

Heat Pump Wiring, Explained: Every Wire, Where It Goes, and Why

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 0 • Start Here • Read after Lesson 0.1 Class time: ~5 hrs (2 reading + 3 at the shop unit with the panels off and a meter in your hand)

1. What you'll be able to do

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

- Explain the **two separate electrical systems** in every heat pump, the big 240 V power side and the small 24 V control side, and never mix up which one you are touching.
- Name every thermostat terminal on a heat pump (**R, C, Y, G, O/B, W2/AUX, E**, and the extras) and say in plain words what turns on when each one gets 24 volts.
- Trace the **power path** from the breaker to the compressor, the fan, the blower, and the heat strips, and name every part the power goes through on the way.
- Trace the **control path** from the transformer through the thermostat to the contactor, the reversing valve, the defrost board, the blower relay, and the sequencers.
- Wire a heat pump from scratch: thermostat to air handler, air handler to outdoor unit, and the big wires to both units.
- Put a meter on the right two points to find out why something is not turning on.

Everything here is written plain on purpose, but it is all of it. If you learn this chapter, Unit 3 and Unit 6 will feel like review.

2. Tools & materials

- The shop heat pump: outdoor panel off, air handler door off, thermostat on the wall
- Multimeter with AC volts and ohms, and a clamp meter
- Thermostat wire (18/8), wire strippers, small flat screwdriver for the terminal strip
- The wiring diagram glued inside each unit's panel (the one that wins every argument)
- Safety glasses, and the lockout rule from Lesson 3.8: pull the disconnect and flip the breakers before your hands go in

3. Watch first

Order	Video	Channel	Length	Why
1	Understanding Low Voltage Wiring for AC and Heat Pumps 3D	HVAC School	15:12	See the 24 V side as a picture before you touch it
2	Heat Pump Thermostat Wiring Explained: Colors, Terminals, Functions, Circuit Path	AC Service Tech	9:34	Every terminal on a heat pump stat
3	How an Air Handler and Heat Pump Work and Are Controlled by 24 V Thermostat Wires	AC Service Tech	19:29	The whole control path, both units
4	Air Handler with Electric Strip Heating: Operation and Troubleshooting	AC Service Tech	15:39	The strip heat side of the air handler
5	Heat Sequencer Operation, Timing, and Testing	AC Service Tech	8:26	What a sequencer is and how to test it
6	HVAC Contactor Operation, Types, Ratings, Problems, Testing	AC Service Tech	16:06	The big switch outside
7	HVAC Compressor Training: Capacitor Wiring, Hard Start Kits and Voltage Drop	HVAC School	47:46	C, S, R, HERM, FAN, all of it
8	How the Reversing Valve Works in a Heat Pump	AC Service Tech	10:29	What O/B is actually moving
9	Heat Pump Defrost Cycle and Heat Strip Wiring Safety	HVAC School	16:29	The defrost board and why strips run during defrost
10	Finding Low Voltage Shorts Fast	AC Service Tech	11:42	When the fuse keeps blowing

4. The idea

4.1 Two systems, one machine

Every heat pump has two electrical systems living side by side in the same cabinets.

	The power side	The control side
Voltage	240 V (and 120 V for some blowers)	24 V
Wire	Fat. 10, 8, 6 AWG	Thin. 18 AWG thermostat cable
Job	Does the work. Spins the compressor, the fans, heats the strips	Gives the orders. Tells the power side when to run
Comes from	The breaker panel	A transformer inside the air handler
Can it hurt you	Yes. It can kill you	It can shock you a little and blow a fuse, but it will not kill you
Color code	Black, red, white, green, bare	Red, blue, yellow, green, white, orange, brown

Think of a car. The battery and starter are the power side. The key is the control side. The key does not spin the engine. It closes a switch that lets the battery do it. In a heat pump the thermostat is the key, and the contactor, relays, and sequencers are the switches it closes.

