

Grounding and Bonding in Houses, Old and New

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 1, Installation. YES Electric Residential Electrical Course.

This module explains what grounding and bonding do, how to fix a house that has no equipment ground, how to bond water pipe, gas pipe, and CSST, and how to find the grounding mistakes that other people left behind. R1.5 covers building the grounding electrode system on a service change: rods, the water pipe electrode, and the concrete-encased electrode. This module does not repeat those steps. It goes deeper on the "why" and on the inside of the house. Commercial modules 1.7 and 2.7 cover grounding theory at commercial scale and the fall-of-potential earth resistance test.

Code edition. This module cites NEC 2026. Where a section number moved, the NEC 2023 number is in parentheses. The local inspector (the AHJ) may enforce an earlier edition, so ask your journeyman which edition applies.

1. Learning Objectives

When you finish this module you will be able to:

1. Tell grounding from bonding and explain what each one does during a fault, with numbers.
 2. Find ungrounded receptacles and bootleg grounds with a plug-in tester and a meter.
 3. Fix an ungrounded two-wire receptacle by one of the three legal methods: a GFCI with the right labels, a new equipment grounding conductor run per 250.130(C), or a rewire.
 4. Bond metal water piping, gas piping, and CSST gas tubing to the right size and in the right place.
 5. Recognize the common grounding mistakes in houses: bootleg grounds, grounds on the neutral bar in a subpanel, three-wire feeders to detached buildings, grounds daisy-chained through devices, and missing water meter jumpers.
-

2. Background in Plain Language

2.1 Two jobs that people call by one name

Electricians say "ground" for two different things. Keep them apart in your head and most of Article 250 makes sense.

Grounding connects the electrical system to the earth. The grounding electrode conductor runs from the service neutral to ground rods, the water pipe, and the footing steel. 250.4(A)(1) says the purpose is to limit the voltage put on the system by lightning, line surges, or contact with higher-voltage lines, and to hold the voltage to earth steady during normal operation.

Bonding connects metal parts together and back to the source. The bare or green wire in every cable, the metal boxes, the panel can, the water pipe jumper, and the gas pipe jumper are all bonding. 250.4(A)(3) and (A)(4) say the purpose is to create an effective ground-fault current path. 250.4(A)(5)(a) says that path must be low enough in impedance to trip the breaker.

The earth is not part of the fault path. 250.4(A)(5)(c) says the earth shall not be considered an effective ground-fault current path. A ground rod alone will not trip a breaker. Section 5, Example 1, shows the numbers.

OSHA says the same thing from the worker's side: grounding is a secondary protective measure that greatly lowers the risk of shock but does not guarantee you will not be shocked (OSHA 3075, Controlling Electrical Hazards, p. 13).

2.2 The fault path in a house

Picture a metal toaster. The hot wire inside rubs through its insulation and touches the metal case.

1. Current flows from the hot wire into the metal case.
2. The case is connected to the equipment grounding conductor (EGC) through the third prong of the plug and the ground screw of the receptacle.
3. The EGC runs back with the circuit to the ground bar in the panel.
4. In the service panel, the ground bar is tied to the neutral bar and the can by the main bonding jumper (250.28).
5. The service neutral runs back to the utility transformer, which is where the current wants to go.
6. That whole loop is copper and steel, so its impedance is a small fraction of an ohm. Hundreds of amps flow for a split second.
7. The breaker sees hundreds of amps on a 20 A circuit and trips in a fraction of a second.

Remove the EGC from that picture and the toaster case sits at 120 V until someone touches it and a sink faucet at the same time. Their body becomes the return path.

Picture coming: Fault-current path in a house, drawn as one loop with arrows: pole transformer, service neutral down to the meter, service panel with the main bonding jumper highlighted, the ground bar, a 20 A breaker, NM cable to a receptacle, a toaster with a lightning-bolt fault from the hot to its metal case, red arrows carrying fault current from the case back through the EGC, ground bar, main bonding jumper, neutral, and back to the transformer. A callout at the breaker: "~400 A for a fraction of a second → breaker trips." A faint grey dashed path from the ground rod through the earth back to the transformer, labeled "earth path: too much resistance to trip a breaker (250.4(A)(5)(c))."

2.3 Where neutral and ground meet, and where they must not

The neutral and the EGC are connected at exactly one place in a house: the service equipment. The main bonding jumper does it (250.24(A), 250.28). Downstream of the service disconnect, 250.24(B) says the grounded conductor (neutral) shall not be connected to equipment grounding conductors, to metal parts of equipment, or be reconnected to ground. 250.142(B) repeats the rule for equipment on the load side.

The reason is current. The neutral carries load current all day. If the neutral is tied to the EGC at a second place, some of that load current splits off onto the EGC, the metal boxes, the conduit, the water pipe, and anything else bonded. 250.6 calls this objectionable current. It shocks people, it heats connections that were never meant to carry current, and it confuses every GFCI downstream.

Kuhlman explains that in a main service panel the neutrals and grounds land on the same bar, and in a subpanel they sit on separate bars with the neutral bar floating. He also notes that because they meet at the service, a continuity test between neutral and ground at any working 120 V receptacle in the house should read continuity ("Neutrals and Grounds connected in panel, main service panel vs sub-panel," p. 43). That test becomes one of your tools in Section 4.

