

Inverter Systems: What's Different and Why It Changes Everything

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 9 • Ductless Mini-Splits • Job Function 18 • Appendix A Competency 48 (opens) — "Install single-zone ductless mini-split systems (indoor head, outdoor unit, lineset, and electrical)" **Class time:** ~4 hrs (2 video/discussion + 2 bench)

1. What you'll be able to do

By the end of this lesson you will be able to:

- Explain **why a mini-split compressor never just clicks on and off** the way a residential split-system compressor does, and what "inverter" actually means electrically.
- Trace the power path a mini-split uses that a fixed-speed system doesn't: **AC in → rectifier → DC bus → inverter (IPM) → variable-frequency AC out → compressor motor.**
- State the one idea that governs every diagnostic and charging lesson in this unit: **there is no single "normal" pressure on an inverter system — normal changes with compressor speed, so you read the manufacturer's service data, not a fixed number.**
- Identify the physical signs of an inverter system on sight: DC bus capacitors, IPM/inverter board, BLDC (brushless DC) fan motors, the absence of a start/run capacitor on the compressor.
- Explain in customer-plain English why inverter equipment is quieter, more efficient, and better at humidity control than an on/off system.

This is the "1.1 of Unit 9." Everything else in this unit — flaring, wiring, charging, commissioning, fault codes, component testing — assumes you understand that this equipment **thinks and modulates**, and that changes how you touch it.

2. Tools & materials

- A running mini-split (shop unit) with the front cover off the outdoor unit (power OFF, panels open, instructor supervision — DC bus capacitors can hold a lethal charge even with power off; do not touch board components this lesson, look only)
- Clamp meter with Hz/frequency function

- Laminated inverter drive-chain diagram (one per student)
- A fixed-speed condensing unit nearby for side-by-side comparison, if the shop has one (Unit 1's trainer works)
- Safety glasses

3. Watch first

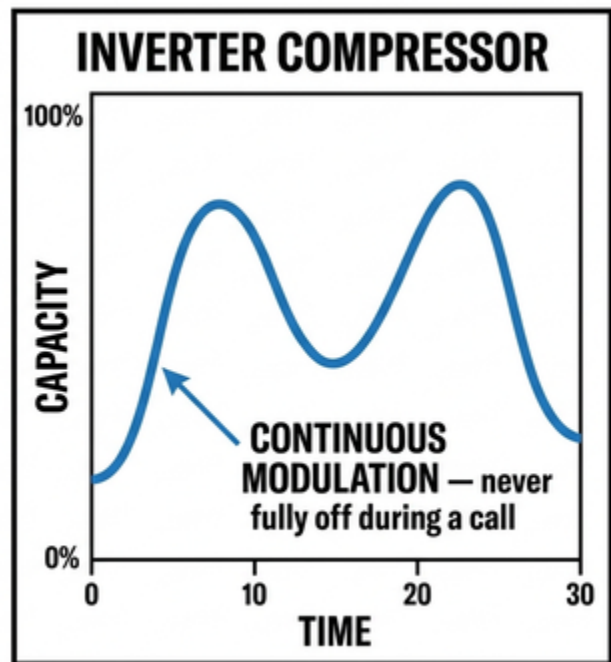
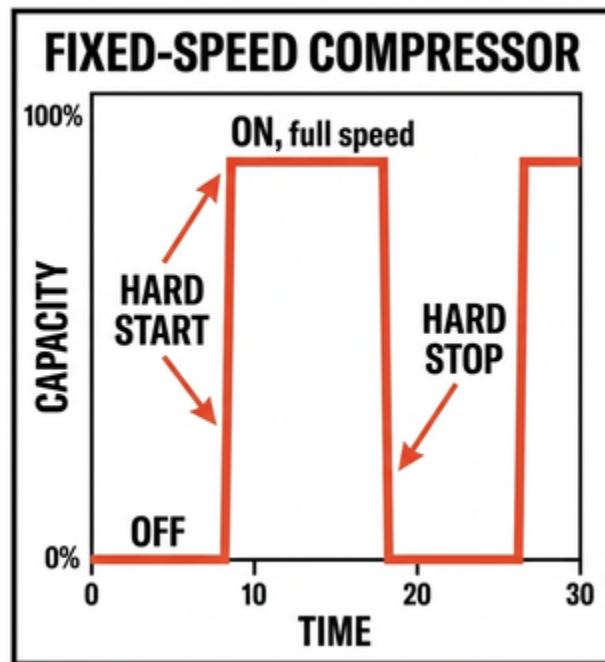
Order	Video	Channel	Length	Why
1	MINI SPLIT Parts Explained! Understand What They Do!	AC Service Tech	19:31	The physical parts tour — matches what you're looking at on the bench unit
2	Cornerstones of Inverter-Based Equipment Commissioning with Chris Hughes and Adam Mufich	HVAC School	43:07	The deep "why inverters are different" theory — the mental model for this whole unit
3	Multi-Zone Mini Split, Mini-VRF, and VRF System Differences Explained!	AC Service Tech	6:15	Where mini-splits sit in the bigger inverter-equipment family (previews Unit 12)
4	Checking the Refrigerant Charge on a Running R-410A Inverter MINI SPLIT Unit!	AC Service Tech	12:28	First look at "there's no fixed target pressure" in action
Optional deep-dive	Inverter Driven Install Considerations Part 1	HVAC School	52:01	Full-length version for students who want the whole picture before the unit builds it lesson by lesson

