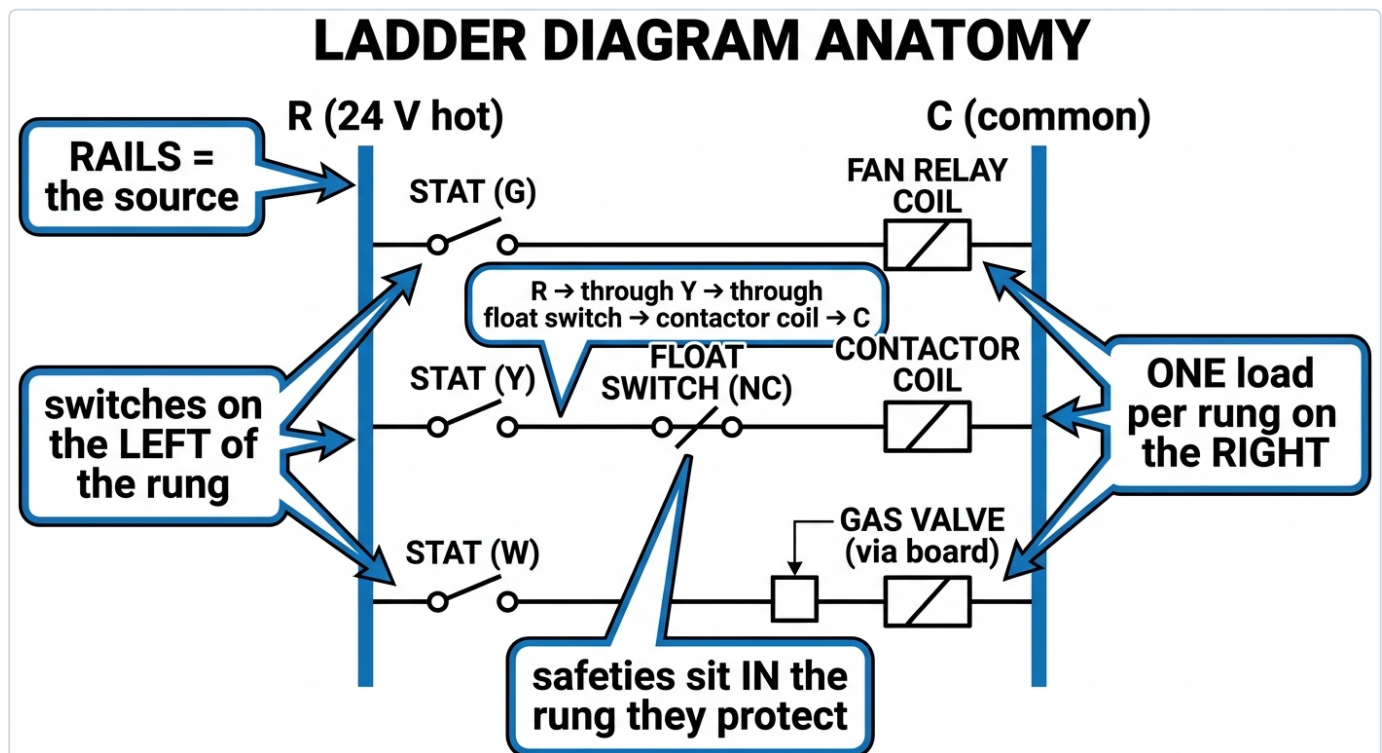
The two failures, with meter fingerprints

	OPEN	SHORT
What happened	Loop broken somewhere	Current found a bypass around the load
Symptom	Nothing runs; silence	Fuse/breaker blows — maybe instantly, maybe on call
Resistance picture	Path reads OL somewhere	Path reads ~0 where it should read load-ohms
Voltage picture	Source voltage appears ACROSS the open point	Voltage everywhere collapses at the bang
Classic causes	Burnt contact, broken splice, tripped safety, rodent	Chafed stat wire on sheet metal, shorted coil, pinched wire at panel edge

The 24 V short is SO common it gets its own hunt lesson (6.5): stat wire stapled too tight, rubbed through on duct edge → 3 A fuse pops → "my thermostat is blank."

Ladder diagrams — the trade's sheet music

Two vertical rails = the source (L1/L2 or R/C). Every horizontal rung = one circuit: switches on the left, ONE load on the right. The furnace door diagram is exactly this. Today: read rungs and say them aloud ("R, through the stat's G, through the fan relay coil, to C"). Drawing full system ladders = 3.7.



5. Bench procedure (training board)

1. **Build the sentence:** wire transformer → SPST → lamp. Run it. Measure across the CLOSED switch (~ 0) and across the LAMP (24). Open the switch — measure across the OPEN switch (24 appears!) and the lamp (0). This is Lesson 3.2's gold rule, now built with your own hands.
2. **Series safeties:** add a second SPST ("float switch") in series. Either switch kills the lamp. State why safeties stack in series, never parallel.
3. **SPDT exploration:** wire one input to two lamps A/B; flip and prove with continuity which path lives in each position.
4. **Make an OPEN:** instructor hides one (pulled spade, broken wire under tape). Find it with voltage-across method in under 5 minutes. Then find the same fault dead, with continuity. Two roads, same answer.
5. **Make a SHORT (sacrificial fuse):** chafe-sim jumper from the rung to the rail before the load → fuse pops on energize. Ohm the rung: ~ 0 instead of coil-ohms. Replace fuse ONLY after the short is found and fixed — say the rule.
6. **Ladder translation:** draw the board's three rungs as a ladder; trade drawings with a partner and build each other's.

Checkout: identify 4 switch types from the bin by name; find one hidden open and one hidden short with correct meter method and narration; read one rung of a real furnace diagram aloud.

6. Field gotchas

- **A switch that drops voltage is a bad switch.** Across a closed switch you want ~ 0 ; finding 3–5 V across "closed" contacts = burnt/pitted = heat = future failure (and the voltage-drop method of 6.5).
- **Replacing the popped fuse without finding the short** = second truck roll, free of charge. Fuses die of murder, not old age.
- **NC safeties read closed when HAPPY.** Continuity across a limit switch proves it's not tripped — not that the furnace has no overheating problem.
- **Series $\neq$ daisy-chain sloppiness:** safeties belong in the SAME rung as the load they protect, per the diagram — moving them "somewhere convenient" changes what they protect.
- **"Normal" means de-energized** on every spec sheet — not "usual operating state." A fan-proving switch is NO at rest and closed all runtime; misread that and every diagnosis inverts.

7. Competency link

- Applies **Comp 6**; builds the circuit grammar for diagrams (3.7), contactors/relays (3.6), board logic (6.6), and the safety-string diagnostics of Unit 7/8.

8. Check yourself

1. The circuit sentence — say it, and name the three roles.
 2. Across a closed switch: ___ V. Across an open switch in a live circuit: ___ V. Across the load when running: ___ V.
 3. Decode DPST. Which famous HVAC part is one, and what's the one-leg-hot trap?
 4. NO vs NC — and why are safeties usually NC?
 5. Open vs short: symptom of each? Resistance fingerprint of each?
 6. The 3 A fuse pops every time the stat calls cooling. Most likely cause and where do you look?
 7. Two safeties protect one load. Series or parallel, and why?
 8. In a ladder diagram, what are the rails and what does one rung contain?
 9. You read 4 V across a "closed" contactor contact under load. Verdict?
 10. A float switch interrupts which rung in a typical air handler (preview: break Y or break R — which one does this program recommend and why)?
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