

Meters and Testers for Houses

YES Electric • NEC 2026 with NEC 2023 numbers in parentheses

Draft 1 (October 2026). This chapter is under review. Code numbers are NEC 2026. Your local inspector may use an earlier edition, so ask your journeyman which one applies. Boxes marked "Picture coming" will get drawings and photos in a later version.

Phase 2, Troubleshooting and Service Calls. Every diagnosis in R2.3 through R2.9 rests on the readings this chapter teaches. Learn them on the training wall before you use them in a customer's house.

Before this module: R1.1 (safety, tools, and the service truck) and R2.1 (the service call). You should know live-dead-live from R2.1.

Code edition. Code references are NEC 2026. Where a section moved, the NEC 2023 number is in parentheses. The local inspector (the AHJ, "authority having jurisdiction") may enforce an earlier edition, so ask your journeyman which one applies before you quote a section to anyone.

Learning Objectives

When you finish this module you will be able to:

1. Use the seven residential testers (non-contact tester, plug-in receptacle tester, GFCI tester, multimeter, clamp meter, circuit tracer, and spot thermometer) and say what each one cannot tell you.
 2. Read the six voltage patterns at a receptacle: healthy, open hot, open neutral, open ground, reversed polarity, and bootleg ground.
 3. Measure current on a running circuit with a clamp meter and compare it to the breaker.
 4. Measure voltage drop under load at the far end of a circuit and compute the percent.
 5. Find which breaker feeds an outlet with a tracer, and follow a hidden cable with a toner.
 6. Pick and check a meter that is safe for panel work.
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Background: Why the Meter Comes First

You cannot see electricity. You see its effects: a light that comes on, a breaker that trips, a smell. The meter turns the invisible part into numbers you can write down. Kuhlman calls the meter the most important tool after your hand tools and screw gun, and he wants one that reads volts (AC and DC), ohms, and amps (Kuhlman, Residential Electrical Troubleshooting, p. 11).

Each tester answers one question. A non-contact tester answers "is there voltage near this wire?" A plug-in tester answers "is this receptacle wired in one of a few common ways?" A multimeter answers "how many volts are between these two points?" A clamp meter answers "how many amps are flowing in this wire?" None of them answers every question, and the cheap ones lie in ways you need to know. A tech who knows what each tool cannot tell you does not get fooled by it.

Words you need

Word	Meaning
Hot	The wire that carries voltage from the breaker. Usually black or red. Also called the ungrounded conductor.
Neutral	The wire that carries current back to the panel. White or gray. Also called the grounded conductor.
Ground	The bare or green wire that carries fault current back to the panel so the breaker trips. Also called the equipment grounding conductor. It carries no current when everything is working.
Leg (L1, L2)	A house gets two hot legs from the utility. Each leg is 120 V to neutral. The two legs together are 240 V.
Voltage (V)	Electrical pressure between two points. You always measure voltage between two points.
Current (A, amps)	How much electricity is flowing through a wire. You measure it in one wire at a time.
Resistance (Ω , ohms)	How hard it is for current to flow. Only measured on a dead circuit.
Continuity	A complete path with very low resistance. The meter beeps.
OL	"Over limit" or "open loop." The meter display for a reading too high to measure, which on the ohms setting means an open path.

The house layout you are testing

A typical house has a 120/240 V split-phase service. At the main panel, the neutral bar and the ground bar are bonded together, and the neutral is connected to the grounding electrode system (rods, water pipe, or the footing). That bond is why the neutral and ground read close to 0 V apart at a healthy receptacle, and why they show continuity to each other on a dead circuit (Kuhlman, p. 43). In a subpanel, the neutral and ground are kept separate. The bond happens only at the service.

Breakers in a standard residential panel alternate legs as you go down each side. Two breakers stacked next to each other on the same side are usually on different legs. A two-pole breaker takes one space on each leg, which is how it gets 240 V. If you need a second receptacle on the other leg for a comparison reading, find one on a breaker in the next space down.

Picture coming: A simple drawing of a residential panel interior with the bus stabs shown alternating L1 (black) and L2 (red) down each side. Single-pole breakers labeled "L1, 120 V" and "L2, 120 V." One two-pole breaker spanning both, labeled "L1 + L2 = 240 V." The neutral bar and ground bar at the side, with the main bonding jumper drawn and labeled "Bonded here, at the service only."

Part A: Meter Safety Before Anything Else

A1. Pick a meter rated for the place you use it

Meters are rated in measurement categories (CAT) by the IEC 61010 standard. The category tells you how big a voltage spike the meter can survive without blowing apart in your hand. The closer you get to the utility, the bigger the spikes.

Category	Where in a house	What you use there
CAT II	Receptacles and plug-in loads	Plug-in testers are usually CAT II
CAT III	Panels, breakers, feeders, hardwired appliances	Minimum for any meter you put inside a panel
CAT IV	The meter base, the service drop, the service entrance conductors before the main	Only with your journeyman, and only a meter rated CAT IV

Use a meter and test leads rated CAT III 600 V or better for all panel work. Commercial Module 2.2 explains that a cheap CAT II meter can explode on a fault in a high-energy system. The service at a house can deliver thousands of amps into a short, so the same rule applies.

Safety: check the leads. Before every call, look at the full length of both leads. Any crack, cut, or exposed metal means replace the leads. Use leads with finger guards and probe tip shrouds. Use the short-tip caps that came with the leads for panel work, so a probe cannot bridge two terminals.

A2. Put the leads in the right jacks

Most multimeters have three or four jacks:

Jack	What goes in it
COM	Black lead, always
V Ω (often with a diode or beeper symbol)	Red lead for volts, ohms, and continuity
A or 10 A	Red lead only for measuring current in series. You will almost never use this on a service call. Use the clamp meter for current.
mA / μ A	Red lead for small currents in series. Not used on residential service.

Safety: never measure volts with the red lead in an amps jack. The amps jack is close to a dead short inside the meter. Touching a live receptacle or a panel with the lead in the amps jack causes a flash and can blow the meter's fuse, or the meter, at your hand. Before every reading, look at where the red lead is plugged in. Good meters have fused current inputs. Check that yours does.