4. The idea

Rule 1: A fixed-speed compressor only has two states. An inverter compressor has hundreds.

Every compressor you've studied so far in this program (Units 1–8) is **fixed-speed**: it runs at one motor speed, full-on, or it's off. The thermostat calls, the contactor pulls in, the compressor slams to full speed in under a second, and it stays there until the call ends. Capacity control on a fixed-speed system is **on/off cycling** — run longer or shorter, not softer or harder.

An inverter compressor **changes its own rotational speed** to match the load, the same way a car's cruise control feathers the throttle instead of stomping the pedal and lifting off over and over. A mini-split serving a small, well-insulated bedroom on a mild day might run its compressor at 20–30 Hz. The same compressor, same unit, on a 98°F Alabama afternoon with the door propped open, might run at 90 Hz or more. **The compressor doesn't turn off between those — it turns down.**

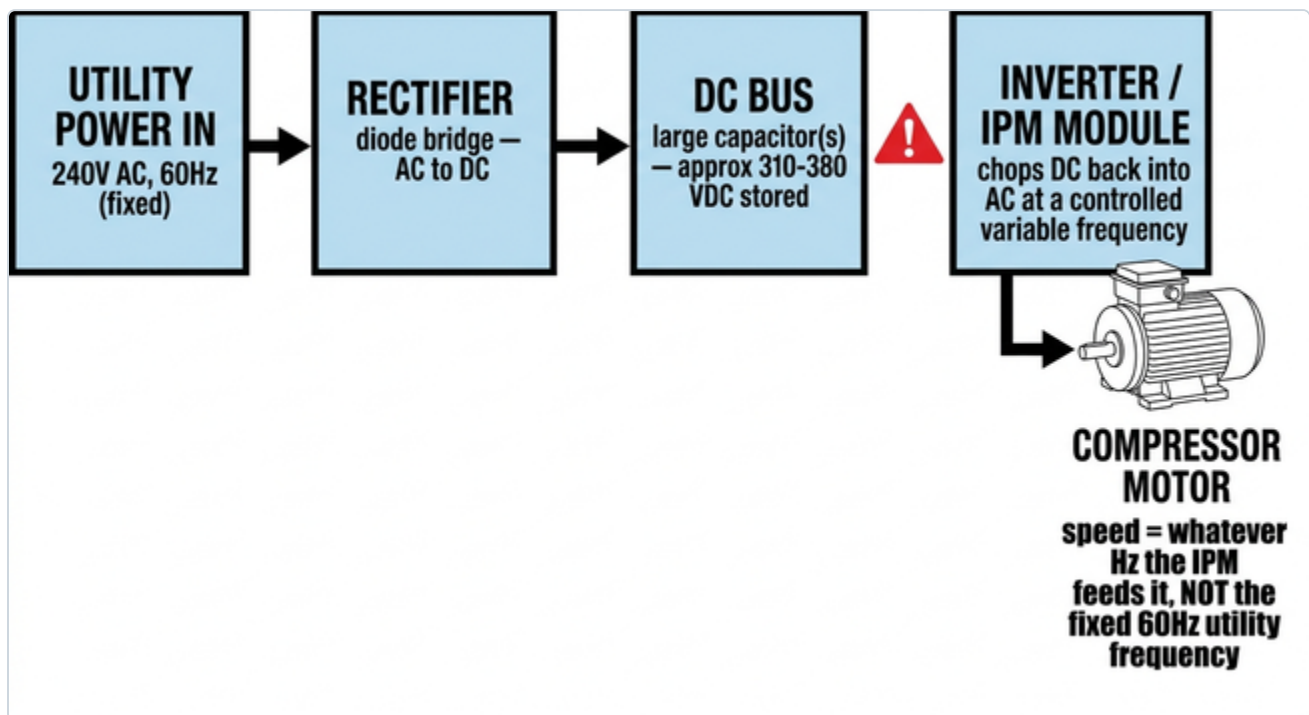


That single fact is why mini-splits are quieter (no hard-start slam), more efficient (no losses from constant stop/start, no oversized-unit short-cycling), and better at dehumidification (long, low, steady runtimes wring more moisture out of the air than short blasts of full capacity ever could — ties back to Lesson 1.6's psychrometrics).

Rule 2: To change compressor speed, you have to change the electricity feeding it — that's the inverter's whole job.

