Grounding & Bonding

Part 1

Multiwire Branch Circuits

Part 2

Grounding & Bonding

As it pertains to home inspection.

Intended to be a guide to help you locate and report on improper grounding and bonding conditions in residential construction within the standards of a home inspection.

You will not know everything when you are done. My intent is to provide enough knowledge to help you figure out what you are likely to see at an inspection.

Code references are from the 2011 NEC, except as noted. 2014 changes in this area were minimal.

Get Your Mind Out of the Gutter

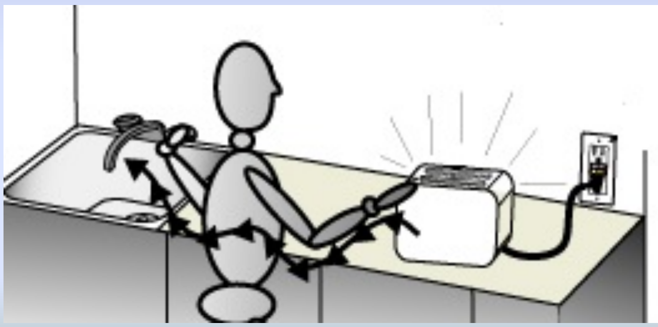
What is Bonding & Grounding?

Bonding is connecting metal stuff together. The intent is to bond all of the metal that we can so it all has the same voltage potential in the event of a ground-fault. This helps to ensure there is a nice, clear path for any unwanted current.

Grounding is connection to the earth. For our purposes, all alternating current electrical systems that are provided by a utility are grounded systems. Even an older knob & tube or NM without an equipment ground. The system is grounded, even if the receptacle outlets are not.

What is a Ground Fault?

An unintentional, electrically conducting connection between a "hot" wire and the frame/chassis of an electrical appliance, tool, etc. A specific type of short circuit.



Definitions from the NEC

Service Equipment. The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuses) and their accessories, connected to the load end of service conductors to a building or other structure, or an otherwise designated area, and intended to constitute the main control and cutoff of the supply.

Grounding Electrode. A conducting object through which a direct connection to earth is established.

Definitions from the NEC

Ungrounded. Not connected to ground or to a conductive body that extends the ground connection. (This is not defined in the NEC as the "hot" or voltage carrying conductor, but is used that way throughout the code)

Grounded Conductor. A system or circuit conductor that is intentionally grounded.

Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.

Definitions from the NEC

Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Grounding Conductor, Equipment (EGC). The conductive path(s) installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.

Informational Note No.1: It is recognized that the equipment grounding conductor also performs bonding.

Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Definitions from the NEC

Ground-Fault Current Path. An electrically conductive path from the point of a ground fault on a wiring system through normally non-current-carrying conductors, equipment, or the earth to the electrical supply source.

Informational Note: Examples of ground-fault current paths could consist of any combination of equipment grounding conductors, metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal water and gas piping, steel framing members, stucco mesh, metal ducting, reinforcing steel, shields of communications cables, and the earth itself. (Article 250)

Definitions from the NEC

Effective Ground-Fault Current Path. An intentionally constructed, low-impedance electrically conductive path designed and intended to carry current under ground- fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors on high-impedance grounded systems. [also, further defined in 250.4 (A)(5)]

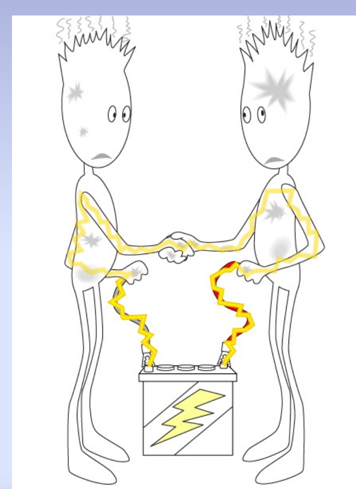
Why Do We Ground & Bond?