2.4 Old houses and the ungrounded receptacle

Most Birmingham houses built before the early 1960s were wired with two-wire cable: a hot and a neutral, no equipment ground. Knob-and-tube wiring in older houses also has no ground. The original receptacles were two-slot. Over the years, homeowners and handymen swapped many of them for three-slot receptacles without adding a ground, because three-prong plugs would not fit the old ones.

A three-slot receptacle with nothing on its ground screw promises a protection it does not give. The Arc Guide lists this as the first of the three most common serious grounding mistakes (Part 10, "Grounding — The 3 Most Common Serious Mistakes").

The NEC gives three legal ways out. Section 4.3 walks through each one.

2.5 Bootleg grounds

A bootleg ground is a jumper from the neutral screw to the ground screw on a receptacle, installed to make a cheap plug-in tester show "correct." It is dangerous for two reasons.

1. It puts neutral and ground together downstream of the service, which 250.142(B) forbids. Normal neutral current now flows on the receptacle frame and anything plugged in.
2. If the neutral opens anywhere upstream, every metal appliance case on that receptacle becomes energized at full 120 V through the load. A plain ungrounded receptacle does not do that.

A three-light plug-in tester cannot tell a bootleg ground from a real ground. Both read "correct." Section 4.2 shows how to find bootlegs with a meter.

Picture coming: Two receptacles side by side, wiring visible. Left, labeled "Real ground": black on the brass screw, white on the silver screw, bare copper from the cable to the green screw. Right, labeled "Bootleg ground": black on brass, white on silver, a short white jumper from the silver screw to the green screw, and no bare wire in the box. Under each, a plug-in tester showing the same "correct" lights, and a meter reading neutral-to-ground voltage with a 12 A load running: left 1.8 V, right 0.0 V.

3. Specs and Tables

3.1 Equipment grounding conductor size, Table 250.122

Size the EGC from the breaker, not from the wire.

Breaker rating, not exceeding (A)	EGC, copper	EGC, aluminum
15	14	12
20	12	10
60	10	8
100	8	6

All four rows are verified in the NEC 2026 text. A 30 A or 40 A circuit falls under the 60 A row: 10 AWG copper. 250.122(A) says the EGC never has to be larger than the circuit conductors.

3.2 What counts as an EGC (250.118(A))

Allowed as an EGC	Notes for houses
A copper, aluminum, or copper-clad aluminum wire, bare, covered, or insulated	The normal case in NM cable
Rigid metal conduit, IMC, EMT	With every joint and fitting made tight (250.120(A))
Listed flexible metal conduit and listed liquidtight flexible metal conduit	Only within the size, breaker, and 6 ft total length limits of 250.118(A)(5) and (A)(6). If flex is there for vibration or movement (an AC condenser whip), a wire EGC is required
Armor of Type AC cable as provided in 320.108	320.108 requires the armor to provide an adequate fault path. Modern AC cable has an internal bonding strip in contact with the armor
Type MC cable	Only as 250.118(A)(10) allows. Standard interlocked MC with a green insulated EGC uses the green wire, not the armor

3.3 EGC identification (250.119(A))

An EGC may be bare, covered, or insulated. If covered or insulated, its outer finish is green or green with yellow stripes. A green or green-and-yellow wire may never be used as a hot or a neutral.

3.4 Bonding jumper sizes for piping

Piping	Rule	Size
Metal water piping	250.104(A)(1), sized from Table 250.102(C)(1) by the largest service conductor, never required to exceed 3/0 Cu	See table below
Metal water piping in a building fed by a feeder (detached garage, shop)	250.104(A)(3), sized per 250.102(D), not required to be larger than the largest feeder conductor	From Table 250.122 by the feeder breaker
Other metal piping likely to become energized, including gas piping	250.104(B), sized from Table 250.122 using the rating of the circuit likely to energize it	Example: a gas furnace on a 15 A circuit, 14 Cu. The EGC of that circuit counts as the bond
CSST gas tubing, yellow-jacket type	Manufacturer's instructions (Gastite TB2014-01, Pro-Flex bonding sheet) based on NFPA 54	6 AWG Cu minimum, no longer than 75 ft (Gastite)

Table 250.102(C)(1), water pipe bond sizes (verified):

Largest service conductor, Cu	Largest service conductor, Al	Bond, Cu	Bond, Al
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0

3.5 Where you may connect a new EGC for an ungrounded receptacle (250.130(C))

When you replace a non-grounding receptacle with a grounding-type receptacle, or extend a branch circuit, the new EGC may connect to any one of these:

1. Any accessible point on the grounding electrode system (250.50).
2. Any accessible point on the grounding electrode conductor.
3. The equipment grounding terminal bar in the enclosure where the branch circuit originates.
4. An EGC that is part of another branch circuit that originates in the same enclosure.
5. For grounded systems, the grounded service conductor inside the service equipment enclosure.

Option 4 is the one you will use most in houses. A three-wire circuit (with ground) from the same panel often passes near the old two-wire receptacle, in a basement or crawl space.

The Arc Guide gets this wrong. Its Part 8 "Older Home Quirks" says not to run a ground wire from a distant ground source unless it is from the original panel or a GFCI is used. The NEC list above allows the connection to any of the five points, including another circuit's EGC from the same panel. Follow 250.130(C).

3.6 Protection of a separately run EGC (250.120(C))

If an EGC smaller than 6 AWG is not run with the circuit conductors (which 250.130(C) allows), protect it from physical damage with an identified raceway or cable armor, unless it runs inside the hollow spaces of walls or framing where it is not subject to damage.