Alabama's utility power is fixed: 240V, 60 Hz, and it never changes. A standard motor fed straight off that power runs at one speed, set by its winding design and that fixed 60 Hz. To run a compressor motor at 30 Hz one minute and 90 Hz the next, the unit has to **build its own variable-frequency power** on board. That's the inverter drive chain:

Stage	What it does	What's physically there
1. Rectifier	Converts incoming 240V AC to DC	A diode bridge — four to six diodes on a small board or heat sink
2. DC bus	Smooths and stores that DC at high voltage (~310-380VDC)	The big electrolytic capacitor(s) — the single most dangerous thing on this unit, see gotcha below
3. Inverter / IPM (Intelligent Power Module)	Chops the DC bus back into AC, but at whatever frequency and voltage the control board decides , many times a second	The largest board in the outdoor unit, usually with its own heat sink and thermal paste, often labeled "IPM" or "PWM"
4. Compressor motor	Spins at a speed set by the frequency it's fed — NOT by the utility's 60 Hz	The compressor itself — usually a 3-phase BLDC or brushless motor even on a single-phase-fed unit, because the inverter builds its own 3-phase output internally



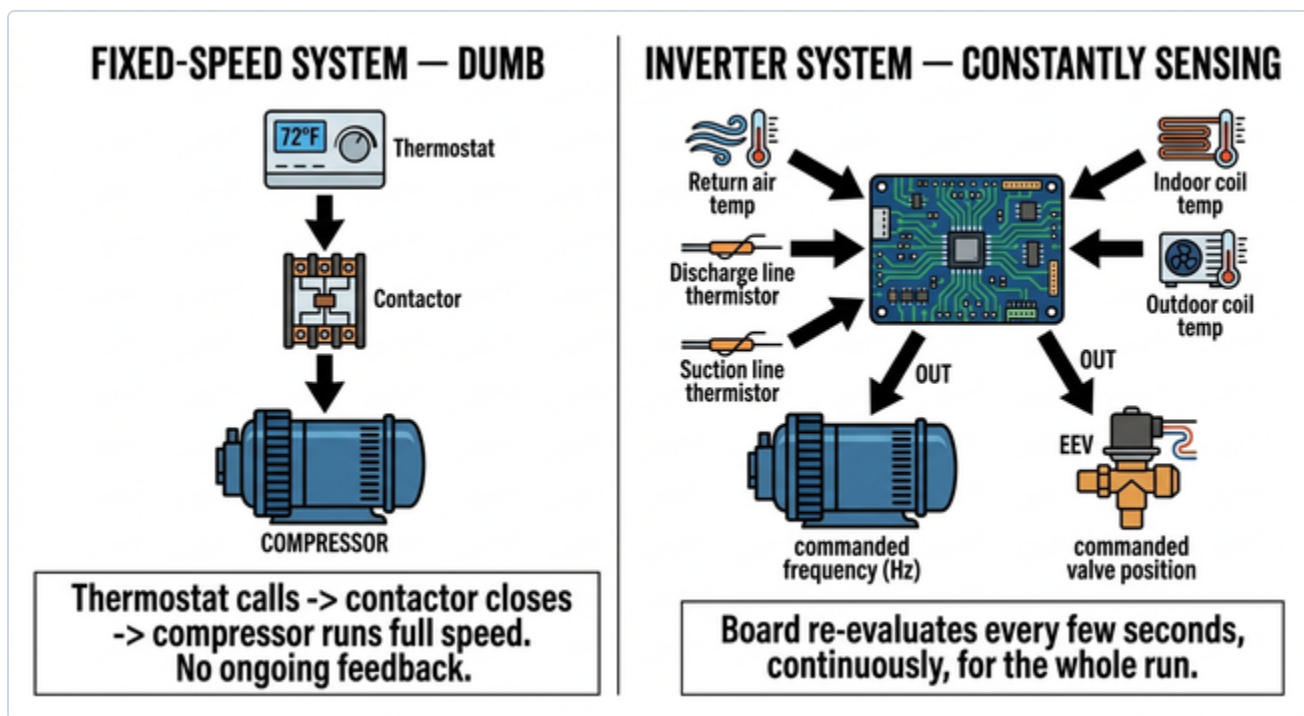
This is also why an inverter compressor **has no start or run capacitor** — a capacitor's whole job on a fixed-speed PSC motor is to fake a second phase for starting torque. An inverter feeds the motor genuine multi-phase power at a controlled ramp, so it never needs that trick. If you're hunting for a cap on a mini-split compressor circuit and can't find one, that's not a missing part — that's correct.