A3. Live-dead-live, every time

1. Prove the meter on a known live source. A receptacle you know works is fine. It should read about 120 V.
2. Test the thing you are about to call dead.
3. Prove the meter on the known live source again.

If step 3 fails, your step 2 reading means nothing. A dead battery, a blown fuse, or a broken lead reads 0 V on a live wire.

A4. Hold the probes the safe way

1. Hold each probe behind its finger guard.
 2. When you can, clip or hook the black lead to the neutral or ground first, then touch the red lead to the hot.
 3. Keep your other hand away from the panel or box, out of the current path.
 4. Wear safety glasses for any reading inside a panel or an open box.
 5. Do not lean on the panel or rest your arm on metal while you read.
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Part B: The Seven Testers

B1. Non-contact voltage tester (NCV)

What it does. It lights or beeps when it senses the electric field around a live conductor. You hold the tip next to a wire, a receptacle slot, or a cord.

How to use it.

1. Turn it on. Hold it to a known live receptacle's short slot. It must light or beep.
2. Hold the tip against the insulation of the wire or into the slot you are checking.
3. Move slowly. Some testers need a second to respond.
4. Prove it on the known live receptacle again.

What it cannot tell you.

- It cannot tell you how many volts. A wire at 60 V and a wire at 120 V can look the same.
- It can give a false "live" from a nearby live wire or from static. Kuhlman reports false positives from several brands and found the Fluke brand most reliable. When he doubts it, he checks

with his meter's leads, which "can't give you false readings" in the sense he means (Kuhlman, p. 11).

- It does not work through metal-jacketed cable such as BX or MC (Kuhlman, p. 11), or through metal conduit, or inside a metal box when the wire is pressed against the metal.
- It cannot tell you whether the neutral or ground is connected. A receptacle with an open neutral still lights the tester.
- A dead battery reads "not live." Prove it every time.

Use it to find out quickly which wire in a box is live. Never use it as your only check that a wire is dead before you touch it. Confirm dead with the multimeter.

B2. Plug-in receptacle tester (three-light)

What it does. You plug it into a receptacle. Three lights show a pattern, and a chart on the tester says what the pattern means: correct, open ground, open neutral, open hot, hot/neutral reversed, hot/ground reversed.

How to use it.

1. Plug it into a receptacle you know is wired correctly. Confirm the "correct" pattern.
2. Plug it into the receptacle you are checking. Read the chart.
3. Use it on every receptacle after a repair. The Arc Guide uses it as a final check on new work (Symptom 11, Step 2).

What it cannot tell you.

- It does not show voltage. A receptacle at 95 V can show "correct."
- It cannot detect a bootleg ground (Part D6). A receptacle with the neutral jumpered to the ground screw shows "correct."
- It cannot detect a loose, high-resistance connection that only fails under load.
- It cannot detect some double faults, such as a hot/ground reversal combined with an open ground.
- It cannot tell you whether the ground goes back to the panel or just to a metal box with nothing behind it.

Use it as a quick pass/fail check, not as a diagnosis.

B3. Plug-in GFCI tester

What it does. It is a three-light tester with a button. Pressing the button leaks a small current from the hot to the ground pin, which is a real ground fault. A working GFCI upstream should trip.

Why it matters. The TEST button on a GFCI receptacle tests the device's own circuit. The plug-in tester tests the protection the way a real fault would, through the ground path. The Arc Guide recommends the plug-in tester because the device's TEST button only tests the button (Part 9).

How to use it.

1. Plug it into the GFCI receptacle or a receptacle downstream of it.
2. Confirm the lights show "correct."
3. Press and hold the tester's button for up to 6 seconds. The GFCI should trip and the lights should go out.
4. Reset the GFCI.
5. Test every receptacle the GFCI is supposed to protect. Each one should trip the same GFCI.

What it cannot tell you.

- It cannot trip a GFCI on a circuit with no equipment ground. The tester needs the ground pin to create the fault. A GFCI installed on an ungrounded circuit and marked "No Equipment Ground" (NEC 406.12(D)(2)(b) and (c), 2023: 406.4(D)(2)) is tested with its own TEST button instead.
- If it fails to trip, the cause could be a failed GFCI, a GFCI wired with line and load swapped, or no GFCI on that circuit at all. You have to find out which.

B4. Digital multimeter (DMM)

This is the tool you trust. The rest of this chapter is mostly about it.

Settings you will use on a house:

Setting	Symbol	Use it for	Circuit must be
AC volts	V~ or VAC	Receptacles, switches, breakers, panel legs	Live
AC volts, low impedance	LoZ	Sorting real voltage from ghost voltage (Part D7)	Live
DC volts	V= or VDC	Batteries, some doorbell and low-voltage supplies, smoke alarm batteries	Live
Ohms	Ω	Measuring resistance of a wire, a heating element, a switch contact	Dead
Continuity	Beeper or diode symbol	Is there a complete path?	Dead

The Arc Guide's Job 9 walks through each test. It says to set the meter to the 200 V AC range or use auto-ranging. Most modern meters auto-range. Use auto-ranging if yours has it.

Safety: ohms and continuity only on a dead circuit. Prove the circuit dead with the AC volts setting first. A meter on ohms touching a live circuit can blow its fuse or the meter, and the reading means nothing.

B5. Clamp meter

What it does. Its jaws close around a wire and measure the current flowing in it without disconnecting anything.

How to use it.

1. Set it to AC amps (A~).
2. Open the jaws and close them around one conductor only. The Arc Guide says the same: encircle a single conductor (Job 9).
3. Keep the wire near the center of the jaws.
4. Read the display with the load running.

Safety: clamping inside a live panel. To clamp a single branch-circuit hot, you usually need to take the panel dead front off with the panel energized. That is live work. Do it only after your journeyman has signed you off, with safety glasses, insulated tools, and your hands outside the panel except for the clamp. Never pull on a wire to make room for the clamp. If the wire is tight, clamp it where it is or clamp it somewhere else, such as at an appliance's own wiring compartment with the cover off.