Grounding serves more than one function. One is to ensure that any bonded metal (appliances, piping, etc.) has the same potential voltage as the earth. Another is to provide a low resistance path via the EGC to complete the circuit and trip the breaker (or blow the fuse) quickly in the event of a ground fault (short).

Why Do We Ground & Bond?

"Electrical current takes the shortest path to ground."

Well… it turns out, electrical current takes **all** available paths to ground. As a result, we cannot just provide a path, we work to isolate other paths. And, we interconnect other systems to make sure that anything that could carry current has the same voltage potential as the earth.



So??

Let's use a major kitchen appliance as an example. Imagine the appliance cord and wire insulation is damaged and the bare wire has come into contact with the cabinet/chassis of our refrigerator. The exterior cabinet/chassis becomes energized. If properly grounded, current flows to ground unimpeded, overloading the circuit and the circuit breaker trips. If not, our homeowner - standing barefoot on the wet concrete slab - grabs the energized handle to get a piece of cheese and gets shocked or possibly wakes up dead. A properly grounded receptacle outlet would complete the circuit and trip the breaker, hopefully before our intrepid cheese eater is electrocuted.

Why not use multiple grounding electrodes?

I need an outlet grounded and it's on the opposite side of the house from the service. Why not just poke a grounding conductor through an exterior wall and drive a rod?

The earth is a poor conductor. Part of what we are trying to do is provide a <u>low resistance</u> path in order to complete a circuit and "trip" the breaker. If we install multiple grounding electrodes without effectively bonding them together, we are then using the earth as our equipment grounding conductor. The high resistance of the earth might prevent the breaker from "tripping" in the event of a ground fault.

Bonding Neutral to Ground

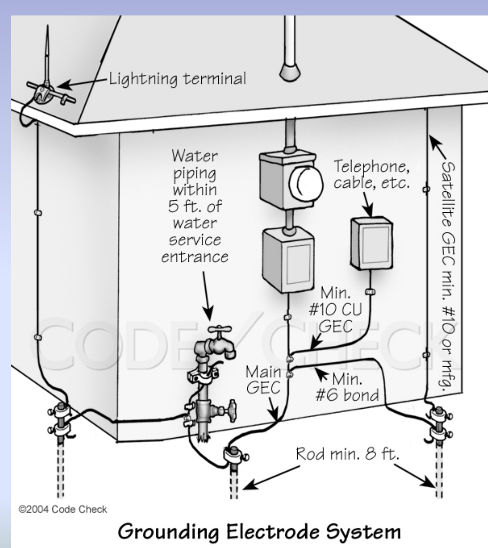
Neutral is bonded to the earth at the transformer (remember – grounded conductor) and bonded to ground at the Service Equipment.

Not bonded/connected to ground at any other panel.

Where is a Residential Electrical System Grounded?

As a general rule, (in my area) either a concrete-encased electrode (Ufer) or a ground rod is used. This should be located at or near the Service Equipment.

Any other grounding electrodes should be bonded back to the grounding electrode at the service equipment.



Approved Electrodes

250.52 Grounding Electrodes

(A) Electrodes Permitted for Grounding

- **(1)** Metal Underground Water Pipe
- **(2)** Metal Frame of Building or Structure
- **(3)** Concrete Encased Electrode
- **(4)** Ground Ring
- **(5)** Rod and Pipe Electrodes
- **(6)** Other Listed Electrodes
- **(7)** Plate Electrodes
- **(8)** Other Local Underground Metal Systems or Structures

Electrodes

(B) Not Permitted for Use as Grounding Electrodes. The following systems and materials shall not be used as grounding electrodes:

(1) Metal underground gas piping systems

(2) Aluminum

Informational Note: See 250.104(8) for bonding requirements of gas piping.

Supplemental Electrodes

250.53 (A)

(2)Supplemental Electrode Required. A single rod, pipe, or plate electrode shall be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8).

Exception: If a single rod, pipe, or plate grounding electrode has a resistance to earth of 25 ohms or less, the supplemental electrode shall not be required.

