

Module 2.3 — Troubleshooting Branch Circuits & Devices

Dead receptacles, GFCI and AFCI trips, shared neutrals, switches, LED and 0-10 V lighting, and breaker trips, diagnosed step by step with a 14-step procedure.

Why this module. Most service calls are on branch circuits: a dead receptacle, a GFCI that will not reset, a breaker that keeps tripping, a 3-way that works from one end, a fixture that flickers. With the safety routine from Module 2.1 and the meter skills from Module 2.2, this module walks step by step through each of those calls. It covers half-splitting a dead string, finding a breaker with a tracer, the danger of a lost shared neutral, hunting GFCI leakage in milliamps, reading a breaker trip, and the meter readings that fool people. It ends with a 14-step troubleshooting procedure you can follow on any branch-circuit call.

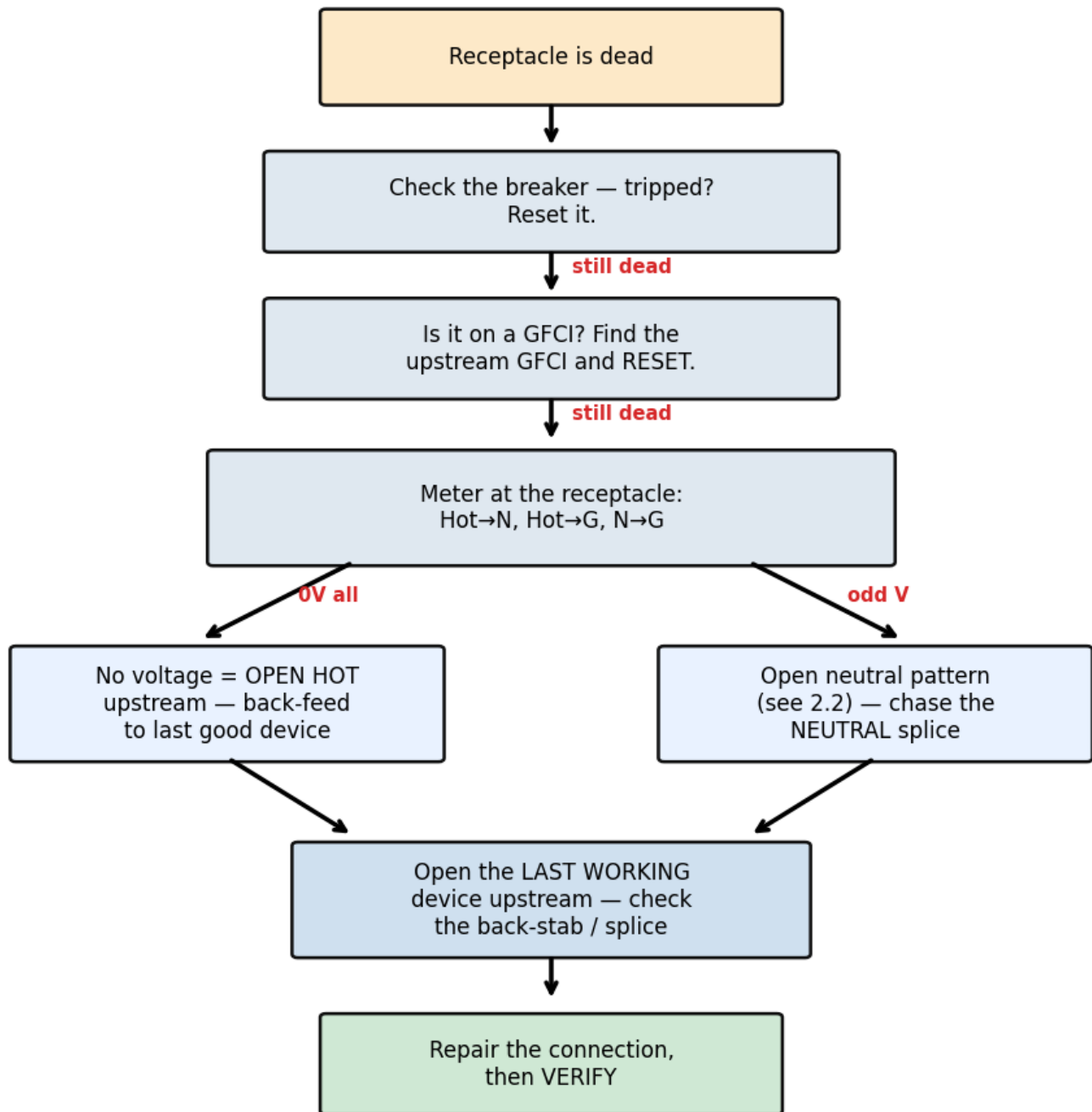
Two code books on the truck. Several branch-circuit rules moved in the 2026 NEC. If a crew member quotes the 2023 book, these are the same rules under new numbers:

Rule	NEC 2026	NEC 2023
Neutral required at lighting switch locations	406.30(C)	404.2(C)
3-way and 4-way switching in ungrounded conductors only; switches do not open the neutral	406.30(A), (B)	404.2(A), (B)
Switch ratings and use	406.46	404.14
Receptacle replacement	406.12(D)	406.4(D)
MWBC neutral not to depend on device terminals	300.15(B)	300.13(B)
Neutrals of multiple circuits grouped or identified	200.6(B)	200.4(B)

Watch 200.4(B): in the 2026 NEC it is a different rule. It now says the continuity of a grounded conductor "shall not depend on a connection to a metal enclosure, raceway, or cable armor." Snap switches now sit in Article 406 Part III, and 404.1 points to 406.1 for wiring devices.

