Create Healthy Homes

Environmental Design and Inspection Services

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Building Biology Wiring Error Evaluation and Mitigation Protocol

Building biologist, give this to your electrician after you have conducted wiring error screening test and determined wiring errors are present. You should become familiar with these steps to guide electrician in finding and fixing wiring errors.

Electricians, use this information to help understand steps in one-page summary.

Objective of Protocol: To trace and repair wiring errors. Definition of a wiring error is incorrect connections in the neutral or grounding system that result in full or partial current flow on either the wrong neutral or the grounding system. The grounding system consists of metal water pipes, conduit sheathing, gas lines, air ducts, freon lines, metal framing, stucco mesh, etc.

This Two-Part Test Procedure is to determine which branch circuits have a problem, and to trace down the problem circuit(s) and correct them.

Tracing Wiring Errors

Trace wiring errors with circuit breakers switched off or on.

Testing for wiring errors with power off:

1. Low voltage continuity Tester: Test neutrals at panel with continuity tester using portable 120 Volt power supply/inverter. This is powered by 12 Volt battery with built-in charger. Refer to blue-box.jpg.
   a. We have constructed continuity testers in plastic junction boxes (“blue box” tester) that contain 120 Volt-to-12 Volt transformer, 12 Volt automotive light, and dimmer switch. Wires from 120 Volt side of tester connect to standard 120 Volt plug. Two test leads from 12 Volt side of tester with alligator clips on each end.

   b. The plug on 120 Volt side of tester transformer is plugged into outlet of inverter. Allows blue box tester to be used at panel as well as inside building to trace wiring errors at junction boxes with house 120 Volt power turned off. This method is strongly recommended for the safety of the electrician.
2. We do not recommend use of Fluke or other digital multi-meter (DMM) as continuity tester. We have seen false positive results. Due to small amount of DC voltage frequently found on neutral or ground. DMM uses DC voltage to verify continuity and measure resistance. Blue box tester uses AC current to test continuity.
3. Dimmer on test light produces buzz on neutral when error is present. Buzz can be traced to location of neutral-to-neutral or neutral-to-ground connection with “buzz stick.”
4. Turn off all circuits in panel. TEST NEUTRAL CONDUCTORS ONLY.
5. Turn on portable power supply. Test the tester by touching two alligator clips together. Test light will light up.
6. Attach one alligator clip to neutral bus in panel. If this is the main panel, this bus will be connected to the ground bus. (NEC now requires separate ground and neutral buses even in the main panel.)
7. With all breakers off, lift first neutral from bus. Clip other alligator clip to lifted neutral.
   a. If test light remains dark, circuit is considered good and is landed back on bus.
   b. If test light does light up, neutral is positive for wiring error. Mark neutral and determine which hot it is paired with. You will later use this hot to find location of wiring error in building.
8. Lift each successive neutral one at a time and repeat test. Always return tested neutral back to bus before lifting next one so that only one neutral lifted off bus is being tested at a time. Avoids false negatives.
9. Continue test until all neutrals on bus have been tested. Note which circuits are involved in preparation to trace each circuit out into the building.

Testing for wiring errors with power on:

NOTE: Having your electrician work live in junction boxes to trace and repair wiring errors is not the preferred method of testing taught by the IBE. We advise you to have electrician keep breakers off when testing, tracing and repairing wiring errors, as described below. There is much less chance of damage to client’s electronics or harm to electrician and others that way. If electrician chooses to keep breakers on and work “live”, he or she assumes full responsibility, not the IBE, for any harm to client’s property or to the electrician or any others present during testing.

1. Turn on loads throughout house. Error produces unbalanced loads between hot and neutral conductors, verified with clamp meter. Current may also appear on ground wires.
2. To determine which circuits have net current, use Triplett 9200A, Ex-Tech or similar small Amp clamp to measure each group of hot, neutral and ground wires in circuit or group of circuits that exit panel.