Why one wire. Current goes out on the hot and comes back on the neutral. The magnetic fields of the two cancel. Clamp a whole cable, or the hot and neutral together, and a healthy circuit reads 0 A or very close to it.

Picture coming: Two side-by-side drawings of a clamp meter. Left: jaws around only the black wire of a branch circuit, display reads "12.4 A," caption "Clamp one conductor." Right: jaws around the whole NM cable (black, white, and bare inside), display reads "0.0 A," caption "Whole cable: fields cancel, reads zero."

What a clamp meter cannot tell you.

- It reads the current that is flowing now. A load that is off reads 0.
- Most basic clamps cannot read a few milliamps accurately. For leakage (Part E4), you need a clamp with a milliamp or leakage range.

B6. Circuit tracer and tone generator

These are two different tools, and techs mix them up.

Tool	Circuit must be	What it finds
Breaker finder (plug-in transmitter plus handheld receiver)	Live	Which breaker feeds a receptacle
Tone generator (toner) and probe	Dead (most models)	Where a cable runs inside a wall or ceiling, and where it goes

Kuhlman describes both. He says the toner can usually read through walls and ceilings and is one of the most important tools after the meter, because it helps find a broken splice. The breaker tracer is most useful when you are alone and the panel is not labeled (Kuhlman, p. 11). His dead-outlet procedure uses a toner with the power off to follow the wiring (Kuhlman, pp. 79-81).

Breaker finder, step by step.

1. Plug the transmitter into the receptacle. Its light shows the receptacle is live.
2. Go to the panel. Read the receiver's instructions for calibration. Most need you to hold the receiver against one breaker and adjust sensitivity.
3. Slide the receiver slowly down each row of breakers, keeping it at the same angle.
4. The breaker that gives the strongest signal is the one. Many receivers beep loudest or light the most bars on that breaker.
5. Confirm by turning that breaker off. The transmitter's light should go out. Turn it back on.

Toner, step by step.

1. Turn off the breaker and prove the circuit dead with your meter.
2. Connect the toner's leads per its instructions. A common setup is one clip on the conductor you want to follow and the other on ground.
3. Turn the toner on and run the probe along the wall, ceiling, or floor.
4. Follow the tone. Where it stops or changes sharply, look for a box, a hidden splice, or a damaged spot.
5. Mark the path on the wall with blue painter's tape as you go.

What they cannot tell you. Tracers pick up signals that jump onto nearby cables, so a strong reading on two breakers or two cable paths happens. Always confirm by turning off the breaker or by opening the box.

B7. Spot thermometer (infrared, point-and-shoot)

What it does. It reads the surface temperature of whatever it is pointed at. It does not see inside things.

How to use it.

1. Know the spot size. Each thermometer reads an area that gets bigger the farther away you are. The ratio is printed on it, such as 12:1, which means at 12 inches it reads a circle 1 inch across. To read one breaker, get close enough that the circle fits on that breaker.
2. Read plastic, painted, or dull surfaces. Shiny bare metal (a copper lug, a bright bus bar) reflects heat from other things and reads too low.
3. Read with the circuits running. The Arc Guide says equipment should be under at least 40 percent of its normal load for a thermal check to mean anything (Part 10, "Thermal Inspection Without a Camera").

4. Compare like to like. Read the faces of breakers of the same size and similar load. The Arc Guide flags a breaker more than 25°F hotter than its neighbors as a likely loose terminal or overload (Part 10).
5. Read receptacle cover plates on a loaded circuit. A plate that is warmer than the others on the same circuit points to a loose or backstabbed connection behind it.

What it cannot tell you. It cannot see through the dead front or the cover plate. A hot connection behind a cover may only warm the cover a few degrees. Commercial Module 2.2 covers infrared cameras, which show the whole panel at once.

Part C: Reading Voltage at a Receptacle

C1. The three readings

At every receptacle you test, take three readings with the multimeter on AC volts. Write all three down.

Reading	Probes
Hot to neutral (H-N)	Red in the short slot, black in the tall slot
Hot to ground (H-G)	Red in the short slot, black in the round hole
Neutral to ground (N-G)	Red in the tall slot, black in the round hole

On a 20 A receptacle, the tall slot may be T-shaped. The T-slot is the neutral side.

C2. Step by step

1. Prove the meter on a known live receptacle.
2. Insert the black probe in the tall slot, then the red probe in the short slot. Read H-N.
3. Move the black probe to the round hole. Read H-G.
4. Move the red probe to the tall slot, keeping black in the round hole. Read N-G.
5. Read the other half of a duplex receptacle too. The two halves can differ if a tab is broken off or a backstab failed.
6. Prove the meter again.

C3. Normal values

The Arc Guide's field targets (Part 3) are a good starting point:

Reading	Normal	Act if
H-N	114-126 V	Below 110 V or above 130 V: look upstream (R2.5)
H-G	114-126 V, within a volt or two of H-N	Very different from H-N: look at the neutral or ground
N-G with nothing running	0-2 V	More than 2 V with no load: suspect a neutral problem
N-G with the circuit loaded	Up to about 5 V	Over 5 V under load: high-resistance neutral connection

N-G rises a little under load because current flowing on the neutral causes a small voltage drop along it. The ground carries no current, so it stays at panel potential. That is why N-G with a load on is a useful test for a bad neutral connection.

Part D: The Six Patterns

Each pattern below gives the three readings, what the plug-in tester shows, and what the pattern means. The fixes are in R2.3.

Picture coming: Receptacle reading chart: six small drawings of a duplex receptacle in a row, labeled 1 Healthy, 2 Open hot, 3 Open neutral, 4 Open ground, 5 Reversed polarity, 6 Bootleg ground. Under each drawing, three lines: "H-N ___ V, H-G ___ V, N-G ___ V," filled in with the values from the table in Part D below. Under pattern 6, a small inset showing the inside of the box: a short white jumper from the silver screw to the green screw, with "Hidden. Tester shows correct."