Part A — STEP-BY-STEP: The Dead Receptacle

TROUBLESHOOTING A DEAD RECEPTACLE



Breaker → GFCI reset → voltage signature at the device → back-feed to the last working device.

Step by step (NAVEDTRA 14026 ch. 5)

1. **Interview.** Ask what died, when, what was plugged in, what else went dead (a whole room can mean a whole multiwire circuit), and what work was done recently. Pull the panel

schedule. NAVEDTRA 14026: "A few moments spent studying the circuit diagrams before you start actual troubleshooting will simplify the task."

2. **Look.** "Inspect the circuit visually. Check for loose connections, loose wires, abraded wires, and loose fittings."
3. **Find the breaker.** If the schedule is wrong or missing, use a circuit tracer (below).
4. **Check the breaker with the meter** on LoZ. Read line terminal to neutral, then load terminal to neutral with the handle ON. About 120 V in and about 0 V out means a failed breaker. NAVEDTRA gives the fuse version: "If you get a voltage reading across the fuse, that fuse is open." A few volts across a closed breaker under load points to a high-resistance contact or lug (IDEAL SureTest manual).
5. **Look for an upstream GFCI**, either a receptacle or a breaker, on the same circuit, and reset it. Part B lists where commercial GFCIs are required.
6. **Read the voltage signature** at the dead device (table below).
7. **Half-split.** On a daisy chain, open the box about halfway between the last good device and the first dead one, test, and keep halving. NAVEDTRA: check "in progressive steps ... from the last point where voltage is known to be present." Eight devices take three splits.
8. **Inspect the boundary.** At the last good and first dead device, check backstabs and splices. NAVEDTRA: "make a visual check for a broken or loose connection at the first dead (nonoperating) outlet."
9. **Repair, then retest every device on the string** with a receptacle analyzer, and record the readings (Part H).

Voltage signatures at a 120 V receptacle (meter on LoZ)

H-N	H-G	N-G	Condition
About 120	About 120	Under 2 V	Normal. "Ground-to-neutral voltage should be less than 2 VAC" (SureTest)
0	0	0	Open hot upstream: breaker, GFCI, splice or backstab
0 or erratic	About 120	Floating	Open neutral upstream
About 120	0	Ghost reading on high-Z	Open equipment grounding conductor (EGC)
About 120	About 120	Over 2 V, rising with load	Loose neutral splice, overloaded or shared neutral, or neutral-to-ground leakage
About 120	About 120	About 0 under heavy load far from the panel; analyzer shows false ground	Bootleg ground (Part F). SureTest can flag a false ground on correct wiring within 15 to 20 ft of the panel

Repair rules

- A burned backstab gets moved to the side screws, or pigtailed with a listed connector. Never re-stab it. NEC 2026 110.14 requires connectors "identified, installed, and used for the

material of the conductor," and 110.14(A) requires a "mechanically secure electrical connection without damaging the conductors." Wire-binding screws are for 10 AWG and smaller.

- Tighten terminals to the torque "as indicated on equipment or installation instructions." 110.14(D): "An approved means shall be used to achieve the indicated torque value."
- Cut heat-damaged insulation back to bright copper. NEC 300.16(A) requires at least 6 in. of free conductor at the box. If the cut leaves less, add a pigtail. NAVEDTRA 14026 repeats the 6 in. rule for repair splices.

Step by step: finding the breaker with a circuit tracer

IDEAL SureTrace 61-957 (rated 0 to 600 V, CAT III 600 V, safe on GFCI circuits):

1. Connect the transmitter to the circuit. An energized circuit gives "a much stronger signal."
2. Set the receiver to Breaker mode.
3. Slide the receiver nose down each breaker. "The breaker with the highest numeric reading is the correct breaker." If two are close, tip the nose 45 degrees each way to break the tie.
4. To find an open: follow the highest reading along the wire "until the signal starts to fall off. This is the location of the open." If it never drops off, the signal is bleeding into nearby wires: "ground the adjacent conductors."
5. To find a short or ground fault: connect one lead to the faulted conductor and one to ground (metal conduit counts). The signal weakens past the fault.
6. Safety: a remote ground must be "less than 100 ohms from remote ground to circuit neutral." Do not use a remote ground in patient-care areas.

Klein ET450 (33 kHz; its LED lights when the circuit is energized above 25 V):

- Hold the receiver perpendicular to the breakers. Use sensitivity 1 to 3 on energized circuits and 4 to 8 on de-energized circuits. Rescan after each change.
- The remote-ground hookup "will trip GFCI receptacles." On a de-energized circuit, connect across neutral and ground for a stronger loop.
- Metal conduit blocks the signal, so check at each box.
- The manual warns: "Neutrals in multi-wire branch circuits may be energized when disconnected and must be retested before handling."