4.2 Where the 24 volts comes from

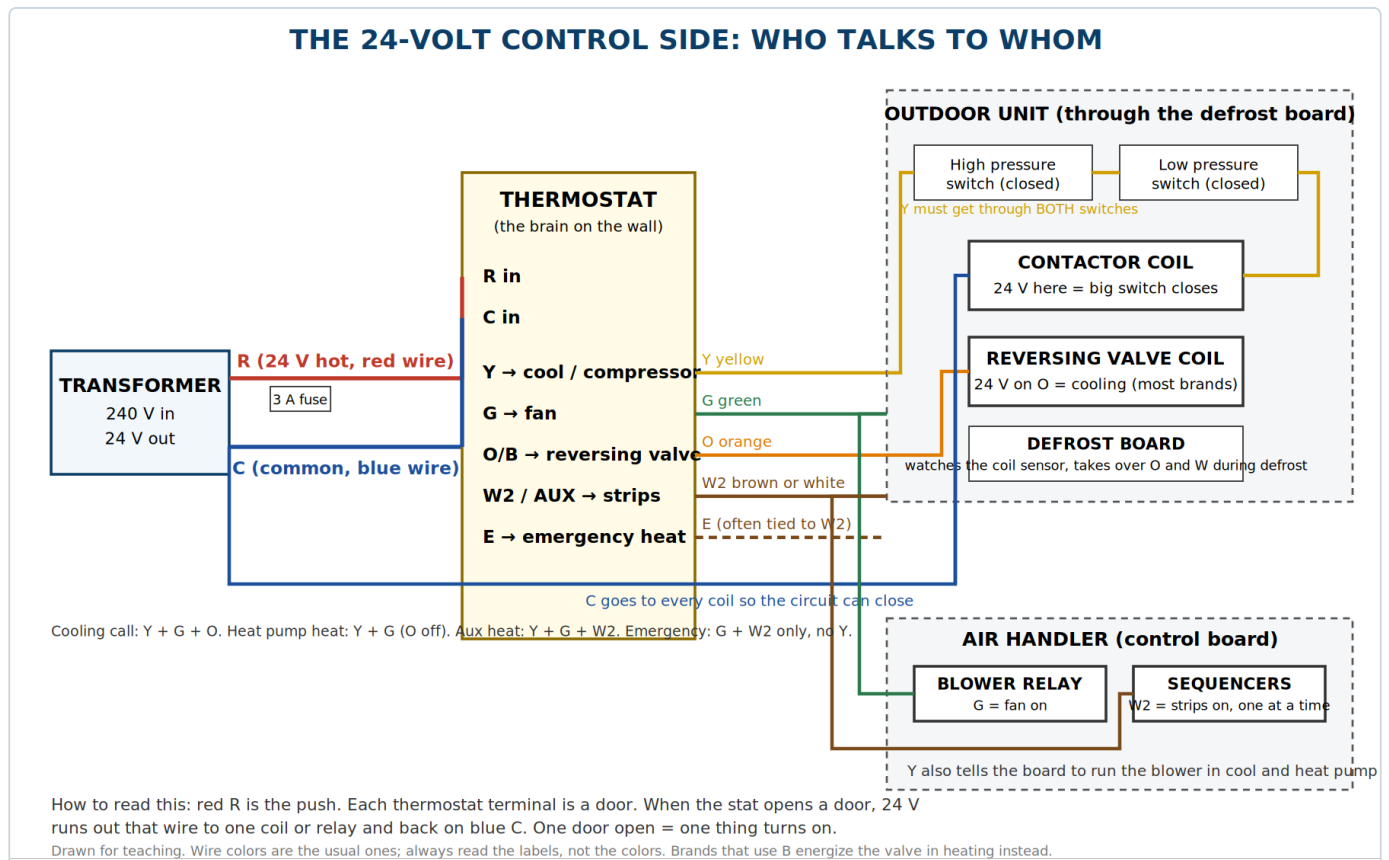
Inside the air handler is a **transformer**. It is a small block with two pairs of wires. The 240 V (or 120 V) side is called the **primary**. The 24 V side is called the **secondary**. The transformer takes the big power and makes a small, safe copy of it.