#	Pattern	H-N	H-G	N-G	Three-light tester shows
1	Healthy	~120 V	~120 V	0-2 V	Correct
2	Open hot	0 V	0 V	0 V	No lights
3	Open neutral	0 V (or a few volts of ghost)	~120 V	0 V with nothing plugged in downstream; can read near 120 V with a load plugged in	Open neutral
4	Open ground	~120 V	0 V or a few volts of ghost	0 V or a few volts of ghost	Open ground
5	Reversed polarity (hot and neutral swapped)	~120 V	0 V	~120 V	Hot/neutral reversed
6	Bootleg ground (neutral jumpered to ground screw, no real ground)	~120 V	~120 V	0 V, and stays at exactly 0 V under load	Correct

D1. Healthy

All three readings sit where Part C3 says. If the device still does not work, the problem is the receptacle itself (worn contacts that will not grip a plug) or the thing plugged into it. The Arc Guide's Symptom 1, Step 4, says a receptacle with correct voltage that still does not power a load usually has a failed device.

D2. Open hot

Nothing is reaching the receptacle on the hot. Causes: a tripped breaker, a tripped GFCI upstream, a failed connection on the hot somewhere between the panel and here. Do the neutral-to-ground continuity test from R2.1 to tell a GFCI trip (both hot and neutral open) from a breaker trip or a broken hot (neutral still connected) (Kuhlman, p. 79).

D3. Open neutral

The hot reaches the receptacle, but the path back to the panel on the neutral is broken. H-G reads full voltage because the ground is still good. H-N reads 0 because the neutral slot is not connected to anything that goes back to the panel.

The N-G reading changes with what is plugged in. If a lamp or other load is plugged into this receptacle or any receptacle downstream on the same broken neutral, the neutral slot is connected through that load to the hot. Then N-G reads close to 120 V. With nothing plugged in, N-G reads near 0 or a few volts of ghost voltage. Unplug everything on the circuit to get a clean reading, then plug one lamp back in and watch N-G rise.

Safety: an open neutral means the white wire can be live. On a circuit with an open neutral and a load plugged in, the white wire downstream of the break carries 120 V to ground. Treat every white wire on that circuit as a hot until you have found and fixed the break.

D4. Open ground

H-N is normal. H-G is 0 or a few volts of ghost. The ground pin is not connected. Causes: a two-wire circuit with a three-prong receptacle installed on it, a ground wire that was never connected to the device or box, a ground that relied on a metal box with nothing connecting the box back to the panel, or a broken ground splice upstream.

An open ground does not stop anything from working, which is why customers rarely notice. It does mean that a fault in a plugged-in appliance can leave its metal case at 120 V with no path to trip the breaker. Note it on the job board. R1.6 and R-OLDHOUSE cover the fixes, including the GFCI replacement allowed by NEC 406.12(D)(2) (2023: 406.4(D)(2)).

D5. Reversed polarity

The hot wire is on the silver (wide-slot) screw and the neutral on the brass (narrow-slot) screw. H-N still reads 120 V because the meter does not care which probe is which on AC. The give-away is H-G reads 0 and N-G reads 120 V. That means the tall slot is the live one.

Reversed polarity is dangerous on lamps and appliances because it puts the switch on the neutral side and leaves the screw shell of a lamp socket live with the lamp switched off. The fix is to put the black wire on the brass screw and the white wire on the silver screw. If the wires are reversed at an upstream box, every receptacle after it is reversed too. Find the first reversed one.

D6. Bootleg ground

Someone jumpered the neutral terminal to the ground terminal on a receptacle that had no ground wire, so a plug-in tester would show "correct." It is a hazard. The ground pin is now connected to the neutral, so any current on the neutral also appears on the metal case of whatever is plugged in. If the neutral opens upstream, the case of the appliance goes to 120 V.

How to find it with readings. A bootleg ground reads like a healthy receptacle at idle. Two tests catch it.

Test 1, N-G under load:

1. Plug a 1,500 W heater or a hair dryer on high into the receptacle or another receptacle downstream on the same circuit.
2. Read N-G at the suspect receptacle.
3. A healthy receptacle on a loaded circuit reads a little N-G voltage, usually somewhere between a few tenths of a volt and 2 or 3 V, because the neutral drops voltage under load and the real ground does not. A bootleg reads exactly 0.0 V, because the neutral and ground are the same wire at that box.

Test 2, compare to a known ground:

1. Run a long test lead or an extension cord's ground pin from a receptacle you know has a real ground back to the panel.
2. With the load running, read from the suspect receptacle's ground hole to that known ground.
3. A real ground reads near 0 V. A bootleg reads the same as the neutral drop, often 1 to 5 V or more depending on load and length.

Confirm by looking. Turn off the breaker, prove the receptacle dead, and pull it out. A short wire from the silver screw to the green screw, with no bare or green wire coming in from a cable, is a bootleg. Remove the jumper. The legal options for a receptacle with no ground are in NEC 406.12(D)(2): another two-prong receptacle, a GFCI receptacle marked "No Equipment Ground," or a three-prong receptacle protected by an upstream GFCI and marked "GFCI Protected" and "No Equipment Ground." NEC 406.12(D)(1) and 250.130(C) also allow connecting a new ground wire from a permitted grounding point. R1.6 covers 250.130(C).

D7. Ghost voltage and the LoZ setting

A standard digital multimeter has a very high input impedance, often around 10 megohms. That is good for accuracy, but it means the meter can read voltage that is capacitively coupled onto a dead wire from a live wire running next to it in the same cable or wall. You may read 20, 40, or even 80 V on a wire that cannot power anything. This is ghost voltage, also called phantom or stray voltage.

How to sort it out:

1. If your meter has a LoZ (low impedance) setting, switch to it and read again. The LoZ setting puts a small load on the wire. Ghost voltage collapses to near 0. Real voltage stays.
2. If your meter has no LoZ setting, plug a lamp across the same points (H-N at a receptacle). Ghost voltage cannot light a lamp.
3. Read the same points with the non-contact tester. A ghost-voltage wire may still light it, so the NCV does not settle the question.

Safety: LoZ is for checking, not for proving dead. Some LoZ settings are not meant for use on circuits above a certain voltage or for long contact. Read your meter's manual. Prove dead on the regular AC volts setting, using live-dead-live.