The lost shared neutral (multiwire branch circuits)

A multiwire branch circuit (MWBC) is two or three hots sharing one neutral. If that neutral opens, the 120 V loads on different legs end up in series across 208 V or 240 V. Mike Holt: "the resultant over- or undervoltage could cause a fire and/or destruction of electrical equipment." Square D says loads "are subject to voltages varying from 0 to 240 V."

Symptoms: lights on one circuit get brighter while another circuit's lights dim; voltage changes when an unrelated load on the other leg switches on; power supplies burn out; and the two legs' H-N readings add up to about 208 V or 240 V.

Worked example 1 (Ohm's law, resistive loads). A 208Y/120 V MWBC, legs A and B, neutral open.

Step	Math	Result
Load A: 1,200 W heater	$R = 120^2 \div 1,200$	12 Ω
Load B: 100 W	$R = 120^2 \div 100$	144 Ω
In series across 208 V	$I = 208 \div (12 + 144) = 208 \div 156$	1.33 A
Voltage on load B	1.33×144	About 192 V on a 120 V load
Voltage on load A	1.33×12	About 16 V
Same loads on a 120/240 V system	$I = 240 \div 156 = 1.54 \text{ A}; 1.54 \times 144$	About 221 V on load B

Electronic loads do not behave like resistors, so treat these numbers as the direction of the problem, not exact values. The small load always takes most of the voltage.

MWBC code rules (NEC 2026)

- **300.15(B) (300.13(B) in 2023):** "the continuity of a grounded conductor shall not depend on device connections such as lampholders, receptacles, and so forth where the removal of such devices would interrupt the continuity." Pigtail MWBC neutrals.
- **210.4(B):** each MWBC needs "a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates." 240.15(B)(1) allows single-pole breakers "with identified handle ties."
- **210.4(D)** requires grouping per **200.6(B) (200.4(B) in 2023):** neutrals "identified or grouped ... by wire markers, cable ties, or similar means in at least one location within the enclosure."

Turn off every leg. If one leg of a MWBC without a handle tie is still on, the neutral is still carrying that leg's current. Turn all legs off and verify absence of voltage on the neutral too before you open it.

Replacing a receptacle: 406.12(D) (406.4(D) in 2023)

"Replacements shall comply with 406.12(D)(1) through (D)(6)":

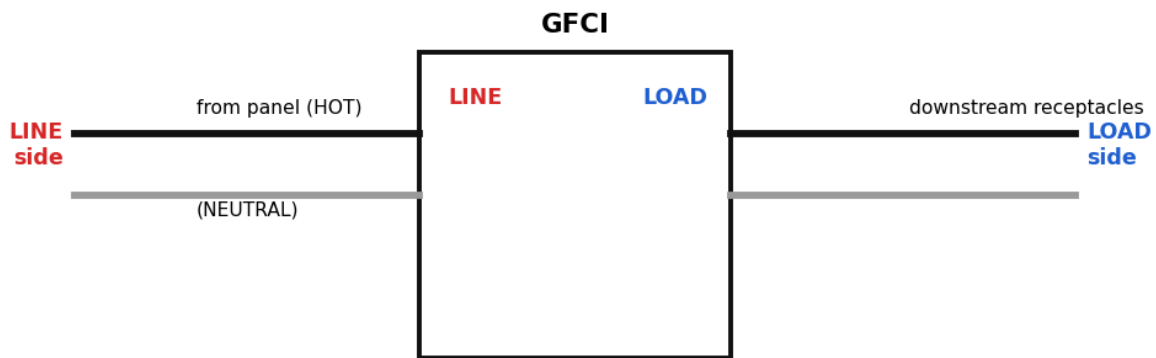
1. Use a grounding-type receptacle where a grounding means exists.
2. Where no ground exists, a GFCI may replace a non-grounding receptacle. Mark it "No Equipment Ground," and do not carry its EGC terminal to downstream outlets. Downstream grounding-type receptacles fed from it are marked "GFCI Protected" and "No Equipment Ground."
3. Provide GFCI protection where it is now required.

4. Provide AFCI protection in the areas listed in 210.12(B), (C) and (D).
5. Use tamper-resistant receptacles where required.
6. Use weather-resistant receptacles where required.

Commercial AFCI areas under 210.12(D): hotel and motel guest rooms, nursing-home and limited-care patient sleeping rooms, and fire, police and EMS sleeping quarters. 210.12(E) extends AFCI to wiring that is modified or extended in those areas, with an exception for extensions of 6 ft or less.

Part B — STEP-BY-STEP: GFCI Troubleshooting

GFCI RECEPTACLE — LINE vs LOAD (the key to isolating a fault)



Power feeds the LINE terminals; the LOAD terminals protect everything downstream. To isolate a tripping fault, move the downstream wires OFF the LOAD terminals — if the GFCI holds, the fault is downstream; if it still trips, it is the GFCI or its LINE feed.

Power feeds LINE; LOAD protects downstream. Move the load wires off to isolate a downstream fault.

