

Transformers & the 24 V Control Circuit

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) — supports Comp 9
Class time: ~3.5 hrs (1 video + 2.5 bench)

1. What you'll be able to do

- Explain how a transformer makes 24 V from 120/240 (magnetics in one breath, terminals in detail).
- **Test a transformer completely:** primary voltage in, secondary voltage out, both windings by ohms — and pronounce it dead honestly (most "dead transformers" were murdered).
- Wire a **multi-tap universal replacement** correctly for 120 / 208 / 240 primaries — and say what happens if you pick the wrong tap.
- Size control transformers by **VA** and explain why a smart stat + zone panel can out-eat a 40 VA donor.
- Find and protect the secondary: board fuse, and why R and C are the rails of everything (3.3's ladder, powered).

2. Tools & materials

- Transformer pile: 40 VA universal multi-tap, dead ones (one open primary, one open secondary), a 75 VA
- Training board, meters, sacrificial 3 A fuses
- A buck-boost on the show shelf (concept only — 12.2 territory)

3. Watch first

Order	Video	Channel	Length	Why
1	How a Transformer Works 3D	HVAC School	4:47	The magnetics, animated
2	Transformer Facts	HVAC School	8:06	VA, taps, and field truths
3	Universal 24 V Transformer Replacement	AC Service Tech	2:54	The multi-tap swap
4	Setting a Transformer for 208 V	HVAC School	3:52	The wrong-tap mishap, live
5	Transformers, Inductance & Common Problems	HVAC School	21:00	Deeper theory + failure modes

4. The idea

One breath of magnetics, then terminals

AC in the primary winding makes a pulsing magnetic field in the iron core; the field induces voltage in the secondary winding. **Turns ratio = voltage ratio**: 10:1 turns turns 240 into 24. No moving parts, nothing to wear — which is why a "bad transformer" almost always died of something else (shorted secondary load, lightning, wrong tap).

TRANSFORMER — ANATOMY & THE FOUR-READING VERDICT

ANATOMY

PRIMARY

NOTE — cap unused taps

COMMON

120 V

208 V

240 V

SECONDARY

R (24 V hot)

3 A FUSE — the cheap sacrifice

C (common)

THE FOUR-READING VERDICT

- 1. PRIMARY VOLTS PRESENT?**
(240 across primary — if not, problem is UPSTREAM)
- 2. SECONDARY OUT?**
(~24–28 V R to C — present = transformer fine)
- 3. NO OUTPUT → kill power, isolate, OHM both windings**
(OL = open = dead)
- 4. BEFORE the new one goes in: FIND THE MURDERER**
(ohm the 24 V loads for shorts)

The terminals you'll touch

- **Primary side:** universal replacements ship multi-tap — common + 120 / 208 / 240 leads (color-coded; CAP THE UNUSED TAPS). Feed a 240 unit on the 120 tap → secondary runs ~48

V → cooked coils and boards. Feed 208 on the 240 tap → ~21 V → chattering contactors and ghost lockouts. **Tap must match supply — measure the supply, don't assume** (208 lives in light commercial; the mishap video).

- **Secondary side: R and C.** R = 24 V hot rail, C = common rail. Every control in the machine is a rung between them (Lesson 3.3 — same ladder, now powered). C is also why smart stats need that 5th wire: their radio runs on R-to-C continuously.

Testing — the full verdict in four readings

1. **Primary voltage present?** (240 across primary leads — if not, the problem is upstream: door switch, breaker... not the transformer.)
2. **Secondary voltage out?** (~24–28 V across R-C. Present = transformer fine, move on.)
3. **No secondary V?** Kill power, isolate, **ohm both windings**: primary typically a few Ω to ~20 Ω ; secondary under ~5 Ω ; OL on either = open winding = genuinely dead.
4. **Before hanging the replacement: find the murderer.** Ohm the 24 V loads/wiring for shorts (a stuck contactor coil reading 2 Ω instead of ~15, a chafed stat wire). A transformer that died with a popped fuse or burnt smell had a cause; replacement without diagnosis = two dead transformers.