Part E: Measuring Current

E1. Compare running current to the breaker

1. Find the breaker for the circuit (Part B6).
2. Have the customer, or you, turn on everything that normally runs on that circuit when the trouble happens.
3. With the panel dead front off and your journeyman's OK, clamp the single hot wire leaving that breaker.
4. Write down the reading.
5. Compare it to the breaker rating.

Breaker	Wire (copper)	Trouble if the steady current is above
15 A	14 AWG	15 A
20 A	12 AWG	20 A
30 A	10 AWG	30 A

NEC 240.4(D) sets these small-conductor limits. The breaker is rated to carry its rating, but a standard breaker can take minutes to trip at small overloads, so you will see some circuits running a little over rating without tripping yet. Kuhlman's method for a breaker that trips occasionally starts here: amp probe the wire at the panel with normal loads on to see how close

it is to the breaker rating (p. 82). In his "Billerica" story, 2.5 A on a 15 A breaker told him the trips were not an overload (p. 98). R2.4 takes it from there.

E2. Two-pole circuits

For a 240 V circuit (water heater, dryer, AC condenser), clamp each hot separately. On a pure 240 V load such as a water heater element, the two readings should match. On a 120/240 V load such as a dryer, they can differ, and the difference flows on the neutral.

E3. Neutral current and the water pipe bond

Kuhlman uses the clamp meter to catch a failing service neutral (pp. 45–46, 86–88). At the main panel:

1. Clamp L1 and write the reading.
2. Clamp L2 and write the reading.
3. Clamp the service neutral. It should read close to the difference between L1 and L2.
Example: L1 20 A, L2 10 A, neutral about 10 A.
4. Clamp the grounding electrode conductor going to the metal water pipe, if there is one. It should read 0 or about 0.1 A.
5. If the water pipe conductor carries more than about 0.1 A, and the neutral carries less than the L1–L2 difference, some neutral current is finding another way home. The service neutral connection is failing somewhere. Kuhlman has measured 6.4 A on a water pipe bond on a house where every LED in the house flickered (p. 46).

To make the test clear, load one leg heavily. Kuhlman runs a shop vacuum and a toaster on the leg that is already higher, to get at least a 10 A difference between L1 and L2 (p. 45).

Safety: service conductors are live with the main off. Clamping the service conductors is done with the panel energized, in the part of the panel that is never de-energized by the main breaker. This is a journeyman task for your first year. Watch it done, then do it with your journeyman beside you. R2.5 covers what to do with the results.

E4. Leakage current

A GFCI trips when the current going out on the hot and the current coming back on the neutral differ by more than a few milliamps. NEC Article 100's informational note for a Class A GFCI says it trips at 6 mA or more and does not trip below 4 mA. Small leakage from long runs and from electronics with filter capacitors can add up (Arc Guide, Part 10, "GFCI Ghost Trips").

To measure it:

1. Use a clamp meter with a leakage or milliamp range.
2. Put both the hot and the neutral of the GFCI-protected circuit inside the jaws together.
Leave the ground out.

3. With loads running, read. A perfect circuit reads 0 mA. Anything above about 2 to 3 mA on a circuit protected by a 4 to 6 mA GFCI leaves little margin.
4. Unplug loads one at a time and watch the reading drop to find the leaky one.

R2.4 uses this test for nuisance-tripping GFCIs.

Part F: Voltage Drop Under Load

F1. Why under load

Voltage drop happens when current flows through resistance. With nothing running, there is almost no current, so the far end of a long circuit reads close to panel voltage even if a connection is bad. The Arc Guide says checking an outlet with nothing plugged in shows near-line voltage and is useless for this (Part 10, "Voltage Drop — The Test Most Electricians Skip"). You must put a load on.

F2. The test, step by step

1. Pick a resistive load with a known wattage: a 1,500 W space heater on high is ideal. It draws about 12.5 A at 120 V.
2. Plug the heater into the receptacle at the far end of the circuit.
3. With the heater off, read H-N at the panel end. Read it at the first receptacle on the circuit if you cannot read at the panel. Write it down as V source, no load.
4. Read H-N at the far receptacle with the heater off. Write it down.
5. Turn the heater on high.
6. Read H-N at the source point again. Write it down.
7. Read H-N at the far receptacle right away. Use the other half of the duplex, or a receptacle right next to it on the same circuit. Write it down.
8. Voltage drop = source voltage under load minus far-end voltage under load.
9. Percent drop = voltage drop $\div$ source voltage $\times$ 100.

Picture coming: Voltage drop test setup: a panel on the left with a meter reading "121.0 V" at the first receptacle; a long dashed line labeled "75 ft of 14/2 NM" running to a far receptacle on the right with a 1,500 W space heater plugged in and a second meter reading "115.2 V." Below: "Drop = 121.0 – 115.2 = 5.8 V. 5.8 $\div$ 121.0 = 4.8 %."

F3. What the number means

NEC 210.19 has an informational note that says branch-circuit conductors sized to keep voltage drop to 3 percent at the farthest outlet, with no more than 5 percent total for feeder plus branch circuit, "will provide reasonable efficiency of operation." An informational note explains. It is not an enforceable rule. Use it as a target.

Percent drop under a 12.5 A load	Meaning
0-3 %	Normal for a long branch circuit
3-5 %	Long run or one loose connection; check the connections before blaming the wire
Over 5 %	Something is wrong: a bad splice, a failed backstab, a loose terminal, or a circuit that is too long for its wire size

F4. Check your answer against the wire

You can estimate what the wire alone should drop and compare it to what you measured. NEC Chapter 9, Table 8 gives the DC resistance of solid uncoated copper at 75°C as about 3.07 ohms per 1,000 feet for 14 AWG and about 1.93 ohms per 1,000 feet for 12 AWG.

Current flows out on the hot and back on the neutral, so the wire length is twice the one-way distance.