(Q&A coming up)

Supplemental Electrodes

(3) Supplemental Electrode. If multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft) apart.

Informational Note: The parallelling efficiency of rods is increased by spacing them twice the length of the longest rod.

(The electrical section of the IRC seems to follow the NEC with some delay. However, as California does not enforce the electrical section of the IRC, I have not kept up with specifics.)

Supplemental Electrodes

(B) Electrode Spacing. Where more than one of the electrodes of the type specified in 2S0.S2(A)(5) or (A)(7) are used, each electrode of one grounding system (including that used for strike termination devices) shall not be less than 1.83 m (6 ft) from any other electrode of another grounding system. Two or more grounding electrodes that are bonded together shall be considered a single grounding electrode system.

Grounding Electrode Conductor

250.64 (B) Securing and Protection Against Physical Damage. Where exposed, a grounding electrode conductor or its enclosure shall be securely fastened to the surface on which it is carried. Grounding electrode conductors shall be permitted to be installed on or through framing members. A 4 AWG or larger copper or aluminum grounding electrode conductor shall be protected if exposed to physical damage. A 6 AWG grounding electrode conductor that is free from exposure to physical damage shall be permitted to be run along the surface of the building construction without metal covering or protection if it is securely fastened to the construction; otherwise, it shall be protected in rigid metal conduit RMC, intermediate metal conduit (IMC), rigid polyvinyl chloride conduit (PVC), reinforced thermosetting resin conduit (RTRC), electrical metallic tubing EMT, or cable armor. Grounding electrode conductors smaller than 6 AWG shall be protected in (RMC), IMC, PVC, RTRC, (EMT), or cable armor.

Grounding Electrode Conductor

250.64 (C) GEC shall be installed in one continuous length (*but there are exceptions – exothermic weld, non-reversible crimp connectors*).

Questions?

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors[a] (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum[b]
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
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Where do we start?

At some point, we need to find the grounding electrode. (250.52)

If there is a ground rod, it is typically near the Service Equipment. Minimum 8’ in contact with soil. (250.53 (G))

If the house is new enough, it might have a concrete encased electrode (Ufer). The connection is required to be visible (if not encased in concrete), but usually isn't.

If the water service is providing ground (connection required within 5 feet of water service entrance), there is no way to determine the type or condition (is the supply pipe metal or plastic?). I recommend installation of a grounding electrode (ground rod).

Ufer

The connection between the grounding electrode and the GEC is required to be accessible.

This was found in a garage. Sometimes the connection is under the house. In my experience, they are rarely accessible.

Ufer

This clamp was loose, but there was also an additional conductor that was improperly placed.

Ufer

In this case, the foundation is isolated from the ground by a vapor barrier under the slab. As a ground, this will not be remarkably effective.

Types of Clamps

The acorn clamp on the left is for ground rods. The GEC is inserted at the pointy end, not near the bolt. The clamp on the right can be used for rods, rebar or pipe, but the moveable half has to be flipped over if used with rebar or a rod. Some are not approved for burial. If corroded, replace.

Made Electrode (Ground Rod)

This rod was not driven deep enough.

Different Versions of Grounding Electrode

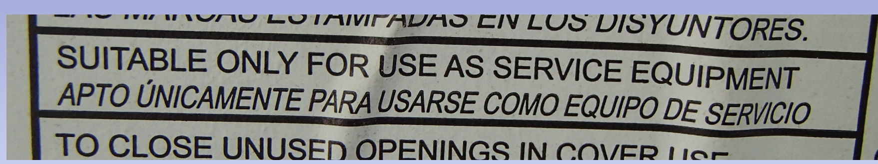
No way of knowing how deep a pipe goes. I recommend a grounding electrode or any needed corrections.