The two 24 V wires coming out are named **R** and **C**.

- **R** is the hot side. Red wire. Think "R for Red, R for the push."
- **C** is the common, the return path. Usually blue, sometimes black or brown. Think "C for Come back."

Every 24 V circuit in the whole system is just R going out through a switch, through a coil, and back to C. That is the entire secret. If you understand R-switch-coil-C, you understand the control side.

There is a little **3 A or 5 A fuse** on the air handler board, right on the R side. It is the only thing protecting the transformer. If a thermostat wire gets chewed and touches ground, that fuse blows instead of the transformer burning up. When you find a blown fuse, something is shorted. Find it before you put a new fuse in.



4.3 The thermostat: a box of doors

The thermostat gets R and C from the air handler. Inside it are switches. When you set it to cool and the room is warm, it closes a switch between R and Y. Now 24 V runs out the Y wire. That is all a "call for cooling" is: 24 V on Y.

Here is every terminal on a heat pump thermostat, what color the wire usually is, and what gets 24 V when the stat closes that door.

Terminal	Usual color	What it means	What it turns on
R (or Rc/Rh)	Red	24 V hot coming in	Nothing by itself. It is the supply
C	Blue (sometimes black)	Common, the return	Nothing by itself. It is the return. The stat needs it to power its screen
Y (or Y1)	Yellow	Run the compressor	The contactor coil outside. On a heat pump, Y runs in cooling AND in heating. The compressor is always what makes heat move; O/B just picks the direction
G	Green	Run the indoor fan	The blower relay on the air handler board
O/B	Orange (O) or blue/dark blue (B)	Which direction. Flip the reversing valve	The reversing valve solenoid outside. O brands energize it in cooling. B brands energize it in heating
W2 / AUX (sometimes W1)	White or brown	Help. The heat pump cannot keep up	The sequencers in the air handler, which bring the heat strips on, with the compressor still running
E	Brown or tan	Emergency. Compressor off, strips only	The sequencers again, but the stat drops Y. On most air handlers E and W2 land on the same place
Y2	Light blue	Second stage compressor (two-stage units)	A second input on the outdoor board
L / X	Tan or gray	A light. "Something is wrong"	Lights an indicator on the stat when the outdoor board says fault or when the stat is in emergency
DH / Hum	Varies	Dehumidify or humidifier	Only on some systems

Most heat pumps use these six: **R, C, Y, G, O, W2**. That is why thermostat cable for a heat pump is 18/8: eight wires, so you have spares for E and Y2.

What the stat sends in each mode. This is the table to memorize.

Mode	Y	G	O (on an O brand)	W2	What is running
Cooling	on	on	on	off	Compressor, outdoor fan, blower. Valve in cooling position
Heat pump heating	on	on	off	off	Compressor, outdoor fan, blower. Valve in heating position
Aux heat (cold day)	on	on	off	on	All of the above, plus the strips come on to help
Emergency heat	off	on	off	on (via E)	Blower and strips only. Outdoor unit stays off
Fan only	off	on	off	off	Blower only
Defrost (the board does this, not the stat)	on	on	on (board forces it)	on (board forces it)	Valve flips to cooling for a few minutes to melt ice. Strips come on so the vents do not blow cold. Outdoor fan stops

The O versus B thing is the one that bites new techs. On Trane, Carrier, Goodman, Lennox, Rheem's newer stuff, and most others, the valve coil gets 24 V in **cooling**, so you use O. On older Rheem and Ruud, the coil gets 24 V in **heating**, so you use B. Set it wrong and the house gets heat on a cool call. The thermostat has a setting for it. The wire lands on the same terminal either way; only the setting changes.