Example, 14 AWG, 50 feet one way, 12.5 A:

- Wire length = $2 \times 50 = 100$ ft.
- Resistance = $3.07 \times 100 \div 1,000 = 0.307$ ohms.
- Drop = $12.5 \text{ A} \times 0.307 \text{ ohms} = 3.8 \text{ V}$.
- Percent = $3.8 \div 120 \times 100 = 3.2 \%$.

Example, 14 AWG, 75 feet one way, 12.5 A:

- Wire length = 150 ft. Resistance = 0.46 ohms. Drop = 5.8 V. Percent = 4.8 %.

If you measure much more drop than the wire alone should cause, the extra is in a connection. Find it with the method in Part F5.

F5. Finding where the drop is

1. Leave the heater running at the far receptacle.
2. Read H-N at each receptacle along the circuit, starting at the panel end and working out.
3. Each reading should be a little lower than the last.
4. A big step down between two receptacles means the bad connection is at the first of the two (the device or splice where the circuit continues), or in the cable between them.
5. You can also read across a single connection with the load on: put one probe on the wire on each side of a splice or terminal. A good connection reads a few hundredths of a volt or less. A bad one reads tenths of a volt or more.

Safety. Step 5 is a live reading inside an open box. Do it only with your journeyman's OK, with the device pulled out far enough to reach the screws safely, and with insulated probes.

Part G: Readings at the Panel

G1. Leg voltages

With the dead front on, you can usually read the main breaker's load-side terminals only by removing the dead front. Until you are signed off for that, read the legs at receptacles instead: pick one receptacle on an L1 breaker and one on an L2 breaker.

With your journeyman's OK and the dead front off:

1. Read L1 to neutral at the main breaker's load terminal or at an L1 branch breaker's terminal screw.
2. Read L2 to neutral the same way.
3. Read L1 to L2.

Reading	Normal (Arc Guide, Part 3)
L1-N	114-126 V
L2-N	114-126 V
L1-L2	228-252 V

The two leg-to-neutral readings normally sit within a few volts of each other. Kuhlman calls a 1 to 3 V difference fairly normal and a 5 V difference a red flag (p. 102). R2.5 covers what to do when they are not normal.

G2. Breaker output

To check whether a breaker that looks ON is passing voltage:

1. Read from the breaker's terminal screw to the neutral bar. It should read about 120 V with the breaker on.
2. Turn the breaker off. It should read 0 V.
3. If it reads 0 V with the breaker on, the breaker has failed or is not seated on the bus (Arc Guide, Job 9, "Testing a breaker output").

Part H: Continuity and Resistance (Dead Circuits Only)

H1. The neutral-to-ground continuity test

R2.1 introduced this test. It tells you whether the neutral at a dead receptacle still connects back to the panel (Kuhlman, p. 79). Full procedure:

1. Prove the receptacle dead with AC volts (live-dead-live).
2. Switch to continuity.

3. Probes in the tall slot and the round hole.
4. Beep: neutral is connected back to the panel. The hot is the open conductor.
5. No beep: the neutral is open too. Look for a tripped GFCI upstream, or a broken neutral.

H2. Testing a wire run for an open

1. Turn off the breaker. Prove the conductors dead at both ends.
2. Disconnect the wire from devices at both ends.
3. At the far end, twist the conductor you are testing together with the ground (or with another conductor in the same cable).
4. At the near end, read continuity between the same two conductors. Beep means the pair is continuous. No beep means one of them is open.
5. Remove the jumper when you are done.

H3. Checking for a short on a dead circuit

1. At the panel, turn the breaker off and disconnect the circuit's hot wire from the breaker.
2. Turn off every switch and unplug everything on the circuit.
3. Read ohms from the hot wire to the neutral bar, then from the hot wire to the ground bar.
4. OL (open) on both: no short with the loads removed.
5. Near 0 ohms to neutral: a hot-to-neutral short in the wiring or a device. Near 0 ohms to ground: a hot-to-ground fault. The Arc Guide's Symptom 2, Step 3, uses this test before mid-pointing (R2.4).

Leave switches off and loads unplugged for this test. A light bulb or a plugged-in appliance between hot and neutral reads a low resistance that looks like a short.

Worked Examples

Example 1: "Outlet works, but the computer keeps rebooting"

Symptom. A home office receptacle powers everything, but the desktop computer restarts when the space heater under the desk runs.

Questions. "When did it start?" Since cold weather. "What's on this outlet?" The computer, monitor, printer, and a 1,500 W heater on a power strip. "Anything else on this circuit?" The customer doesn't know.

Tests.

1. Three readings at the receptacle with the heater off: H-N 121.4 V, H-G 121.6 V, N-G 0.3 V. Healthy at idle.
2. Heater on high: H-N 109.2 V, H-G 117.5 V, N-G 8.1 V.

3. The N-G reading jumped to 8.1 V under load. The Arc Guide flags over 5 V under load as a high-resistance neutral (Part 3).
4. Heater still on, readings at the first receptacle on the circuit near the hall: H-N 118.8 V, N-G 1.9 V.
5. Readings at the second receptacle (bedroom wall): H-N 110.0 V, N-G 7.6 V. The big step is between the hall receptacle and the bedroom receptacle.
6. Breaker off, hall receptacle proven dead and pulled. The neutral leaving to the bedroom is backstabbed and the white insulation is brown at the hole.

Fix. Cut back to clean copper, reinstall on the screw terminals, torque to the label. Heater on again: office receptacle H-N 115.9 V, N-G 2.4 V. The remaining drop is the wire. The computer runs through 10 minutes of heater cycling.

Write-up. "Failed backstabbed neutral at hall receptacle caused 8 V N-G under load at office. Moved to screws. Recommend checking the remaining backstabbed receptacles in the house." Kuhlman says that when he finds a backstabbed receptacle on a no-power call, the cause always turns out to be a backstabbed connection somewhere in the house (p. 27).

Example 2: The receptacle tester says "correct," but the GFCI tester won't trip

Symptom. A home inspector's report says the downstairs bath GFCI "does not trip with tester." The customer wants it fixed.

Tests.