Connections at the Service Equipment

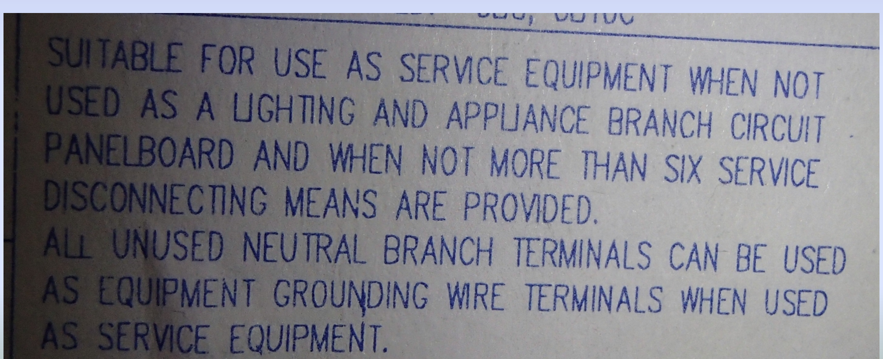
Grounded (neutral) and grounding conductors are bonded together at the service equipment. Nowhere else. Sort of…

Often, the grounded and grounding conductors will share same the terminal block. Occasionally, separate terminal blocks will be provided. The "neutral" terminal block is required to be bonded.

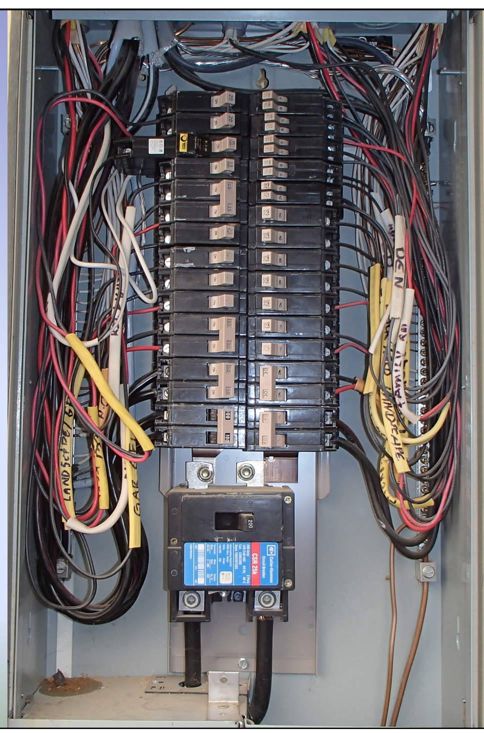
Service Equipment Types



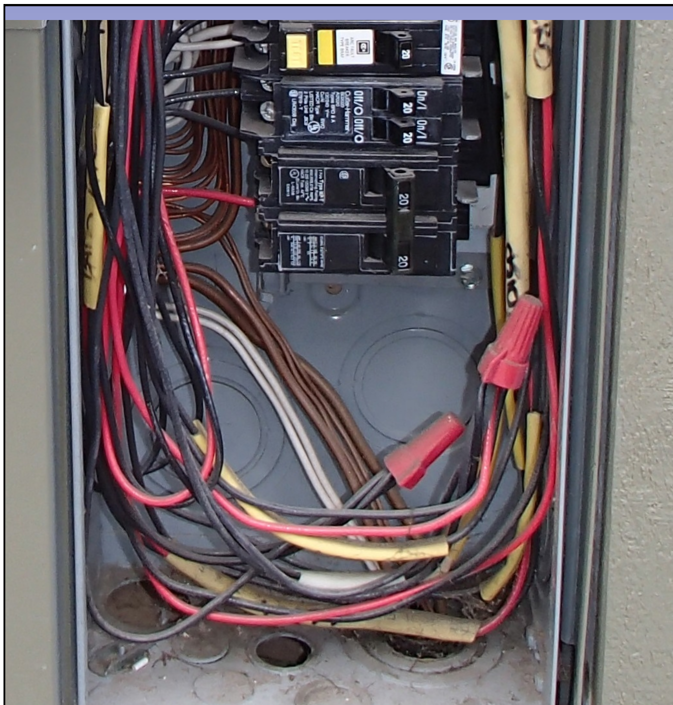
Dedicated above. Modifiable below.