The numbers

- UL 943 Class A GFCIs trip "when the ground-fault current is 6 mA or more but not when the ground fault current is 4 mA or less." NEC 210.8 requires "A listed Class A GFCI."
- A SureTest GFCI test leaks 6 to 9 mA from hot to ground (per UL 1436) and shows the trip time. Equipment protection (EPD) breakers trip above 30 mA. Square D AFCIs sense residual current "starting at approximately 50 mA."
- Fluke: "GFCI breaker manufacturers recommend one-way feeder length be limited to 250 feet (76.2 m), maximum," because the capacitance of a long run adds leakage.

Where commercial GFCIs are required: 210.8(B)

210.8(B) covers 125 to 250 V receptacles on single-phase circuits 150 V or less to ground and 50 A or less, and on three-phase circuits 150 V or less to ground and 100 A or less. The locations are: bathrooms, kitchens, food and beverage prep areas, buffet serving areas, rooftops,

outdoors, within 6 ft of a sink, indoor damp and wet locations, locker rooms with showers, garages, service bays and accessory buildings, crawl spaces, unfinished basements, aquariums and bait wells (within 6 ft), laundry areas, and within 6 ft of a tub or shower. The three-phase clause puts 208 V three-phase kitchen receptacles up to 100 A on GFCI, which produces many nuisance-trip calls.

Step by step: a GFCI that will not hold

1. Press **RESET**. If it will not hold, there is a fault or a wiring error.
2. **Move the downstream wires off the LOAD terminals** (or unplug all loads). If the GFCI now holds, the fault is downstream. If it still trips, it is the device itself, or a neutral-to-ground contact or shared neutral on the line side.
3. Confirm LINE and LOAD are not reversed. A reversed GFCI will not protect downstream outlets and may not reset.
4. Check for a downstream neutral touching ground, or a neutral shared with another circuit. Siemens: "Ensure neutral conductors have not inadvertently been connected to a ground conductor at any point in the circuit."
5. Check for two 1-pole GFCI breakers on one neutral. Schneider FAQ FA109025: two 1-pole GFI, AFI or EPD breakers on one neutral "will cause both breakers to nuisance trip." Use a 2-pole GFCI (120/240 V or 208Y/120 V). A 2-pole combination AFCI is 120/240 V only.
6. Look for moisture in rooftop and outdoor boxes, and for leakage from motors and heat trace.
7. If the wiring is clean, measure leakage (next procedure).

Step by step: hunting leakage with a leakage clamp (Fluke 368 FC class)

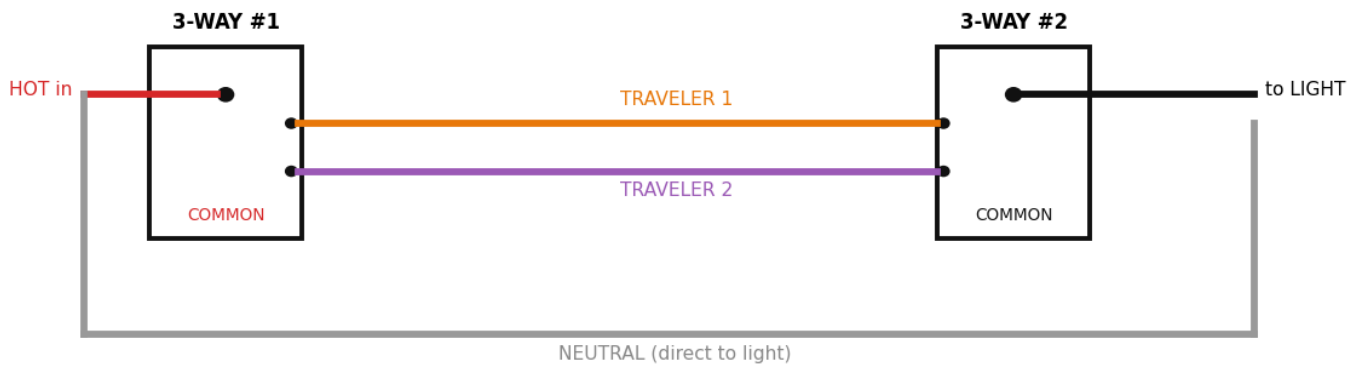
1. Clamp hot and neutral together (single-phase), or all phases and the neutral (three-phase). The load current cancels and what remains is leakage. The clamp must resolve below 0.1 mA. An ordinary clamp cannot read below about 5 mA.
2. Read with loads off (wiring only), then with loads on. Fluke example: 240 V with loads off reads 0.02 mA, so the wiring insulation is $240\text{ V} \div 20\text{ }\mu\text{A} = 12\text{ M}\Omega$.
3. Clamp the EGC alone to see leakage on the intended path. Clamp hot, neutral and EGC together to see leakage leaving by unintended paths such as the slab or a water pipe.
4. Work from the main to each circuit to each load until you find who carries the milliamps. Electronics with EMI filters add leakage "in the order of milliamps," and adding equipment "could trip the GFCI."
5. Keep the jaws clean and fully closed, and do not twist the clamp while reading.