4.4 Thermostat wire: the cable itself

- **18/8** means eight 18-gauge wires in one jacket. Use 18/8 on every heat pump. 18/5 is for straight AC with a furnace and will leave you a wire short.
- One cable runs from the **thermostat to the air handler**. Another runs from the **air handler to the outdoor unit** (usually only four wires used: Y, C, O, and sometimes a wire for the fault light or Y2).
- Strip 3/8 inch, wrap clockwise under the screw or push straight into the spring clip, pull on it to prove it is tight.
- Keep it away from the big wires, do not run it through the same hole as the whip, and never staple through it. At the outdoor unit, leave a drip loop so rain runs off the wire, not into the cabinet.
- Label both ends. Tape with the letter on it. The next tech, which is probably you, will thank you.

4.5 Outside: what the 24 volts does when it gets there

The Y wire and the C wire arrive at the outdoor unit. Before Y reaches anything it goes through the **safety switches in series**, meaning one after the other on the same wire:

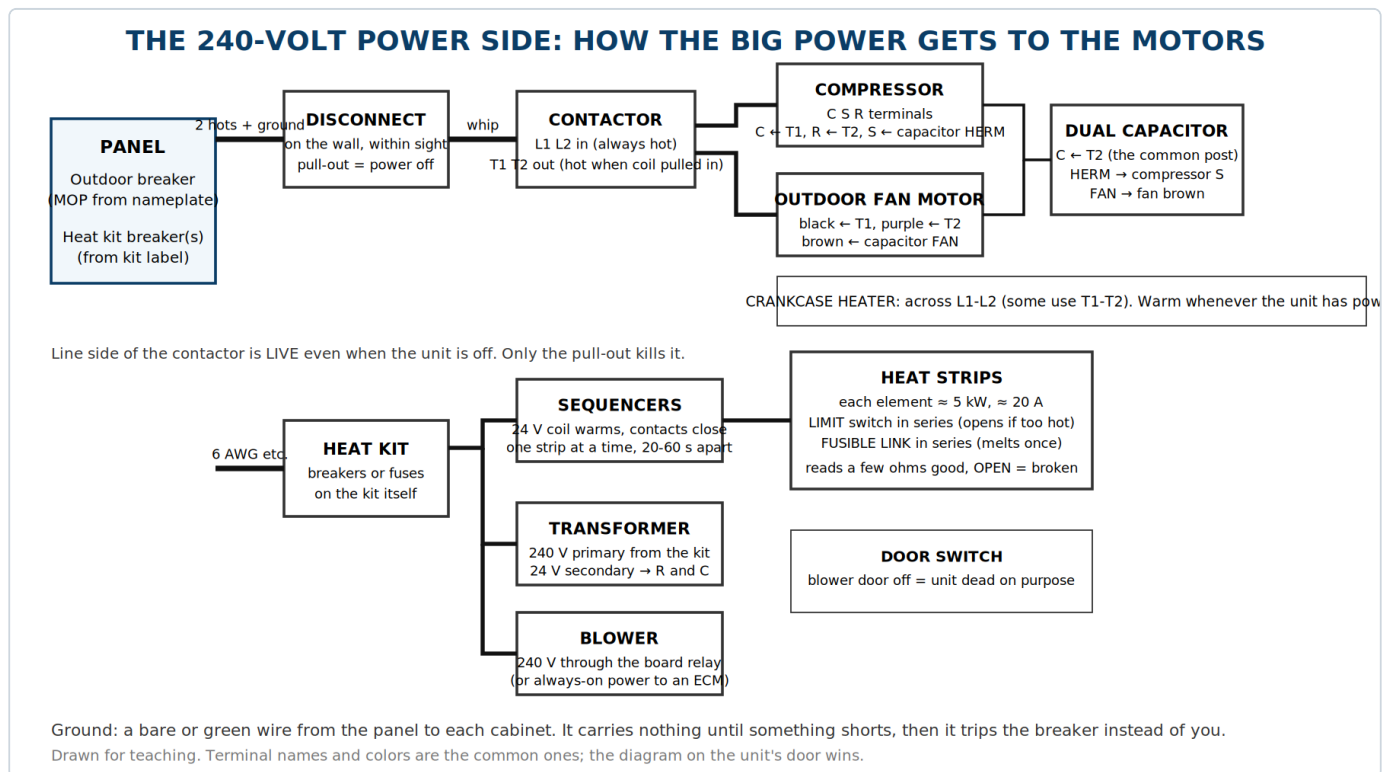
1. **High pressure switch.** Closed normally. Opens if the head pressure goes crazy (dirty coil, dead fan). Y stops here.
2. **Low pressure switch.** Closed normally. Opens if the pressure drops too low (refrigerant leaked out, iced coil). Y stops here.