3. If circuit has two hots sharing one neutral (12-3 or 14-3), measure current on black and red hots together as one. Reading on two hots should equal current on neutral. Clamp around all three. You should get zero net Amps everywhere that 12-3 circuit goes.
4. Determine which circuits have unbalanced loads, also known as net current.
5. If circuit or group of circuits has net current, measure current separately on hot, neutral and ground of that 12-2, 14-2 or 12-3 circuit.
6. Correct configuration should be:
   a. Load on neutral of every circuit equals load on hot(s) of same circuit. No more, no less.
   b. Ground of each circuit should normally have zero Amps on it, or very close to it. Current flows on grounding paths only in emergency fault condition.
   c. No net current on circuit when all conductors are clamped together.
7. Determine which hot exits panel in same circuit with "bad" neutral. By turning that breaker off, (or leaving it on with all other breakers off), you can trace location of affected circuit in house. Note: If there is no net current on circuit or group of circuits, you cannot be certain there is no wiring error because there may not be load on hot. Use protocol with power off to be certain (listed above).
8. If circuit has fewer Amps on neutral than on hot, shut off all other breakers in panel.
9. Then, look for other path for that missing returning current by clamping around every other neutral. If you find a second neutral with current, turn off first breaker. Load on both neutrals should go to zero. A test: Does sum of loads on both neutrals equal load on first hot when breaker of first hot is turned back on?
10. Turn breaker to first hot off. Turn on breaker for circuit with second neutral. Verify there is a load on that second hot conductor with your clamp meter. Do both neutrals have current that equals current on hot of second circuit?
11. If these criteria are met, these two neutrals are connected in a J-box through a neutral-to-neutral wiring error. Look for lighting switch box or J-box in attic, basement or crawl space with these two circuits. Neutrals from different (12-2 or 14-2) circuits will be under one wire nut.
12. Separate the neutrals and reconnect properly, and problem should be solved. We say, neutrals from different circuits in same J-box should always follow hots for each of those circuits. Where hots are separated in a J-box, neutrals should likewise be separated, as well.
13. If circuit has net current and that circuit has current on ground, see below in section on Neutral-to-Ground Wiring Errors.

Tracing and Repairing Neutral-to-Neutral Wiring Errors

1. If you have two or more circuits in J-box, neutrals should always follow hots. No ganging of neutrals. The NEC does not allow mixing of neutrals from different circuits in same J-box (NEC Section 310-4).
2. Note: Neutrals sharing two hots of 12-3 or 14-3 circuits must also not be mixed with neutral of any other circuit.

3. Note: If you have net current when comparing load on hot to neutral of same circuit but no current on ground, you are dealing with neutral-to-neutral wiring error. (See below if current exists on ground.)
4. With all other breakers off, turn on breaker for hot associated with first bad neutral. Creates unbalanced load. Look for other neutral carrying deficit between first hot/ neutral pair.
5. Verify two circuits with connected neutrals by shutting off first breaker and turning on second breaker. Note similar deficit showing up on second hot/neutral pair as on first hot/neutral pair.
6. Determine what locations both circuits go to in building. Look for J-box where these two circuits are present together.
7. Open that switch box. Verify both circuits are present. You will find all neutrals tied together.
8. When neutrals from different circuits are separated and reconnected properly, turn breakers back on and turn on light switches. You will have equal loads on all hot/ neutral pairs in and out of this J-box and with these two circuits at the panel.