Worked example 2. A circuit shows 3 mA of standing leakage. The GFCI may trip anywhere from 4 to 6 mA, so the circuit is only 1 to 3 mA from a trip. Split the loads onto another protected circuit or replace the leaky equipment. Never move a required outlet off GFCI protection to stop the trips.

Part C — Switches (3-way is most calls)

THREE-WAY SWITCH WIRING (control a light from two places)

Hot lands on #1 COMMON; the two TRAVELERS run between the switches; #2 COMMON feeds the light. Neutral goes straight to the light.
Troubleshoot: a swapped common/traveler = "works from only one switch". Verify the COMMON (dark screw) on each switch.



3-way: hot on #1 common, two travelers between, #2 common to the light. Verify the COMMON (dark screw).

Step by step: a 3-way that misbehaves

1. Power on. At switch 1, read common to ground. About 120 V means this is the line-side switch.
2. Flip switch 1. The voltage should move from traveler A to traveler B. If it does not, the hot is landed on a traveler screw.
3. At switch 2, one traveler should be hot in each position of switch 1.
4. With power off, take the switch out and ohm it: common to A is closed in one position and common to B in the other, open (OL) otherwise.

Symptom	Cause
Works from one switch only	Common and traveler swapped at one switch. The common is the dark screw
Works only in some combinations	One traveler is open
Breaker trips when a switch is flipped	A traveler is landed on the neutral

4-way switches

A 4-way sits between two 3-ways. It has an in-pair and an out-pair of traveler terminals. In one position it passes straight through (in-1 to out-1, in-2 to out-2). In the other it crosses (in-1 to out-2, in-2 to out-1). Ohm it in both positions to test it. The common wiring fault is a traveler pair split across the device, one in-traveler landed on the out side. Check the terminal layout on the device's wiring sheet, because it differs by maker.

Code (NEC 2026)

- **406.30(A) (404.2(A) in 2023):** 3-way and 4-way switches are "wired so that all switching is done only in ungrounded circuit conductors." Switch loops do not need a grounded conductor.
- **406.30(B) (404.2(B)):** "Switches shall not disconnect the grounded conductors of circuits."
- **406.30(C) (404.2(C)):** a neutral is required at lighting switch locations in bathrooms, hallways, stairways, and habitable or occupiable rooms, with exceptions. It must "be connected to switching devices that require line-to-neutral voltage to operate the electronics of the switch in the standby mode." The retrofit exception caps neutral-less electronic switches at five per branch circuit and 25 per feeder. In the field, a sensor with no neutral leaks its standby current through the EGC or through the load, which is why LED fixtures glow or flicker when "off."
- **406.46 (404.14):** switches are "marked with their ratings." Motor loads are limited to 80 percent of the rating. Confirm a switch on a 277 V lighting circuit is rated for 277 V.

Part D — Lighting

Step by step: a dead 277 V LED fixture

1. Confirm the system at the panel. On 480Y/277 V, line to neutral is 277 V and line to line is 480 V. Use a meter rated CAT III 600 V or higher.
2. Open the fixture's disconnect and verify absence of voltage.
3. Check line voltage in at the LED driver. Many drivers accept 120 to 277 V, but not all.
4. Check the driver's DC output on its red and black leads to the LED board. The output is polarity-sensitive. Input present with no output means the driver has failed. Output present with the board dark means the board or its connector has failed.
5. Replace like for like. The driver and LED engine must match.

0-10 V dimming

- The dimming pair is purple (+) and gray, now pink (common). The driver puts out about 10 V DC on the pair. Pair open = full bright. Pair shorted = minimum or off. Pink replaced gray starting in 2022 because gray dimming leads were being tied to 277 V neutrals (Acuity Pathway).
- Short test (Lighting Services Inc. FAQ): first check the pair for line voltage. Then disconnect purple and gray from the dimming circuit and touch them together. A working driver drops to minimum, about 10 percent. No response means the driver. A response means the wiring or the dimmer.
- At the controller expect about 10 V DC at 100 percent, about 5 V at 50 percent, and about 1 V at 10 percent (Paratus).
- One fixture with the pair reversed can upset a whole zone. Split the zone in half to find it (Paratus).
- Keep the Class 2 dimming wiring separated from line-voltage wiring, as the fixture maker's instructions require.

Occupancy sensors

- Line-voltage sensors need a neutral (406.30(C)). See the standby-current note in Part C.
- Low-voltage sensors run off a power pack. Check the pack's DC output and its relay before you look at the fixtures. Get the expected values from the pack's data sheet.
- Lights that cycle on and off: check the timeout and sensitivity settings first.
- Lights that never turn off: check for test or override mode, or for the line wire touching the load wire.