"In series" means all of them have to be closed for Y to get through. If any one opens, the contactor never pulls in, and the unit sits there with the fan off and the compressor off. When you meter across a switch and read 24 V, that switch is the open one. A closed switch reads 0 V across it, because both sides are the same.

Then Y arrives at the **contactor coil**. The coil is a little electromagnet. 24 V on it (Y on one side, C on the other) pulls the big switch closed, and 240 V flows to the compressor and fan. Take the 24 V away and a spring pushes it back open.

The O wire arrives at the **reversing valve solenoid**. It is a coil wrapped around a pin on the valve. 24 V on it (O on one side, C on the other) pulls the pin and slides the valve. Take it away and a spring slides it back. On an O brand, 24 V means cooling. You can hear it click when the stat changes mode, and you can feel the valve body change which line gets hot.

On a heat pump, Y and O do not go straight to those coils. They go through the **defrost board** first. The board passes them through most of the time. During defrost it takes over: it energizes O on its own (flipping the valve to cooling), turns off the outdoor fan, and sends 24 V back to the air handler on W to bring the strips on. The board also has terminals for R, C, the **defrost sensor** (a thermistor clipped to the outdoor coil), the outdoor fan relay, and a pair of **test pins** you short with a screwdriver to force a defrost.



4.6 Outside: the power side, wire by wire

Now the 240 V. It goes like this:

1. **Breaker in the panel.** Two-pole, sized to the nameplate MOP. Two hot wires and a ground come out of it. There is no neutral on a 240 V outdoor unit.

2. **Disconnect** on the wall within sight of the unit. The two hots land on the line side. A pull-out block or a lever breaks both. Pull it and the unit is dead. Leave it in your pocket while you work.
3. **Whip** from the disconnect to the unit: 3/4 inch liquid-tight flex with the two hots and the ground inside.
4. **Contactor, line side**: the two hots land on **L1** and **L2**. These two lugs are live all the time, even when the unit is off. Only the disconnect kills them.
5. **Contactor, load side**: **T1** and **T2**. Live only when the coil is pulled in. From here the power goes to the loads.
6. **Compressor**: three terminals under a cover, **C** (common), **S** (start), **R** (run). T1 goes to C. T2 goes to R. S goes to the capacitor's HERM post. The compressor cannot start without the capacitor giving the S winding its push.
7. **Dual run capacitor**: three posts. **C** (common, gets a hot from T2), **HERM** (goes to compressor S), **FAN** (goes to the fan motor's brown wire). The can says two numbers like 45+5 μ F: 45 for the compressor, 5 for the fan.
8. **Outdoor fan motor**: typically black to T1, purple (or another color) to T2 or the cap's C post, brown to the cap's FAN post, and brown-with-white-stripe also to the cap's C post. Read the motor's label. Fan motors vary more than anything else out here.
9. **Crankcase heater**: a band or belt around the compressor, wired across L1 and L2 on most units so it is warm whenever there is power, even with the unit off. On some it is across T1 and T2 with a switch.
10. **Ground**: the bare or green wire lands on the green screw in the cabinet. Every metal box gets one. It does nothing until a hot wire touches the case, then it trips the breaker instead of making the case live.