4. Step-by-Step Procedures

4.1 Test a receptacle with a plug-in tester

⚠ Plug-in testers work on live circuits. Hold the tester by its body, keep your fingers off the prongs, and never test a receptacle with a cracked face.

1. Plug a three-light tester into the receptacle.
2. Read the light pattern against the chart printed on the tester. The common results are: correct, open ground, open neutral, open hot, hot/ground reversed, and hot/neutral reversed.
3. Write the result on your survey sheet with the room and the wall.
4. Treat every "correct" reading in a house built before the mid-1960s as unproven until you check it with a meter (Section 4.2). A bootleg ground reads "correct."
5. On a two-slot receptacle, you cannot use the tester. Use the meter.

4.2 Find a bootleg ground with a meter

You need a multimeter, a plug-in load that draws 10 A or more (a hair dryer or a space heater on high), and a long test lead or a known-good ground (the panel ground bar, a metal water pipe, or a grounded receptacle on a modern circuit) if the box has no visible wiring.

Method A: Look.

1. Turn the circuit off at the breaker. Test before touch: prove your meter on a live circuit, test the receptacle hot to neutral and hot to ground, then prove the meter again.
2. Pull the receptacle out of the box.
3. Look for a jumper between the silver screw and the green screw, or a ground screw with nothing on it, or a bare wire wrapped around a neutral. Look at the cable. Two-wire cable with no bare conductor and a wire on the green screw means a bootleg or a ground stolen from somewhere.

Method B: Measure neutral-to-ground voltage under load (use this when you cannot open the box, or to confirm).

1. With the circuit on, measure neutral to ground at the receptacle with nothing plugged into the circuit. Write it down. On a real ground it is usually under 1 V.
2. Plug the 10 A or larger load into the other half of the duplex and turn it on.
3. Measure neutral to ground again.
4. On a real ground, the reading rises, often to 1 to 3 V, because load current through the neutral wire makes a voltage drop on the neutral that does not appear on the separate ground wire.

5. On a bootleg ground, the reading stays at 0.0 V, because the neutral and ground are the same wire from that box back.

Method C: Continuity to a known ground with the neutral lifted. Your journeyman may use this in the panel.

1. Turn the circuit off and prove dead.
2. Lift the circuit's neutral off the neutral bar in the panel.
3. At the receptacle, measure continuity from the ground slot to the neutral slot.
4. A real ground now shows open (no continuity), because the only place they meet was the bar you just lifted the neutral . A bootleg shows continuity.
5. Reland the neutral and torque it.

4.3 Fix an ungrounded receptacle: the three legal ways

Check first whether the circuit has an EGC you missed. In a metal box fed by metal conduit or old AC cable, the box itself may be grounded. Measure hot to the metal box. If you read 120 V, measure hot to neutral and compare; if the two are within a volt or two, and the box path is continuous back to the panel, the box may serve as the ground path. Bond the receptacle to the box per 250.146 with a bonding jumper. Have your journeyman confirm the raceway or armor counts under 250.118 before you rely on it.

If there is no ground path, pick one of the three fixes below. Explain the choice to the customer in plain words and put it on the work order.

Fix 1: GFCI protection with labels (406.12(D)(2)(b) and (c), 2023: 406.4(D)(2)(b) and (c)).

1. Turn off the breaker and prove dead.
2. Find the first receptacle on the circuit, the one closest to the panel on the run. A GFCI there protects everything downstream on its LOAD terminals.
3. Install a GFCI receptacle. LINE terminals get the incoming power. LOAD terminals feed the downstream receptacles.
4. Do not connect anything to the GFCI's green screw. 406.12(D)(2)(b) says the equipment grounding terminal shall not be connected from the GFCI to any outlets it supplies.
5. Mark the GFCI receptacle or its cover plate "No Equipment Ground." GFCI receptacles come with these stickers in the box.
6. You may now replace each downstream two-slot receptacle with a three-slot receptacle. Mark each one, or its cover plate, "GFCI Protected" and "No Equipment Ground," visible after installation (406.12(D)(2)(c)).
7. Do not connect a wire between the ground terminals of the downstream receptacles (406.12(D)(2)(c)).
8. Test: press TEST on the GFCI. Every downstream receptacle must go dead. A plug-in tester's GFCI button may not trip a GFCI on an ungrounded circuit, because the tester leaks current to the ground pin and there is no ground. Use the GFCI's own TEST button.

9. Also check 406.12(D)(4): if the receptacle is in an area that now requires AFCI under 210.12, the replacement must be AFCI-protected too. A dual-function GFCI/AFCI receptacle or a combination AFCI breaker covers it.

Why Fix 1 is legal. A GFCI does not need a ground to work. It trips when the current leaving on the hot does not match the current returning on the neutral, about 5 mA (Kuhlman, "Ground Fault Circuit Interrupter circuit breakers (GFCI)," pp. 38–39, describes the 5 mA difference). It protects a person from shock. It does not give surge-protector strips or computer power supplies the ground path they expect, which is why the label says "No Equipment Ground."

Fix 2: Run a new EGC (250.130(C)).