Part E — Breaker Trips: Read the Trip

How it trips	Likely fault	First test
After running a while under load	Overload	Clamp the hot at the panel; compare to the rating and 210.20(A)
Instantly on reset, with loads unplugged	Bolted short, hot to neutral or hot to ground	Lock out; ohm H-N and H-G at the panel
Only when one load is plugged in	Bad load or cord	Try the load on a known-good circuit
AFCI or GFCI trips where a standard breaker would hold	Ground fault, arcing, or shared neutral	Leakage clamp; check the pigtail and neutral landing
Randomly, in a hot panel or on hot days	Heat-related nuisance trip or loose lug	Volts across the closed breaker under load; IR scan

- 210.20(A): the breaker must be "not less than the noncontinuous load plus 125 percent of the continuous load." A standard 20 A breaker therefore carries 16 A continuous. A load of 18 A for 3 hours or more on a 20 A circuit is an overload, not a bad breaker.
- 240.4(D) caps 14 AWG at 15 A and 12 AWG at 20 A. Never put in a bigger breaker to stop trips.
- A receptacle analyzer's load estimate is rough. SureTest: "accurately measuring circuit current has to be done with a clamp meter at the electrical panel."

Step by step: hunting a short (NAVEDTRA 14026 pp. 5-40 to 5-41)

1. Lock out and verify absence of voltage (Module 2.1).
2. Unplug the loads, remove lamps, and reset. "If the short is clear, then the trouble will be found in the equipment."
3. Lift the hot and neutral at the panel "to isolate the circuit and to prevent feedback from the other circuits."
4. Ohm hot to neutral and hot to EGC. "'Infinity' means that the circuit is good, and 'continuity' means a short."
5. Open the midpoint box, separate the splices, test each direction, and keep halving. In the faulted section, look for staples, screws through cable, and nicks at box edges.
6. If the fault is inside a wall, put a tracer on the faulted conductor and follow it until the signal drops (SureTrace).

Step by step: megger for intermittent faults and nicked wire

An ohmmeter tests at a few volts and misses insulation that only breaks down at line voltage. Megger's guide says insulation tests are usually run "at an applied voltage of 500 volts or more," and for "a short run of house wiring, the spot reading test is all that is necessary." Its one-megohm rule calls 1 M Ω "a fair allowable lower limit for insulation resistance of ordinary industrial electrical equipment rated up to 1000 volts."

1. Lock out and verify dead.
2. Disconnect every load, LED driver, sensor, GFCI and AFCI device, and electronic switch. 500 V DC destroys them.
3. Lift the conductors at the panel.
4. Test each conductor to the EGC and conductor to conductor at 500 V DC. Five hundred volts is the usual choice for 120/277 V circuits; Megger's table starts its 500 V row at 440 V equipment.
5. Discharge each conductor after the test.
6. A short run that reads only a few megohms points to a nick, moisture, or a crushed conductor.

NAVEDTRA 14026 describes the "floating ground": fuses blow "a number of times, and a circuit test shows no defects." That is typical of a nick that only closes when the wire is warm or wet, and the megger finds many of them.

Step by step: an AFCI that keeps tripping (Siemens guide; Square D)

1. Press TEST. If it does not trip, replace the breaker.
2. Check the landings: load hot and load neutral on the breaker, and the white pigtail on the neutral bar. Plug-on-neutral breakers have no pigtail.
3. Look for a shared neutral: "A single-pole AFCI will not operate properly on shared neutral wiring." The clue is black, red and white from one cable landed on two single-pole AFCIs. Use a 2-pole AFCI or run separate neutrals.
4. Look for a neutral touching ground anywhere. Square D's example: a bare ground touching a fixture neutral trips the AFCI "immediately when the lamp is turned on."
5. Remove all loads. If it still trips, the problem is in the wiring. A nail or screw through a cable is "the most common cause of arcing in permanent circuits." Then add loads back one at a time.
6. An IDEAL SureTest 61-165 NEUT test puts 300 mA from hot to neutral to find a shared or grounded neutral. Its AFCI test makes a 106 to 141 A arc per UL 1436.

Heat-related trips

A breaker in a hot rooftop panel, or next to a loose lug, can trip below its rating. Look for discoloration and measure volts across the closed breaker under load. If you find a loose connection, de-energize and remake it to the marked torque (110.14(D)). Ambient derating for a breaker comes from the manufacturer's data.

Resetting onto an unknown fault is arc flash exposure. Stand to the side, face away, and wear the PPE from Module 2.1. Before touching any conductor, OSHA 1910.333(b)(2)(iv) (B) requires a qualified person to "use test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and shall verify that the circuit elements and equipment parts are deenergized."

Part F — Meter Traps

Ghost voltage and LoZ

- A dead conductor running beside live ones acts like a capacitor. A 10 M Ω DMM completes the circuit and shows coupled voltage. Longer, fuller raceways make it worse (Fluke note 2105317).
- Fluke: ghost readings "can be 80-85% of what the 'hard' voltage should be." They are common at blown fuses, spare conductors, and an "open ground or neutral on a 120 V branch circuit." Auto-V/LoZ (about 3 k Ω) collapses them to near zero.
- Fluke note 6002580: LoZ meters (2 to 100 k Ω) "should only be used for testing power circuits." Use high impedance on electronics and controls. In a Fluke 117 case study, 73 V on a dead control circuit turned out to be ghost voltage.
- Confirm every open-neutral or open-ground call with LoZ or a loaded analyzer before you start opening boxes.

Neutral-to-ground voltage

N-G should be under 2 V AC (SureTest). Read it with the load off, then on.