A **hard start kit** is a start capacitor and a relay you add in parallel with the run capacitor to give a tired compressor a bigger shove. It is a legitimate fix for a compressor that hums and trips on start, not a vitamin for a healthy one.

A **single-pole contactor** (common on residential) only breaks one leg. The other leg is live at the compressor all the time. That is why you pull the disconnect and do not trust the contactor being open.

4.7 Inside: the air handler, wire by wire

The air handler has its own breaker or breakers, sized from the heat kit's label, because the strips are the biggest load in the house.

1. **Breaker(s)** in the panel. A 10 kW kit takes one 60 A breaker on 6 AWG. A 15 or 20 kW kit usually takes two circuits. The kit's label tells you.
2. The big wires land on the **heat kit's own breakers or fuse block**, which is the first thing inside the air handler. Those protect the strips.
3. From the kit, 240 V feeds three things: the **sequencers** (which feed the strips), the **transformer primary** (which makes the 24 V), and the **blower**.

4. **Sequencers:** a sequencer is a slow switch. It has a little heater inside. Put 24 V on its coil terminals and the heater warms a bimetal strip, and 20 to 60 seconds later its contacts close and 240 V goes to one heat strip. Take the 24 V away and it cools and opens, again with a delay. Several sequencers in a kit are set to close one after another, so a 15 kW kit comes on in three steps instead of slamming 60 A onto the line at once. Terminals are usually marked **M1 and M2** for the 240 V contacts and a pair for the 24 V coil. Some kits use **relays** instead of sequencers; same job, no delay.
5. **Heat strips:** each strip is a coil of wire about 5 kW, which draws about 20 A at 240 V. In series with every strip are two safeties: a **limit switch** (a disc that opens when the air around it gets too hot, usually around 140 to 160°F, and closes again when it cools) and a **fusible link** (a one-time fuse that melts if the limit fails; when it melts, you replace it, and you find out why the air got that hot first). A strip reads about **10 to 20 ohms** on your meter with the power off. Open means it is broken.
6. **Transformer:** 240 V in on the primary, 24 V out on R and C. Some have extra taps for 208 V. Land the right one or the 24 V comes out low.
7. **Control board:** gets R and C from the transformer. Has the thermostat terminal strip (R, C, Y, G, W, O, E). Has the **blower relay** that sends 240 V to the blower when G is on, or when Y is on, or when W is on. Has the 3 A fuse. On an ECM blower, the board sends low-voltage signals to the motor instead of switching the 240 V.
8. **Blower:** a PSC blower gets 240 V through the relay, picks its speed from which tap wire is on the relay (low, medium, high), and needs its own run capacitor. An ECM blower gets 240 V all the time plus a signal plug from the board that tells it how hard to run.
9. **Door switch:** a plunger switch on the blower compartment. Door off, switch open, blower and 24 V dead. It keeps your fingers out of the wheel. If the unit is dead and the door is off, push the switch in.
10. **Float switches:** wired into the 24 V, usually breaking the R wire to the stat or the Y wire. Float goes up, the circuit opens, the unit stops. Wire them so that a full pan kills the compressor, not just the blower.
11. **Ground** to the cabinet, same as outside.

4.8 The whole story on a cooling call

Put it together once, slowly, with the power side and the control side both in the picture.

1. Thermostat is set to cool at 72. The room hits 73. Inside the stat, R connects to Y, G, and O.
2. 24 V leaves on G to the air handler board. The blower relay closes. 240 V reaches the blower. Air moves.
3. 24 V leaves on Y through the thermostat cable to the air handler board, out the other cable to the outdoor unit, through the defrost board, through the high pressure switch (closed), through the low pressure switch (closed), to the contactor coil, and back on C. The coil pulls the contactor in. 240 V jumps from L1-L2 to T1-T2. The compressor starts with a push from the capacitor's HERM side. The fan starts with a push from the FAN side.