1. Find a connection point from the list in Section 3.5. Usually the nearest receptacle or junction box on a grounded circuit from the same panel, or the panel ground bar.
2. Size the new EGC from Table 250.122 by the breaker on the ungrounded circuit: 14 AWG copper for 15 A, 12 AWG copper for 20 A.
3. Route it. In a crawl space or attic, run it along framing. If it is smaller than 6 AWG and runs outside walls where it can be hit, protect it in a raceway or cable armor (250.120(C)).
4. At the connection point, splice it to the existing EGC with a listed connector, and keep that box's EGC continuous (250.148(A) and (B)): all EGCs in the box are connected together, and taking a device out must not break the ground to anything else.
5. At the ungrounded receptacle, land the new EGC on the green screw of a grounding-type receptacle (406.12(D)(1)). In a metal box, also bond the box (250.148(C)).
6. Test continuity from the receptacle ground slot to the panel ground bar with the circuit off, using a long lead. Then test with power on: hot to ground should read about the same as hot to neutral.
7. Under 406.12(D)(3) and (D)(4), the replacement receptacle must also meet the GFCI and AFCI rules that apply to its location today.

Fix 3: Rewire the circuit.

1. Run new NM cable with a ground from the panel to each outlet, using the old-work methods in R1.12.
2. This is the best fix and the most expensive. Offer it when the old wiring is cloth-insulated, brittle, or knob-and-tube, when the walls are open for a remodel, or when the customer wants grounded receptacles for electronics.

Picture coming: The three legal fixes for a two-wire receptacle, as three panels. Panel 1: a GFCI receptacle at the first box with "No Equipment Ground" sticker, two downstream three-slot receptacles with "GFCI Protected" and "No Equipment Ground" stickers, no wire on any green screw. Panel 2: a new green 12 AWG wire from the ungrounded receptacle's green screw through the crawl space to a junction box on a grounded circuit from the same panel, spliced to that circuit's EGC. Panel 3: new 12-2 with ground NM cable from the panel to the receptacle.

4.4 Bond the metal water piping

R1.5 Section 4.10 covers the water pipe as a grounding electrode during a service change. This procedure covers the bond on any existing house where it is missing or broken.

1. Find the cold water line where it enters the house. Look for a clamp and a wire. Follow the wire to see where it goes.
2. If no bond exists, choose the connection point. 250.104(A)(1) lets the bonding jumper land on the service equipment enclosure, the grounded conductor at the service, the GEC if it is large enough, or a grounding electrode if its conductor is large enough.
3. Size the jumper from Table 250.102(C)(1) (Section 3.4). For a 200 A service with 4/0 Al conductors: 4 AWG copper. For a 100 A service with 2 AWG Al conductors: 8 AWG copper.
4. Clean the pipe to bright metal. Install a listed clamp sized for the pipe.
5. Protect and secure the jumper the same way as a GEC (250.104(A)(1) sends you to 250.64(A), (B), and (E)).
6. Keep the clamp accessible (250.104(A)(1)).
7. Install a jumper around the water meter, water filter, or softener, the same size as the bond. Kuhlman shows this jumper and explains that if a plumber removes the meter without it, the house's piping is no longer bonded (p. 88).
8. Look for dielectric unions or plastic sections at the water heater. A plastic section breaks the metal path. Jump the hot and cold lines together at the water heater with the same size wire if any metal piping on the far side is not otherwise bonded.

⚠ **Opening a water pipe can be dangerous.** If the service neutral is bad, neutral current may be flowing on the water pipe bond. Kuhlman measured 6.4 A on a water pipe GEC at one house (p. 46) and 9 A at another (p. 102). Before anyone cuts a metal water pipe or removes a water meter, clamp an ammeter on the bond wire. Any current above about 0.1 A means a neutral problem (Kuhlman, "Neutral wire in electrical service," p. 45). Install a temporary jumper across the cut before it is made, and call your journeyman.

4.5 Bond the gas piping

1. 250.104(B) requires metal piping that is likely to become energized, including gas piping, to be bonded.
2. The simplest compliant bond for black iron gas piping is the EGC of the circuit that serves gas equipment: the furnace, the water heater igniter, the range. That EGC already bonds

the piping through the appliance frame. The bond is sized from Table 250.122 by that circuit's breaker.

3. Some AHJs want a visible bond at the gas entry. If so, install a listed clamp on the rigid black iron pipe on the house side of the meter, and run a jumper to the service equipment or GEC.
4. Never use gas piping as a grounding electrode (250.52(B)(1)).
5. Never clamp to the utility's meter or to the underground service line.

4.6 Bond CSST gas tubing

Corrugated stainless steel tubing (CSST) is the flexible yellow-jacketed gas line in many houses built or remodeled since the 1990s. Lightning nearby can arc through its thin wall and start a gas fire. The manufacturers now require a direct bond, which is in addition to the 250.104(B) bond.

1. Identify the brand from the jacket printing (Gastite, TracPipe, Pro-Flex, WardFlex, and others). Pull that manufacturer's bonding instruction. The steps below come from the Gastite and Pro-Flex sheets.
2. Find a rigid section of gas pipe, or a rigid fitting, downstream of the gas meter (or the second-stage regulator on propane), near where the gas enters the house. Do not clamp to the yellow CSST itself (Gastite TB2014-01).
3. Clean any paint off the pipe for metal contact. Install one bonding clamp listed to UL 467. Keep it accessible.
4. Run a bonding conductor no smaller than 6 AWG copper to the electrical service grounding electrode system: the service enclosure, the bonding bus, the GEC, or a grounding electrode (Gastite TB2014-01; Pro-Flex bonding sheet).
5. Keep it 75 ft or shorter (Gastite TB2014-01). Shorter works better.
6. Protect and secure it per the NEC as you would a GEC.
7. Some black-jacket "arc-resistant" CSST products state that they need no direct bond beyond 250.104(B). Check the product's own instructions and the AHJ before skipping the bond.