1. Three-light tester at the GFCI: correct.
2. GFCI's own TEST button: trips and resets.
3. Plug-in GFCI tester: does not trip.
4. Meter: H-N 120.5 V, H-G 120.4 V, N-G 0.0 V. Load test with a hair dryer on high plugged into the same receptacle: N-G still exactly 0.0 V. Suspect bootleg.
5. Breaker off, proven dead, GFCI pulled out: a two-wire cable with no ground, and a short white jumper from the GFCI's LINE neutral to its green screw.

Why the GFCI tester didn't trip. The tester leaks current from the hot to the ground pin. With a bootleg, the ground pin is the neutral, so the "leaked" current returns on the neutral through the GFCI and the GFCI sees no imbalance.

Fix. Remove the jumper. Leave the green screw with no connection. Apply the "No Equipment Ground" label that comes with the GFCI (NEC 406.12(D)(2)(b)). Test with the GFCI's own TEST button, which works without a ground. Note on the job board that the plug-in tester cannot be used on this receptacle because it has no ground.

Example 3: Ghost voltage on a "dead" switch leg

Symptom. A tech replacing a ceiling light turned off the breaker, but the meter reads 38 V between the black fixture wire and the ground.

Tests.

1. NCV on the black wire: faint beep.
2. Meter on LoZ, same points: 0.6 V.
3. Meter back on regular AC volts: 38 V.
4. A known live receptacle reads 120 V on both settings.

Meaning. The 38 V is capacitively coupled from a live circuit in the same wall. The fixture wire is dead. The reading collapses under the LoZ load. The tech proceeds after live-dead-live on the regular AC volts setting and on LoZ.

Common Mistakes

1. **Trusting the non-contact tester to prove dead.** It misses dead batteries, metal-clad cable, and open neutrals. Prove dead with the multimeter.
 2. **Measuring volts with the red lead in the amps jack.** Look at the jacks before every reading.
 3. **Using ohms or continuity on a live circuit.** Prove it dead on AC volts first.
 4. **Clamping the whole cable.** It reads 0 A on a working circuit. Clamp one conductor.
 5. **Checking voltage drop with nothing running.** Put a 1,500 W load on the far end.
 6. **Believing a "correct" three-light pattern.** It cannot see bootleg grounds, low voltage, or loose connections.
 7. **Writing "120 V" without saying which two points.** Always write H-N, H-G, or N-G.
 8. **Chasing ghost voltage.** A high-impedance meter reads voltage that cannot light a lamp. Use LoZ or a lamp.
 9. **Reading only one half of a duplex receptacle.** The halves can differ.
 10. **Taking the dead front off before you are signed off.** Clamping and leg readings inside the panel are journeyman-supervised work in your first year.
 11. **Reading shiny metal with a spot thermometer.** Read the plastic faces of breakers and devices.
 12. **Forgetting to prove the meter again after the dead reading.** That is the step that catches a meter that failed during the test.
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Field Exercise

Setup. Use the training wall with switchable faults, a 1,500 W space heater, a long run of 14 AWG on the training wall (at least 50 feet one way), and an unlabeled training panel. Your journeyman controls the faults.

Part 1: Name the fault from the readings. The journeyman sets each of these faults in turn without telling you which one: healthy, open hot, open neutral, open ground, reversed polarity, and bootleg ground. For each:

1. Do live-dead-live with your meter.
2. Take H-N, H-G, and N-G and write them down.
3. Plug in the three-light tester and write what it says.
4. Name the fault from the meter readings alone.
5. For the open neutral, take N-G with nothing plugged in, then with a lamp plugged in downstream, and explain the difference.
6. For the bootleg, run the heater and show N-G stays at 0.0 V. Then explain why the three-light tester said "correct."

Part 2: Voltage drop. Plug the 1,500 W heater in at the end of the long 14 AWG run.

1. Read H-N at the panel end with the heater off and on.
2. Read H-N at the far receptacle with the heater off and on.
3. Compute the drop in volts and in percent.
4. Measure the one-way length and compute what the wire alone should drop using 3.07 ohms per 1,000 feet.
5. Compare. If the measured drop is more than the computed drop by 1 V or more, find the connection that is costing the difference.

Part 3: Clamp a running circuit. With your journeyman's OK and the training panel's dead front off, run the heater and a second load on one circuit. Clamp the hot at the breaker and compare it to the breaker rating. Then clamp the whole cable and show it reads near 0.

Part 4: Tone out an unlabeled circuit. Plug the breaker finder's transmitter into a receptacle on the training wall. Find the breaker. Confirm by turning it off. Then turn the circuit off, connect the toner, and follow the cable from the receptacle back toward the panel, marking its path with tape.

Pass standard. You pass when you named all six patterns correctly from the meter readings, used live-dead-live every time, computed the voltage drop and percent correctly, got a clamp reading within 1 A of your journeyman's, and found the right breaker with the tracer on the first try or confirmed it by switching off before declaring it.

NEC 2026 Cross-References

Section	What it says	Why it matters here
110.14(D)	Terminal torque to the value on the equipment or in the manufacturer's instructions, using an approved means such as a torque tool	A loose terminal shows up as voltage drop and heat on your meter and thermometer
210.19, Informational Note	Branch conductors sized for no more than 3 % drop at the farthest outlet and 5 % total give reasonable efficiency	Your voltage-drop target. It is a note, not a rule.
240.4(D)	Small-conductor protection: 14 AWG copper 15 A, 12 AWG copper 20 A, 10 AWG copper 30 A	What you compare clamp readings to
Article 100, Ground-Fault Circuit Interrupter (Class A), Informational Note	Class A GFCIs trip at 6 mA or more and do not trip below 4 mA	Leakage target in Part E4
406.12(D)(2) (2023: 406.4(D)(2))	Options for replacing a receptacle where no ground exists: non-grounding receptacle, GFCI marked "No Equipment Ground," or grounding receptacle on an upstream GFCI marked "GFCI Protected" and "No Equipment Ground"	What to do after you find an open ground or a bootleg
250.130(C)	Connecting an equipment grounding conductor for a replacement or extension on an existing circuit	The other legal fix for an open ground (R1.6)
Chapter 9, Table 8	Conductor resistance	Used to compute expected voltage drop

The meter work in this module is method, not code. Meter categories come from the IEC 61010 and UL 61010 product standards, which the NEC lists in its informative annex but does not enforce on your meter.