VA — the secondary's budget

VA = volts × amps available. A 40 VA / 24 V transformer can feed ~1.6 A of control load. Contactor coil (~8–10 VA) + furnace board + smart stat (~3–7 VA) + 4 zone dampers + a couple of relays... budgets blow fast. Symptoms of an overdrawn transformer: hums hot, secondary sags under load (24 unloaded → 18 when everything pulls in), random brownout reboots of the stat. Fix = bigger VA (75/100), not a parade of 40s.

Protection

The **3 A or 5 A automotive-style fuse** on the furnace board protects the secondary. No board? Inline fuse holder is a 2-dollar professional habit on every transformer you hang. The fuse is the cheap sacrifice; the alternative sacrifice is the winding.

5. Bench procedure

1. **Four-reading verdict drill:** three mystery transformers on the board (one healthy, one open primary, one open secondary). Each student: full verdict with narration, including "what would I check before replacing" on the dead ones.
2. **Multi-tap wiring:** wire the universal onto the 240 V demo supply — correct tap, unused taps capped, polarity of secondary to R/C. Instructor then re-wires to the 120 tap (de-energized), energizes briefly: meter the secondary (≈ 48 V!) — burn the lesson in without burning a board.
3. **VA sag demo:** 40 VA feeding the training board; add coil loads one at a time, watch secondary droop on the meter; swap to the 75 VA, watch it hold. Log the numbers.

4. **Murder mystery:** instructor shorts a hidden coil; fresh fuse pops on energize. Hunt by ohming rungs (3.3 skills) until the culprit coil confesses; ONLY then a new fuse.
5. **R/C rail mapping:** on the real furnace, find R and C at the board, verify 24 V, then find the same pair at the stat base and the condenser contactor coil — one circuit, three ZIP codes.

Checkout: full transformer verdict unaided on an unknown unit + correct multi-tap selection narrated + "the fuse popped, what now?" answered with the murder rule.

6. Field gotchas

- **Most replaced transformers weren't dead** (upstream open) **and most actually-dead ones get their replacement killed** (un-found short). The two rules in one breath: prove primary first; find the murderer before hanging the new one.
- **Wrong-tap = slow murder:** 208 supply on 240 tap under-volts everything into intermittent gremlins — the worst kind of callback. Measure the building's real voltage.
- **Polarity/ground on secondaries matters more than it used to:** many boards reference C to chassis ground; two transformers in one system (furnace + AHU add-ons) must not fight — phase them or isolate loads (the fan-center special, 6.x).
- **Hot to the touch ≠ failed,** transformers run warm; smelling like varnish ≠ fine. Calibrate your nose on the dead pile.
- **Lightning season in Alabama:** post-storm "everything dead" calls — transformer + board fuse first stop.

7. Competency link

- Applies **Comp 6**; powers the rails for Comp 9 (thermostats/low-voltage, 6.3–6.4) and the contactor coil story (3.6).

8. Check yourself

1. Turns ratio 10:1 fed with 240 — secondary voltage?
2. The four-reading verdict, in order, with what each rules out.
3. No 24 V out, primary has 240, both windings ohm normal-ish. What's left to suspect? (Internal thermal fuse opens count as open winding — recheck; otherwise connections.)
4. Universal transformer on a 208 V rooftop — which tap, and what do the symptoms look like if someone used 240?
5. What does VA cap, and three symptoms of an overdrawn transformer?
6. Smart stat + 4 zone dampers + contactor on a 40 VA — sketch the budget problem.
7. Why must the unused primary taps be capped?
8. Fuse pops on every cool call. Whodunnit list, top three?
9. Where are R and C in a system — name three places you can reach them.

10. The replacement transformer hums and reads 19 V with everything connected. Two suspects?

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