4. 24 V leaves on O, through the defrost board, to the reversing valve solenoid, and back on C. The valve slides to the cooling position. Hot gas goes to the outdoor coil, cold refrigerant goes to the indoor coil.
5. The room cools to 72. The stat opens Y, G, and O. The contactor drops out, the compressor and fan stop, the solenoid releases, and after a short delay the blower relay opens.

On a heating call it is the same story with O off, so the valve sits the other way and the indoor coil is the hot one. On a cold morning when the heat pump cannot keep up, the stat adds W2: 24 V to the sequencers, which bring the strips on one at a time behind the blower, with the compressor still running. When the stat is set to Emergency, it drops Y and keeps W2, so only the blower and strips run.

4.9 Wiring it from scratch: the order

1. Lock out both breakers. Pull the outdoor disconnect.
2. Run 18/8 from the stat to the air handler and 18/8 from the air handler to the outdoor unit.
3. At the **air handler board**, land: R, C, Y, G, O, W2 (and E on E if the board has a separate E; if not, put E with W2). Land the outdoor cable's Y, C, O on the same Y, C, O.
4. At the **outdoor unit**, land Y and C on the defrost board's Y and C (or on the contactor coil if there is no board), and O on the board's O.
5. At the **thermostat**, land R, C, Y, G, O/B, W2/AUX, E. Set it to Heat Pump. Set O or B per the brand. Set Aux heat to Electric.
6. Land the big wires: outdoor breaker to disconnect to L1 and L2 on the contactor, ground to the green screw. Heat kit breaker(s) to the kit's lugs, ground to the cabinet.
7. Check the transformer tap matches your voltage.
8. Put the panels and the blower door back on. Power up. Run every mode from the table in 4.3 and watch the right things turn on.

4.10 Where to put the meter

You want to know	Meter across	Good reading
Do I have 24 V at all?	R to C at the air handler board	24 to 28 V AC
Is the stat calling for cool?	Y to C at the board	24 V with a cool call
Is the call getting outside?	Y to C at the outdoor unit	24 V
Which pressure switch is open?	Across each switch, one at a time	0 V = closed (good). 24 V = this one is open
Is the contactor coil getting its signal?	The two coil terminals	24 V during a call
Is the contactor passing power?	L1 to L2, then T1 to T2	Both about 240 V during a call. 240 in and 0 out = burnt contacts
Is the capacitor good?	Power off, discharged, meter on μF , C to HERM and C to FAN	Within 6 percent of the numbers on the can
Is the compressor winding good?	Power off, C-S, C-R, S-R	A few ohms each. C-S plus C-R equals S-R. Nothing to the case
Is the valve getting its signal?	O to C at the outdoor unit	24 V in cooling (O brand), 0 in heating
Are the strips being told to run?	W2 to C at the board	24 V with an aux call
Is a strip broken?	Power off, across each element	10 to 20 ohms. Open = broken
Is a sequencer working?	24 V across its coil, then 240 V on its contacts a minute later	Coil 24 V, contacts pass 240 V after the delay
Is the blower getting power?	Across the motor's power leads during a G call	240 V (or 120 V on a 120 V blower)
Is the fuse blown?	Power off, ohms across the fuse	Near 0 ohms. Open = blown, go find the short

5. Bench procedure

1. **Lockout.** Pull the disconnect, flip the breakers, meter L1-L2 at the contactor to prove 0 V.
2. **Trace and tag.** With the panels off, put a piece of tape on every 24 V wire in the outdoor unit and write what it is: Y, C, O, fan, sensor. Do the same at the air handler board. Photograph it.
3. **Draw it.** On paper, draw the control map from this chapter for the shop unit, in the shop unit's actual wire colors. Compare it to the diagram on the panel door.
4. **Power up and prove each mode.** Set the stat to each mode in the 4.3 table. At the board, meter Y, G, O, W2 to C and write down which ones have 24 V. They should match the table.