Picture coming: CSST and gas pipe bonding detail: gas meter outside, a black iron pipe entering the house, a UL 467 bonding clamp on the black iron section just inside the wall, 6 AWG copper running 20 ft to the GEC at the service with a listed split-bolt or irreversible connector, yellow CSST continuing past the clamp to the furnace and water heater. Callouts: "clamp on rigid pipe, not on CSST," "6 AWG Cu minimum," "75 ft maximum," "accessible."

4.7 Check a subpanel

1. Turn the subpanel's feeder breaker off at the main panel. Prove the subpanel dead.
2. Remove the dead-front.
3. Look for a green bonding screw or a bonding strap from the neutral bar to the can. There should be none.
4. Look for equipment grounds on the neutral bar. There should be none.

5. Count the feeder conductors. There should be four: two hots, a neutral, and an EGC (or three plus a metal raceway that qualifies under 250.118).
6. With the feeder still off and the neutral feeder conductor lifted from the bar, measure continuity from the neutral bar to the can. It must read open. If it reads continuity, a bond is hiding somewhere (a screw, a strap, a ground wire on the neutral bar, or a neutral touching the can).
7. Fix whatever you find: remove the bond, install a ground bar bonded to the can (408.40), move grounds to it, reland the feeder neutral, torque.

The Arc Guide calls a subpanel with neutral and ground on the same bar "the most common serious grounding error found in field inspections" (Part 10).

4.8 Detached garage or shop (250.32)

1. A detached building fed by a feeder needs its own grounding electrode system and GEC (250.32(A)). Two rods at least 6 ft apart, as in R1.5.
2. Exception: a building fed by only one branch circuit (a multiwire branch circuit counts as one) that includes an EGC does not need an electrode (250.32(A) Exception).
3. Run a four-wire feeder. The EGC runs with the supply conductors and lands on the building disconnect enclosure and the GEC. The neutral is not connected to the EGC or the electrodes at the detached building (250.32(B)(1)).
4. Old three-wire feeders to detached buildings may stay only if all three conditions in 250.32(B)(1) Exception No. 1 still hold: no EGC run with the supply, no continuous metal path (water pipe, phone, metal fence) bonded between the buildings, and no ground-fault protection of equipment on the supply side. If you add a metal water line, a data cable with a grounded shield, or anything else that connects the two buildings, the exception ends and the feeder must become four-wire.
5. Bond any metal water piping in the detached building per 250.104(A)(3).

4.9 Ranges and dryers on three-wire circuits (250.140)

1. New range and dryer circuits are four-wire: two hots, a neutral, and an EGC. The frame connects to the EGC (250.140(A)).
2. Existing three-wire circuits (two hots and a neutral, no EGC) may stay, with the frame bonded to the neutral, only under all of the conditions in 250.140(B). This is for existing branch-circuit installations only.
3. When a customer buys a new dryer and the receptacle is three-wire, the cord matches the receptacle. The appliance comes with a bonding strap between its neutral and frame terminals. On a three-wire hookup the strap stays. On a four-wire hookup the strap comes out. R1.13 covers the hookup.

4.10 Keep EGCs continuous in every box (250.148)

1. All EGCs that enter a box are connected together (250.148(A)).

2. Removing a device must not break the ground to anything else (250.148(B)). Splice the EGCs with a listed connector and run one pigtail to the device's green screw. Do not run the incoming ground to one device screw and the outgoing ground from a second screw. The Arc Guide lists this daisy-chain as its third most common serious grounding mistake (Part 10).
 3. In a metal box, add a connection used for nothing else between the EGC and the box: a green grounding screw in the box's tapped hole or a listed grounding clip (250.148(C)).
 4. In a plastic box, bring the EGC to every device that needs one (250.148(D)).
-

5. Worked Examples

Example 1: Why a ground rod alone cannot trip a breaker

Given. A 120 V hot wire faults to a metal well-pump casing. The casing is connected only to a ground rod, with no EGC back to the panel. The rod measures 25 ohms to earth (the most the NEC tolerates for a single rod under 250.53(A)(2) Exception). Assume the utility's grounding and the earth path back to the transformer add little.

1. Fault current through the earth $\approx 120 \text{ V} \div 25 \Omega = 4.8 \text{ A}$.
2. The pump is on a 20 A breaker. 4.8 A is less than 20 A. The breaker never trips.
3. The casing sits at a dangerous voltage above the earth around it for as long as the fault lasts.

Same fault with a 12 AWG EGC. Say the fault loop (hot, EGC, back through the service) measures 0.3Ω . Fault current $\approx 120 \div 0.3 = 400 \text{ A}$. 400 A on a 20 A breaker trips it on the magnetic trip in a fraction of a second.

Lesson. The EGC clears faults. The rod limits lightning and surge voltage. Both are required, and neither does the other's job.

Example 2: Size the EGC for an added ground

Given. A bedroom receptacle on a 15 A breaker, two-wire cable. A three-wire 20 A laundry circuit from the same panel runs in the crawl space 10 ft away.