End-of-Chapter Checklist

Meter safety - [] Meter and leads rated CAT III 600 V or better for panel work. - [] Leads inspected, shrouds on, red lead in the V Ω jack. - [] Live-dead-live on every dead reading.

Testers and their limits - [] I can say what the NCV cannot tell me (voltage level, metal-clad cable, neutral, false positives). - [] I can say what the three-light tester cannot tell me (voltage, bootleg ground, loose connections). - [] I know the plug-in GFCI tester needs a ground and the device TEST button does not.

Receptacle readings - [] I take H-N, H-G, and N-G at every receptacle and write all three with labels. - [] I can name healthy, open hot, open neutral, open ground, reversed polarity, and

bootleg ground from the readings. - [] I can sort ghost voltage from real voltage with LoZ or a lamp.

Current - [] I clamp one conductor and compare it to the breaker rating. - [] I know the whole-cable clamp reads zero and why. - [] I know how leakage is measured with hot and neutral together in a leakage clamp.

Voltage drop - [] I test with a 1,500 W load on the far end. - [] I compute drop in volts and percent and compare to 3 % and 5 %. - [] I can compute the expected drop from wire size and length.

Tracing - [] I can find a breaker with a breaker finder and confirm by switching it off. - [] I can follow a dead cable with a toner and mark the path.

Panel - [] I only take the dead front off with my journeyman's OK. - [] I know normal L1-N, L2-N, and L1-L2 readings and when a leg difference is a red flag.

Sources

- Jesse Kuhlman, Residential Electrical Troubleshooting (2019). Pages cited: 11 (meter, non-contact tester limits, tone generator, breaker tracer, arc-fault diagnostic tool), 43 (neutral and ground joined at the main panel), 45–46 (clamping the water pipe bond; loading one leg; 6.4 A photo), 79–81 (continuity test and toner use on dead outlets), 27 (backstab failures), 82 (amp-probing a tripping circuit), 86–88 (neutral connection issue), 98 (Billerica), 102 (leg voltage difference). All paraphrased.
 - Arc Workforce, Residential Electrical Field Guide. Job 9 (testing with a multimeter), Part 3 (voltage and amperage targets, voltage drop), Part 9 (tools), Part 10 ("Voltage Drop — The Test Most Electricians Skip," "Thermal Inspection Without a Camera," "GFCI Ghost Trips"), Symptoms 1, 2, and 11.
 - BCcampus, Line E: Electrical Fundamentals, Unit IV, "Using Multimeters," sections 12.1–12.3 (care and storage of meters, meter safety precautions, digital multimeters).
 - YES Electric commercial course, Module 2.2 (CAT ratings, the clamp meter, megger, phase rotation, infrared cameras).
 - NFPA 70, National Electrical Code, 2026 edition, sections listed above.
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Videos to watch

These videos are made by other electricians and companies, not YES Electric. Watch each one after you read the section it goes with. Where a video does something differently from this module, the caution line says so. Follow this module and your journeyman, not the video. Click a title to open it on YouTube.

Section	Video
Part B, B1 Non-contact voltage tester (NCV)	Common Safety Issue Non-Contact Voltage Testers Everyday Home Repairs • 7:37 Shows how an NCV whose 'on' light looks the same as 'off' can give a false 'dead' reading when its battery dies, which is why you check it on a known live source and confirm with a meter. Caution: Aimed at homeowners and ends by recommending a plug-in tester and clamp meter as the main tools; the module still requires live-dead-live with a meter.
Part B, B4 Digital multimeter; Part G1 Leg voltages	How To Use a MULTIMETER (Volts, Amps, Ohms, Continuity) Electrician U • 5:42 Electrician U shows the meter functions and the order he tests a panel: hot to hot about 240 V, each hot to neutral about 120 V, each hot to ground, then neutral to ground near 0 V. Caution: He calls it a '600 volt meter' but does not discuss CAT ratings; use the CAT rating rules in A1. Panel readings are taken with the dead front off; follow your journeyman's PPE rule.
Part C Reading voltage at a receptacle (the three readings)	How to Test Voltage in a Receptacle Repair and Replace AMRE Supply • 2:59 A short supply-house video showing hot-neutral about 120 V, hot-ground about 120 V, and neutral-ground near 0 V at a receptacle, with the probes placed one at a time. Caution: Says normal is '110 to 120 V'; the module's normal-value table governs. It says a 120 V neutral-to-ground reading means a short; more often it is reversed polarity or a miswire, as Part D explains.
Part B, B5 Clamp meter; Part E1 Compare running current to the breaker	How to Use a Clamp Meter to Measure Amps in a Breaker Panel Joseph Ask a Real Electrician • 4:53 An electrician clamps one hot conductor on a 20 A breaker (under 1 A) and then each service leg (about 27 A) to show how to check a circuit or a house for overload. Caution: He reaches into a live panel to pull the wire out for the clamp; he wears gloves, but helpers do this only with a journeyman present. He applies an '80% rule' to the service reading loosely; use Part E's comparison instead.
Part D, D7 Ghost voltage and the LoZ setting	Ghost Voltage and How Electricians Test It? Electrician U • 10:42 Electrician U reads 52 to 65 V on a disconnected bare conductor with a normal meter, then switches a Fluke 117 to LoZ and the ghost reading drops to zero while the real 120 V circuit still reads 120 V.

Part D, D6 Bootleg
ground (and reversed
polarity)

[How To Identify Reverse Polarity Bootleg Ground Receptacles](#)

Sparky Channel • 5:51

A three-light tester reads 'correct' on a reverse-polarity bootleg-ground receptacle, then a Fluke NCV shows the whole metal box is live, and the box is opened to show the neutral-to-ground jumper.

Caution: This is the reverse-polarity version of a bootleg, found here with an NCV; the module's D6 method with a meter and the neutral-to-ground continuity test still applies to the ordinary bootleg, which an NCV will not catch.