5. **Follow Y outside.** During a cool call, meter Y to C at the outdoor unit, then across each pressure switch, then at the contactor coil. Write the readings.
6. **Catch the valve.** Switch heat to cool with the unit running. Listen for the click. Feel which copper line gets hot.
7. **Force a defrost.** Short the test pins with the unit in heat. Watch the fan stop, hear the valve click, and meter W to C at the air handler to see the board calling for strips.
8. **Pull a strip.** Power off. Ohm each element and each sequencer coil. Write the readings.
9. **Checkout.** Your journeyman pulls one wire somewhere in the control side without telling you where. Find it with the meter in under ten minutes, using the table in 4.10, and say what it was before you look.

6. Field gotchas

- **O versus B.** Heat on a cool call. Check the brand and the stat setting before you condemn a reversing valve.
- **Y only breaks one place.** Techs land the outdoor Y on the stat cable and forget to land the air handler's Y, so the blower never runs on a cool call. The board needs to see Y too.
- **E and W2 on the same terminal.** Fine on most air handlers. On a few, landing E on W makes emergency heat also run the compressor. Read the board.
- **No C wire at the stat.** Old houses ran 18/5 and skipped C. A smart stat will not stay alive. Run new 18/8 or use the spare if there is one.
- **Thermostat wire in the whip.** Never. The 240 V next to the 24 V makes false signals and can fry the board.
- **Shorted at the outdoor unit entry.** The cable rubs through on the sheet metal edge. The 3 A fuse pops every time the compressor call comes. Grommet it.
- **Float switch wired to break G.** Fan stops, compressor keeps running, coil freezes, pan still fills. Break R or Y, so the compressor stops.
- **Breaker sized to the old wire.** MCA sets the wire, MOP caps the breaker. Both from the nameplate. A 60 A breaker on 10 AWG is not a breaker, it is a fire.
- **208 V tap.** Transformer on the 240 tap in a 208 V building reads 21 V out. Relays chatter. Move the tap.
- **Trusting the contactor to be off.** The line side is always live. One leg may be live past the contactor on a single-pole. Pull the disconnect. Every time.
- **Capacitor not discharged.** It holds a charge with the power off. Short across the posts with an insulated screwdriver before you unplug the wires.
- **Wire colors as gospel.** Colors are a habit, not a rule. The last tech may have used whatever was in the truck. Trust the terminal letters and the meter.

7. Competency link

This chapter previews Competencies 6 (electrical fundamentals) and 9 (thermostat wiring), which sign in Units 3 and 6, and Competencies 19, 20, 24, and 26 (contactors and capacitors, electrical

diagnosis, heat pump controls, defrost systems), which sign in Units 6 and 8. Nothing signs here. Know this chapter cold and those units will go fast.

8. Check yourself

1. Name the two electrical systems in a heat pump, their voltages, and where each one comes from.
2. What are R and C, and what color are they usually?
3. On a heat pump, which thermostat terminals get 24 V on a cooling call? On a heat pump heating call? In emergency heat?
4. Why does Y run in both cooling and heating on a heat pump?
5. What does O do, and what is the difference between an O brand and a B brand?
6. Y goes through two switches before it reaches the contactor coil. Name them and say what "in series" means.
7. You read 24 V across the low pressure switch. What does that tell you?
8. Name the three compressor terminals and which contactor or capacitor post each one connects to.
9. What is a sequencer, and why does a heat kit use several of them instead of one big switch?
10. Name the two safeties in series with every heat strip and what each one does.
11. The 3 A fuse on the board is blown. What do you do before you put a new one in?
12. Why do you pull the disconnect instead of trusting the contactor being open?

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