N-G reading	Meaning
Rises with load	Voltage drop on the neutral: a loose splice or a long run
High with no load	Current on the EGC from a downstream neutral-to-ground bond, or leakage
Zero under heavy load far from the panel	Neutral tied to ground at the device (bootleg)
High on a three-phase shared neutral	Load imbalance or harmonic current

Voltage drop under load

- 210.19 Informational Note: 3 percent at the farthest outlet, and 5 percent for feeder plus branch, for "reasonable efficiency." The note is advice, not an enforceable rule.
- SureTest: loaded voltage "should not drop below 108VAC," and the drop should get smaller as you move toward the panel. Over 5 percent and flat all the way toward the panel means the problem is between the first device and the panel. A jump between two receptacles means "a high impedance point at or between two receptacles."

Worked example 3 (NEC Chapter 9, Table 8). A 120 V circuit, 100 ft one way, carrying 16 A. 12 AWG stranded uncoated copper is 1.98 Ω per 1,000 ft at 75°C.

Wire	Math	Drop	Percent of 120 V
12 AWG (1.98 Ω /kft)	$2 \times 100 \times 1.98 \div 1,000 \times 16$	6.34 V	5.3%
10 AWG (1.24 Ω /kft)	$2 \times 100 \times 1.24 \div 1,000 \times 16$	3.97 V	3.3%

Reversed polarity and bootleg grounds

- The SureTest 61-165 detects correct wiring, reverse polarity, hot/ground reversal, no ground, and "false (bootleg) grounds" made by "a ground jumper wire at the outlet device or inadvertent contact of the ground wire to the neutral connection."
- Its limits: "Will not detect two hot wires in a circuit. Will not detect a combination of defects. Will not detect reversal of grounded and grounding conductors." Do not use it on UPS outputs, dimmers or square-wave sources. Wait 20 seconds between insertions. Its ground impedance test trips GFCI circuits.
- NEC 250.142(B): grounded conductors "shall not be connected to non-current-carrying metal parts of equipment on the load side of the service disconnecting means." To fix a bootleg, run an EGC per 250.130(C), or use the GFCI replacement option in 406.12(D)(2) with the labels.
- Reversed polarity puts voltage on lamp shells and appliance internals even with the switch off. White goes to the silver screw.

Part G — The 14-Step Branch-Circuit Troubleshooting Procedure

Follow the steps in order. "Go to" means skip to that step.

1. Is the breaker tripped? Yes: go to step 10. No: go to step 2.
2. On LoZ, is there voltage at the breaker's load terminal? No: replace the breaker. Yes: go to step 3.
3. Is the circuit downstream of a tripped GFCI? Reset it. If it will not hold, go to step 14. If there is no GFCI, go to step 4.
4. Read H-N, H-G and N-G at the dead device on LoZ.
5. If H-G is about 120 V and H-N is about 0 V, the neutral is open: go to step 7.
6. If all three read about 0 V, the hot is open: go to step 8.
7. Is it a multiwire branch circuit? Yes: turn all legs off, check the neutral splices and any neutrals landed on device terminals, and pigtail per 300.15(B). No: go to step 8.
8. Half-split between the last good and first dead device. Inspect splices and backstabs at the boundary. Use a tracer if the wiring is concealed.
9. Repair, torque to the marked value, retest every device with an analyzer, and record the readings. Done.
10. Does it trip instantly with all loads unplugged? Yes: go to step 12. No: go to step 11.

11. Clamp the load. Over 80 percent of the breaker rating for a continuous load is an overload: move loads to another circuit. Under that, measure volts across the breaker and look for lug heat; repair the connection or replace the breaker. Done.
12. Lock out, lift the conductors, and ohm H-N and H-G. Short found: half-split the boxes, repair, and go to step 9. No short: go to step 13.
13. Megger at 500 V DC with all electronics disconnected. Under about 1 M Ω : find the nick or moisture, then go to step 9. Good reading: replace the breaker and monitor it.
14. Lift the GFCI LOAD wires or remove the loads. Still trips: the device, or a neutral-to-ground contact or shared neutral on the line side; fix or replace. Holds: leakage-clamp each load and segment to find the neutral-to-ground contact, shared neutral, moisture, or leaky equipment, then go to step 9.

Worked example 4. A tenant reports four dead receptacles on one wall. The breaker is not tripped (step 1). The breaker load terminal reads 120 V (step 2). There is no GFCI on the circuit (step 3). At the first dead receptacle, H-N reads 0, H-G reads 120 (steps 4 and 5): open neutral. The panel schedule shows a 3-wire home run with a red and a black, so it is a MWBC (step 7). With both legs off and verified dead, you find the neutral passing through the screws of the last working receptacle, with one screw burned loose. Pigtail the neutral per 300.15(B), retest all devices on both legs, and record the readings (step 9).

Part H — Document the Call

1. Record the panel, circuit number, fault location, cause and parts used.
2. Record the readings: H-N, N-G, loaded voltage drop percent at the last device, GFCI trip time, and the megger value with its test voltage. Megger's guide: "The trend of the curve may be more significant than the numerical values themselves."
3. Correct the panel directory. NEC 2026 408.4(A) requires descriptions "unlikely to result in confusion between circuits."
4. Label and handle-tie MWBCs per 210.4(B) and (D).
5. Note problems outside your scope, such as bootleg grounds or neutral-less sensors, for the customer.