1. 250.130(C)(4) allows connection to the EGC of another branch circuit that originates in the same enclosure. The laundry circuit qualifies.
2. Size from Table 250.122 by the ungrounded circuit's breaker: 15 A $\rightarrow$ 14 AWG copper.
3. The new 14 AWG runs in the crawl space under the joists. It is smaller than 6 AWG and not run with the circuit conductors, so protect it if it is exposed to damage, or run it through the bored holes in the joists where framing protects it (250.120(C)).
4. Splice it to the laundry circuit's EGC in that circuit's box with a listed connector, keeping that box's grounds continuous (250.148).

Example 3: Water pipe bond on a 100 A service

Given. An older house, 100 A service, 2 AWG aluminum SE cable. Metal water service. No bond exists.

1. Table 250.102(C)(1), row "1/0 or smaller Al": bond is 8 AWG copper.
2. Clamp within 5 ft of entry if it will serve as the electrode connection (250.68(C)(1)). Jumper around the water meter, also 8 AWG copper.
3. Run the 8 AWG in a raceway or protected location. 250.64(B)(3) requires a GEC smaller than 6 AWG to be in RMC, IMC, Schedule 80 PVC, RTRC-XW, EMT, or cable armor, and 250.104(A)(1) applies 250.64(B) to this jumper.

Practical note. Many crews run 6 AWG copper instead, because 6 AWG may run exposed along the surface where it is not subject to damage (250.64(B)(1)), which saves the raceway.

Example 4: CSST bond length

Given. The gas enters at the back corner of the house. The service is on the front corner, 62 ft away measured along the route the wire will take.

1. Gastite TB2014-01: 6 AWG copper minimum, 75 ft maximum.
2. 62 ft is under 75 ft. Run 6 AWG copper from a UL 467 clamp on the black iron pipe to the GEC or service enclosure.
3. If the route were 80 ft, look for a closer point on the grounding electrode system. A grounding electrode near the gas entry that is bonded into the system is a permitted connection point under the Gastite bulletin.

Example 5: Bootleg ground found with Method B

Given. A 1958 house. A kitchen receptacle on a two-wire circuit reads "correct" on a plug-in tester.

1. Neutral to ground, no load: 0.0 V.
 2. Plug in a 1,500 W hair dryer on high (about 12.5 A). Neutral to ground: still 0.0 V.
 3. Hot to neutral dropped from 121 V to 117 V under load, so there is real voltage drop on the circuit. A real separate ground would show part of that drop between neutral and ground.
 4. Conclusion: bootleg. Turn off, pull the receptacle, find the jumper, remove it, and apply Fix 1 or Fix 2. Kitchen countertop receptacles must also meet today's GFCI rules on replacement (406.12(D)(3)).
-

6. Safety Warnings Summary

The warnings sit at the steps where they apply. These apply to all grounding work.

1. **A ground wire can carry current.** On a house with a bad neutral, the GEC, the water pipe bond, and the EGCs can carry amps. Clamp an ammeter on a ground or bond wire before you disconnect it. Kuhlman describes a water pipe bond as the only thing carrying neutral current at some houses, and warns that a plumber who removes that wire can be hurt or killed (p. 87).
 2. **Never lift the main bonding jumper or a service GEC with the service energized.**
 3. **Bootleg grounds can make metal parts live** if the neutral opens. Treat appliance cases and receptacle plates in a bootlegged circuit as possibly energized until tested.
 4. **Lost neutral.** If lights in different parts of the house go bright and dim together, or you measure one leg high and one leg low (for example 140 V and 100 V) to neutral, suspect a lost service neutral. Turn off the main and call your journeyman and the utility (Arc Guide, Part 10, "Lost / Floating Neutral"; Kuhlman, "Neutral connection issue," pp. 86–88). Phase 2 covers the diagnosis.
-

7. Common Mistakes

Mistake	Why it is wrong	Fix
Three-slot receptacle with nothing on the ground screw, no GFCI, no label	Promises a ground that is not there	Fix 1, 2, or 3 (Section 4.3)
Bootleg jumper from neutral to ground	Neutral-ground connection downstream of the service (250.142(B)); case goes live if the neutral opens	Remove the jumper; Fix 1, 2, or 3
Grounds on the neutral bar in a subpanel, or bonding screw left in	Objectionable current on grounds and metal (250.6, 250.24(B))	Section 4.7
Three-wire feeder to a detached garage that now has a metal water line or other metal path between buildings	250.32(B)(1) Exception No. 1 no longer applies	Upgrade to a four-wire feeder
GFCI's ground screw connected to downstream grounds on an ungrounded circuit	Forbidden by 406.12(D)(2)(b); creates a false ground path	Leave the green screws unconnected; label
Ground daisy-chained through two device screws	Removing one device ungrounds the rest (250.148(B))	Splice and pigtail
No jumper around the water meter	Bond lost when the meter is changed (250.53(D)(1))	Add a jumper the same size as the bond
Water pipe clamp on a plastic pipe section, or past a dielectric union	No metal path to the rest of the piping	Clamp on metal pipe; jump across plastic sections
CSST bond clamp on the yellow CSST jacket	Not the manufacturer's method	Clamp on rigid pipe or a rigid fitting (Gastite TB2014-01)
Gas pipe used as a grounding electrode	Forbidden (250.52(B)(1))	Use rods, water pipe, or footing steel
Ground rods only 4 ft long, or two 4 ft rods called one electrode	Each rod must have at least 8 ft in contact with soil (250.53(A)(4)(a)); rods at least 6 ft apart (250.53(A)(3))	Drive 8 ft rods. The Arc Guide "Grounding and Bonding" list wrongly calls two 4 ft rods 6 ft apart acceptable
Relying on a plug-in tester to prove a ground	It cannot detect a bootleg	Meter method (Section 4.2)

8. Field Exercise (from the course outline, written out in full)

Where: a pre-1965 house with two-wire circuits, on a real YES job or a training house, with a journeyman present. **Time:** half a day.