Rule 3: The board doesn't just run the compressor — it's constantly reading the system and deciding.

A fixed-speed system is dumb by comparison: pressure switches trip, a contactor closes, a capacitor spins the motor, done. A mini-split's control board is continuously reading:

- Return air temperature at the indoor head (its thermostat) vs the setpoint
- Discharge and/or suction line temperature via thermistors (Lesson 9.8)
- Coil temperatures, indoor and outdoor
- Sometimes outdoor ambient

...and using that data to decide the compressor frequency, the EEV/LEV (electronic expansion valve) opening, and the indoor/outdoor fan speeds — every few seconds, continuously, for as long as the unit runs. That's the whole reason **superheat and subcooling numbers you memorized in Unit 5 don't map cleanly onto this unit's gauge readings** — the "system" you're reading is a moving target that the board is actively steering. Manufacturers solve this by giving techs a way to read the board's own data directly instead of guessing from gauges (Lesson 9.6).



What this means for every lesson after this one

- **Charging (9.6):** you won't hit a superheat/subcooling target off a P/T chart the way you did in Unit 5. You'll use weigh-in charge plus the service data the board reports.
- **Diagnosis (9.7-9.8):** you pull a fault code FIRST, then verify with meter readings — not the other way around.

- **Electrical (9.4):** power feeds the outdoor unit only; the indoor head runs on low-voltage DC communication and gets its power routed through the interconnect wire, not a separate circuit.
- **Component testing (9.8):** you'll be testing thermistors, EEVs, and IPM boards — parts that don't exist on the fixed-speed equipment you've studied so far.

5. Bench procedure — see the drive chain, hear the modulation

1. **Panels-off tour (power OFF, instructor unlocks/opens):** Instructor points out, in order, the rectifier, the DC bus capacitor(s), the IPM/inverter board, and the compressor terminals. Student sketches the four-stage chain from memory afterward — no looking.
2. **DC bus safety briefing (mandatory before power goes back on):** The DC bus capacitor(s) can hold 300+ volts DC for minutes after power is cut — long after the compressor stops making noise. This is NOT a "just wait 5 minutes like a run capacitor" situation on every brand; some units need a bleed resistor to discharge or a meter-verified check before board work. **Rule for this whole unit: nobody touches a board with a meter until Lesson 9.8, under direct supervision, with a documented discharge check.** Today is look, not touch.
3. **Power up, panels reinstalled, unit running.** Set the indoor head to a small, easy call (a couple degrees off setpoint) and let the compressor idle at low speed. Clamp the compressor common wire and read frequency-adjacent behavior: listen to the pitch and the fan speed.
4. **Force a big call** (open a door, crank the setpoint hard) and listen again. The compressor sound changes pitch, the outdoor fan speeds up, the whole unit gets audibly "louder and higher" without ever shutting off first. That pitch change IS the frequency changing — you're hearing Hz.
5. **Side-by-side, if a fixed-speed unit is available:** start it and listen to the hard clunk-and-slam of the contactor pulling in at full speed immediately, versus the mini-split's soft ramp-up. Students narrate the difference out loud in their own words.
6. **Find the missing capacitor.** Have the student locate where a run capacitor "should" be on the compressor circuit (by comparison to Lesson 3.5/3.6 wiring) and confirm there isn't one — then explain why, unprompted.