Tracing and Repairing Neutral-to-Ground Wiring Errors

1. If you have unbalanced loads on hot/neutral pair of circuit in panel with current on ground, you have neutral-to-ground error.
2. Shut off all other breakers in panel. Clamp around ground of circuit with net current. If you measure current, shut off breaker. Does load on ground go down or disappear? If yes, you have found neutral- to-ground error.
3. Determine where circuit goes in building.
   You are looking for place(s) where neutral and ground are connected.
4. Buzz stick will help you locate path of affected circuit.
   a. With power on, use buzz stick to sense magnetic field from the net current.
   b. With power off, keep “bad” neutral connected to test lead of blue box.
   c. Dimmer switch in blue box generates buzz on bad neutral that will be sensed by the buzz stick. Sound on buzz stick will stop and test light will go dark when you separate ground from neutral.
5. Find first J-box that circuit goes to.
6. Using color of wires as guide, if necessary, check current loads on each pair of hots and neutrals in box.
   a. Find circuit in J-box coming from panel.
   b. That hot/neutral pair will have an unbalanced load that matches unbalanced load measured at panel.
7. If first box does not have neutral-to-ground connection, look downstream. Find branch from first J- box with net current. Follow until neutral-to-ground connection is located.
8. Problem could be in:
   a. Light fixture where the neutral is touching the metal fixture body due to wiring being nicked, or
   b. J-box containing light fixture

9. If branch goes to outlets, problem will either be:
   a. ground wire under same wire nut as neutrals
   b. nick or break in insulation of neutral — exposed wire touches metal box or inside of flexible or rigid metal conduit, caused by improper or non-existent bushing or break in flexible conduit sheathing
   c. bare ground wire touches exposed neutral screw of outlet
10. Note: GFCI outlets take up much space in J-box and cause abrasion and nicking of neutral wires when pushed into box
11. If working with power off and you have a bare ground wire touching an outlet neutral screw, sound on buzz stick will stop and test light will go dark when you pull outlet out from wall, thereby separating ground from neutral.
    a. Separate ground wire from neutral screw when you carefully push outlet back in.
    b. Wrap outlet screws with tape.
12. If current on ground is not resolved, open J-boxes. Separate hots and neutrals in each one. Use continuity tester with long wire and test leads to “tone out” conductors of each circuit to determine where each branch goes next.
13. Once conductors are separated in J-boxes at both ends of portion of flexible metal-clad circuit with neutral-to-ground error, you can test each conductor for continuity with ground in the closest J-box. None of the wires should have continuity with ground in box, especially the neutral. (The hot would have already tripped breaker if it touched ground.)
14. If neutral is continuous with ground, before opening wall to replace circuit, you could swap neutral with insulated ground, but only if that ground is not also damaged.
    a. Damaged neutral could become ground for that segment of circuit.
    b. Use appropriately-colored tape at both ends to indicate swapping of neutral and ground wire.
    c. Damage to neutral or ground insulation can occur from:
       i. piercing of insulation by broken flexible metal-clad sheathing
       ii. improper bushing that cuts into insulation
       iii. missing bushing

Wiring Errors as Violations of National Electric Code (NEC)

Neutral-to-neutral and neutral-to-ground wiring errors are actual violations of National Electric Code, although they are often unknowingly caused by electricians and rarely, if ever, found by code inspectors.

More than one-third of buildings in North America contain multiple wiring errors. Includes almost all high-rise commercial and residential buildings. Magnetic fields caused by wiring errors are a health hazard for occupants.

Neutral-to-neutral wiring errors violate NEC Section 301-3(b), which states, "all conductors of the same circuit -- including the neutral and all equipment grounding conductors -- must be run in the same raceway, cable tray, trench, cable, or cord." This

is referenced at www.mhprofessional.com/downloads/products/0071546529/NECch3.pdf .

The second citation is NEC Section 310-4, which states, “Conductors may not be paralleled, that is joined at both ends, so you can’t join two neutrals at a junction box because they are also joined at the circuit breaker panel where they terminate at the neutral bus.”

Section 310-4 also ”prohibits connecting a neutral to another neutral such that a parallel return path to the panel is set up, unless the conductors are 1/0 or larger and meet exacting conditions." Circuits in most residential settings are not larger than gauge 1/0, and therefore this provision applies.

Neutral-to-ground errors violate NEC Sections 250.6 and 250.142. Section 250.6 says “objectionable” current is not to flow on grounding or bonding paths. 250-24 A5 states: “Neutral shall not be connected to ground at any point after the main service panel (containing the main disconnect switch).”