Part 1: Find the ungrounded and bootleg receptacles.

1. Make a list of every receptacle in two rooms. Number them.
2. Test each with a three-light plug-in tester. Record the result.
3. For every three-slot receptacle that reads "correct," do Method B (Section 4.2): neutral to ground with no load, then with a 10 A or larger load. Record both readings.
4. Mark each receptacle as grounded, ungrounded, or bootleg. For any you mark bootleg, turn off the circuit, prove dead, pull the receptacle, and photograph the jumper.

Part 2: GFCI fix with labels.

1. Pick one ungrounded circuit. Find its first receptacle.
2. Replace it with a GFCI receptacle, LINE to the incoming cable, LOAD to the downstream cable. Do not connect the green screw to anything.
3. Apply the "No Equipment Ground" label to the GFCI or its plate.
4. Replace one downstream two-slot receptacle with a three-slot. Apply "GFCI Protected" and "No Equipment Ground."
5. Press TEST on the GFCI. Show the journeyman that the downstream receptacle goes dead.

Part 3: Run a separate EGC.

1. On a second ungrounded receptacle, find a connection point allowed by 250.130(C). Write down which of the five options you used.
2. Size the EGC from Table 250.122 by the circuit's breaker.
3. Run the EGC, protecting it where required, and splice it at the source with a listed connector, keeping that box's grounds continuous.
4. Land it on a new grounding-type receptacle.
5. With the circuit off, measure continuity from the receptacle ground slot to the panel ground bar with a long lead. Record the resistance.
6. With power on, measure hot to neutral, hot to ground, and neutral to ground. Record them.

Part 4: Piping bonds.

1. Find the water service entry. Install a listed water pipe bonding clamp on metal pipe within 5 ft of entry. Size the bonding jumper from Table 250.102(C)(1) based on the service conductors you see at the meter. Run it to the service enclosure or GEC.
2. Install a jumper around the water meter.
3. Install a gas pipe bonding jumper. If the house has black iron gas pipe, clamp it on the house side of the meter and run the jumper to the service. If it has CSST, follow the

manufacturer's bonding sheet: UL 467 clamp on a rigid section, 6 AWG copper, 75 ft maximum.

Sign-off questions:

- Why does the earth not trip the breaker? Give the numbers.
 - Why must the GFCI's green screw stay empty on an ungrounded circuit?
 - Where in this house do neutral and ground meet? Show it.
-

9. NEC 2026 Cross-References

Section	Topic
250.4	Performance requirements; (A)(5)(c) earth is not an effective fault path
250.6	Objectionable current
250.24	Service grounding; (B) no neutral-to-ground on the load side
250.28	Main bonding jumper
250.32	Detached buildings fed by a feeder; four-wire rule; Exception No. 1 for existing three-wire
250.52(B)(1)	Gas piping is not a grounding electrode
250.53	Rod installation, 8 ft, 6 ft spacing, water meter continuity
250.64(B)	Protection of GEC and bonding jumpers
250.68(C)(1)	5 ft water pipe rule
250.102(C)(1)	Bonding jumper size table
250.104	Bonding water piping, other piping including gas, structural metal
250.114	Cord-and-plug equipment that must be grounded, including residential appliances
250.118	What counts as an EGC
250.119	EGC color
250.120(C)	Protection of EGCs smaller than 6 AWG run separately
250.122	EGC size
250.130(C)	Connecting a new EGC for a non-grounding receptacle or branch-circuit extension
250.140	Ranges and dryers, three-wire for existing installations only
250.142(B)	No neutral used to ground equipment on the load side
250.146	Bonding the receptacle to the box
250.148	EGC continuity in boxes
320.108	AC cable armor as EGC
406.12(D) (2023: 406.4(D))	Replacing receptacles: grounding, non-grounding, GFCI, AFCI, tamper-resistant, weather-resistant
408.40	Panelboard grounding; no EGCs on the neutral bar except where bonding is permitted

10. End-of-Chapter Checklist

- [] Every three-slot receptacle has a real EGC, or is GFCI-protected and labeled "GFCI Protected" and "No Equipment Ground."
 - [] No bootleg jumpers. Checked with a meter, not only a plug-in tester.
 - [] GFCI green screws on ungrounded circuits have nothing connected.
 - [] Any added EGC connects at a point listed in 250.130(C), is sized from Table 250.122, and is protected where required.
 - [] Grounds spliced and pigtailed in every box; metal boxes bonded.
 - [] Neutral and ground meet only at the service equipment.
 - [] Subpanels: no bonding screw, separate ground bar, four-wire feeder.
 - [] Detached buildings: four-wire feeder (or a verified Exception No. 1), own electrode system.
 - [] Water pipe bonded, sized from Table 250.102(C)(1), clamp accessible, jumper around the meter.
 - [] Gas pipe bonded per 250.104(B).
 - [] CSST direct-bonded per the manufacturer: UL 467 clamp on rigid pipe, 6 AWG Cu minimum, 75 ft maximum.
 - [] Ground rods 8 ft long, at least 6 ft apart.
 - [] Ammeter check on every bond or GEC before disconnecting it.
 - [] All findings and fixes written on the work order with photos.
-