Checkout (graded, pass/redo): Student draws the four-stage inverter drive chain from memory, labels each stage's approximate voltage/state (AC in, DC ~310–380V, variable AC out), and explains in one paragraph why an inverter system's gauge readings can't be judged against a single fixed target the way Unit 5's charging lessons taught. This is the mental-model checkout for Competency 48 — hands-on install skills open in Lesson 9.2.

6. Field gotchas

- **"It's not making a fixed pressure, something's wrong" is a rookie panic, not a diagnosis.** A tech trained only on fixed-speed equipment will see gauges drift up and down

over a few minutes and assume a failing TXV or a hunting system. On an inverter unit, that drift is often just the board changing compressor speed to match load — completely normal. Confirm against service data (Lesson 9.6) before you condemn anything.

- **DC bus capacitors are a real electrocution risk, and they don't announce themselves.** Unlike a compressor's run capacitor (which most techs have been trained since Unit 3.5 to respect), the DC bus lives inside a control board assembly and looks like "just electronics." It isn't. Treat every inverter board as energized until you or your instructor has verified a safe discharge.
- **Oversizing kills the whole benefit.** An inverter unit sized too big for the space spends most of its life at minimum modulation and still short-cycles — you lose the efficiency and comfort story that's the entire reason to sell/install this equipment. Sizing discipline (Lesson 9.2, and the load-calc content in Unit 12) matters more here than on fixed-speed gear, not less.
- **BLDC fan motors (indoor and outdoor) are also inverter-driven** — they're 5-wire, DC, and speed-commanded by the board, not the simple PSC/ECM motors from Unit 6. Don't wire-nut into one like a conventional fan motor; that's Lesson 9.8 territory.
- **Every major brand does this the same way underneath** (Mitsubishi, Daikin, Fujitsu, Gree, Samsung, MrCool) even though the board layouts, fault codes, and service menus differ brand to brand. Learn the concept here once; the brand-specific navigation is a smaller lift once the underlying idea is solid.

7. Competency link

- **Competency 48 (opens)** — this lesson lays the theory foundation for "install single-zone ductless mini-split systems"; the install itself is Lesson 9.2, and the competency completes across 9.2–9.5.
- Sets up every lesson in Unit 9: 9.6 (commissioning via service data), 9.7 (fault codes), 9.8 (component testing) all assume the drive-chain mental model from this lesson.
- Cross-references: Lesson 1.1 (refrigeration cycle — still true, just modulating), Lesson 3.5 (capacitors — why compressor caps don't exist here), Lesson 6.1 (motor types — BLDC as the family this unit's motors belong to).

8. Check yourself

1. Name the four stages of the inverter drive chain in order, from utility power to the compressor motor.
2. Why doesn't an inverter compressor need a start or run capacitor?
3. A fixed-speed compressor's capacity control is on/off cycling. What is an inverter compressor's capacity control?
4. Approximately what voltage does the DC bus capacitor hold, and why is that dangerous even with the unit powered off?

5. You watch gauge pressures drift slowly up and down over several minutes on a running, otherwise-healthy mini-split. Is that automatically a fault? What should you check before condemning anything?
 6. Why can't you charge a mini-split to a single fixed superheat/subcooling number the way you would a Unit 5 fixed-speed system?
 7. What kind of motor does a mini-split typically use for its indoor and outdoor fans, and how is it different from what you studied in Unit 6?
 8. Name two comfort or efficiency benefits customers get from inverter modulation, in plain language you could say on a sales call.
 9. True or false: every brand of mini-split uses a completely different underlying technology to achieve variable speed. Explain your answer.
 10. What is the ONE thing this program says you may NOT do to an inverter board before Lesson 9.8, no matter how confident you feel?
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