Part I — Common Mistakes

Mistake	Result	Source
Calling dead or live from a high-Z reading	Chasing ghosts, or missing an open neutral	Fluke 2105317
Opening a MWBC neutral with one leg still on	Arc or shock from the other leg	Klein ET450; 210.4(B)
MWBC neutral run through receptacle screws	Removing one device opens the neutral for the string	300.15(B)
Two 1-pole AFCI or GFCI breakers on a shared neutral	Both trip	Schneider FA109025
Meggering with electronics connected	Damaged devices and false low readings	Megger; Fluke 6002580
Putting in a bigger breaker to stop trips	Overheated conductor	240.4(D)
Re-stabbing a burned backstab	The failure comes back	110.14(A), (D)
Remote-ground tracer on a GFCI circuit	GFCI trips mid-trace	Klein ET450
Trusting a 3-light tester on a neutral-ground reversal	The tester cannot see it	SureTest manual
Gray 0–10 V lead tied to a 277 V neutral	Driver or controller damage, shock	Acuity; Paratus
Replacing a receptacle without checking 406.12(D)	Failed inspection	406.12(D)

NEC 2026 Checkpoints (2023 number in parentheses where it moved)

- **110.14, 110.14(A), 110.14(D)** connections and torque • **300.16(A)** 6 in. free conductor.
- **200.6(B)** neutral grouping (200.4(B)) • **200.4(B)** in 2026 = neutral continuity not through enclosures or raceways (a new rule at that number).
- **210.4(B), (D)** MWBC disconnect and grouping • **240.15(B)(1)** handle ties • **300.15(B)** MWBC neutral continuity (300.13(B)).
- **210.8, 210.8(B)** Class A GFCI, commercial locations • **210.12(D), (E)** commercial AFCI areas.
- **210.19** Informational Note voltage drop • **210.20(A)** 125 percent continuous • **240.4(D)** small conductor limits.
- **250.142(B)** no neutral-to-frame bond after the service • **250.130(C)** adding an EGC.
- **406.12(D)** receptacle replacement (406.4(D)) • **406.30(A), (B), (C)** switch connections and neutral at switches (404.2) • **406.46** switch ratings (404.14).
- **408.4(A)** panel directory.

Hands-On Field Exercise

- Diagnose a dead receptacle on a string by its voltage signature on LoZ, half-split to the open splice, repair it, and retest every device with an analyzer.
- Check a breaker with the meter: line terminal to neutral, load terminal to neutral, and volts across it under load.
- Find a breaker with a circuit tracer in a panel with a missing directory, then correct the directory.
- On a training board, open a MWBC neutral and read the voltage on each leg. Compare to the Worked example 1 math.
- Isolate a tripping GFCI with the LINE/LOAD split, then measure leakage with a leakage clamp, loads off and on.
- Fix a 3-way that works from one switch only, and ohm a 4-way in both positions.
- Run a 0–10 V short test on a dimmable fixture.
- Meter the de-energized circuit on an instant-trip breaker and find the short by half-splitting.
- Calculate the voltage drop for your circuit and compare it to a loaded analyzer reading at the last device.

Sources used in this module (public documents)

- NFPA 70, National Electrical Code 2026 (free read-only access): [nfpa.org](https://www.nfpa.org)
- NAVEDTRA 14026 Construction Electrician Basic, Chapter 5, "Troubleshooting and Repair of Interior Wiring Systems," pp. 5-36 to 5-41: [maritime.org](https://www.maritime.org)
- IDEAL SureTest 61-164/61-165 and SureTrace 61-955/957/959 instruction manuals: [idealind.com](https://www.idealind.com)
- Klein Tools ET450 instruction manual: [kleintools.com](https://www.kleintools.com)
- Fluke: Leakage current measurement basics; app notes 2105317 (ghost voltages) and 6002580 (input impedance); Dual Impedance Digital Multimeters; 117 ghost-voltage case study; 368/369 FC data sheet: [fluke.com](https://www.fluke.com)
- UL, Understanding Ground Fault and Leakage Current Protection: [ul.com](https://www.ul.com)
- Mike Holt, 210.4 Multiwire Branch Circuits newsletter: [mikeholt.com](https://www.mikeholt.com)
- Square D, Determining the Cause of AFCI Tripping; Schneider Electric FAQ FA109025: [se.com](https://www.se.com)
- Siemens, AFCI-GFCI Circuit Breaker Diagnostic Guide: [siemens.com](https://www.siemens.com)
- Megger, "A Stitch in Time": [megger.com](https://www.megger.com)
- Acuity Brands / Pathway, 0-10VDC Best Practice: [acuitybrands.com](https://www.acuitybrands.com); Lighting Services Inc., 0-10V FAQ: [lightingservicesinc.com](https://www.lightingservicesinc.com); Paratus Service Group, How to Troubleshoot 0-10V Lighting: [paratusservice.com](https://www.paratusservice.com)
- OSHA 29 CFR 1910.333: [osha.gov](https://www.osha.gov)

Next: Module 2.4 — Panelboards, Feeders & Overcurrent Protection.