11. Sources

- NEC 2026 (NFPA 70), sections as cited.
- Kuhlman, Residential Electrical Troubleshooting (2019) (PDF page equals book page): GFCI breaker 5 mA trip, pp. 38–39; "Neutrals and Grounds connected in panel, main service panel vs sub-panel," p. 43; "Neutral wire in electrical service," p. 45, with the 6.4 A water pipe reading on p. 46; "Neutral connection issue," pp. 86–88, including the water meter jumper on p. 88; three-family neutral story with 9 A on the water pipe bond, p. 102. Paraphrased.
- Arc Workforce, Residential Electrical Field Guide: Part 2 "Grounding and Bonding," Part 8 "Older Home Quirks (1950s–1980s)," Part 10 "Grounding — The 3 Most Common Serious Mistakes" and "Lost / Floating Neutral." Two Arc Guide statements are corrected in this module: the two 4 ft rods claim and the advice against a remote EGC connection.
- OSHA 3075, Controlling Electrical Hazards, p. 13, "What is grounding and what protection does it offer?"
- [erico-practical-guide-to-electrical-grounding.pdf](#), Chapter 3, "Building Interior Bonding and Grounding" (begins p. 47), for further reading.
- Titeflex/Gastite, Technical Bulletin TB2014-01, Electrical Bonding of Gastite CSST (U.S. use January 1, 2015): https://www.gastite.com/downloads/pdfs/Direct-bonding_TB2014-01.pdf
- Pro-Flex, Electrical Bonding instruction sheet: <https://proflexcsst.com/wp-content/uploads/2023/12/Electrical-Bonding.pdf>

- Commercial modules 1.7 (grounding and bonding) and 2.7 (verifying grounding and bonding, fall-of-potential test).
-

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
§2.3 Where neutral and ground meet, and where they must not; §4.7 Check a subpanel	Why Do We Bond at the Service Panel and Not a Subpanel? Electrician U • 19:46 Whiteboard walk-through of the fault path back to the transformer, why neutrals and grounds join at one point at the service, and how a bond in a subpanel puts objectionable current on grounds and metal parts. Caution: Long and conversational, with a merch plug at the start; the teaching starts about one minute in.
§4.3 Fix an ungrounded receptacle: the GFCI method with labels	Replace Old 2-Prong Circuit of Receptacles with GFCI Protection Per 2026 NEC 406.4 (2) Sparky Channel • 22:33 Maps a whole circuit of two-prong receptacles with a breaker finder, uses voltage-drop readings to find the first receptacle, puts a GFCI there, installs grounding-type receptacles downstream, and reads the NEC 2026 'No equipment ground' and 'GFCI protected' label rules. Caution: He confirms dead with a non-contact tester; YES adds the meter check (R1.1 §3.2). He cuts backstabbed wires flush at the receptacle; only do that when the box has enough conductor left (6 in. free, R1.3). He briefly re-energizes open splices to find the line cable, which is a journeyman task.
§4.1 and §4.2 Test with a plug-in tester; find a bootleg ground	What is a Bootleg Ground? Why are Bootleg Grounds Dangerous? Morgan Inspection Services • 4:22 On a test rig, a three-light tester reads 'correct' on a bootleg-grounded receptacle, a circuit analyzer flags a false ground, and opening the neutral upstream puts 120 V on a toaster oven's metal case. Caution: Home inspector, not an electrician. He detects the bootleg with a SureTest analyzer; R1.6 §4.2 teaches the meter method YES uses. Do not recreate the energized-case demonstration.
§4.6 Bond CSST gas tubing	How to Properly Bond HOME-FLEX CSST Valencia Pipe Co • 1:49 The manufacturer shows where its UL 467 bonding clamp goes (on the first CSST brass fitting or on the black iron pipe ahead of it, sanded to bare metal) and runs at least 6 AWG copper to the service grounding. Caution: Brand-specific (HOME-FLEX). HOME-FLEX allows the clamp on its brass fitting; R1.6 says never clamp the yellow tubing itself and to follow each brand's own sheet. The 75 ft length limit in R1.6 is from the Gastite sheet and is not mentioned here.

§4.9 Ranges and dryers on three-wire circuits (250.140)	Changing a 3 Prong Dryer Outlet to 4 Prong Apartment Maintenance Pro • 4:51 Replaces a three-prong dryer receptacle with a four-prong one where an EGC was already run to the box: hots on X and Y, neutral on W, ground on G, ground bonded to the metal box, and terminals torqued. Caution: Maintenance tech, not an electrician. The swap only works because an EGC was present; with no EGC the existing three-wire circuit stays under 250.140(B) or gets rewired (R1.6 §4.9). The dryer's neutral-to-frame strap must come out on a four-wire hookup; he does not show the dryer side (R1.13).
§2.1 and §3 EGC versus GEC (Tables 250.122 and 250.66)	What's the Difference Between an EGC and a GEC? Sparky Channel • 8:05 Uses NEC Handbook exhibits to show what a grounding electrode conductor is (service to water pipe and ground rods) versus an equipment grounding conductor (the bare wire in every circuit). Caution: NEC 2020 section numbers; use the 2026 numbers in R1.6.