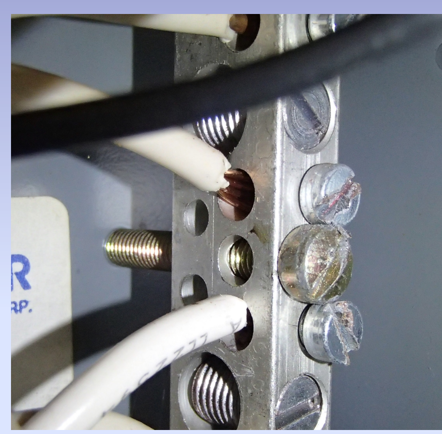
Connections at the Service Equipment



The grounding electrode conductor and the bonding conductor can be seen at the lower/right of the panel. The grounded ("neutral" & equipment ground) terminal block is attached to the enclosure.



The GEC and bonding conductors can be seen at the left side of this panel. Again, the grounded ("neutral" & equipment ground) terminal block is attached to the enclosure.



Bonding at the Service Equipment can be done in a variety of ways. This type of panel can be used as a "sub panel" or Service Equipment as long as grounded (neutral) and equipment grounding conductors are properly addressed.

New Service Equipment

On occasion, I will inspect a home that has been added/modified and a new service has been brought in. This is fine if the old service equipment has been removed, replaced or abandoned.

However, every once in a while, I will find the former/original service equipment still in use, but as a "sub-panel". The problem is that "service equipment only" cannot be modified by isolating "neutral" and equipment grounding conductors within the panel's listing.

Other Panels

"Neutral" conductors and equipment grounds must be isolated at any panel that is not Service Equipment.

The feeder cable should consist of two ungrounded (hot) conductors, a "neutral" (grounded) conductor and an equipment grounding conductor.

300.3 Conductors.

(B) Conductors of the Same Circuit. All conductors of the same circuit and, where used, the grounded conductor and all equipment grounding conductors and bonding conductors shall be contained within the same raceway, auxiliary gutter, cable tray, cablebus assembly, trench, cable, or cord, unless otherwise permitted in accordance with 300.3(B)(1) through (B)(4)

Equipment Grounding Conductors

Nonmetallic cable (NM) must have an EGC
Metal-clad (MC) must have an EGC
Flexible metal conduit (FMC) must have an EGC

Armor-clad (AC) can function as an EGC
Electric metallic tubing (EMT), rigid metallic conduit (RMC) and intermediate metal conduit (IMC) can function as an EGC.

Metal boxes must be bonded to the EGC. No reason to bond plastic.

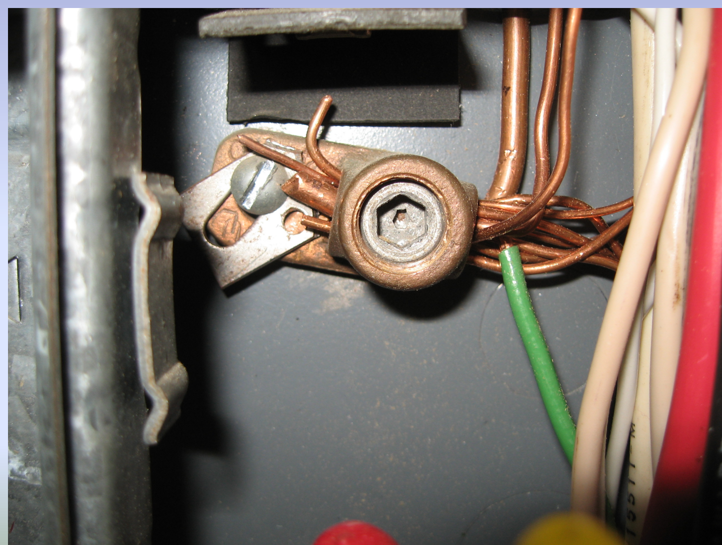
Q&A coming up

Conduit Connections

Bonding jumpers required at the service, before the main disconnect at concentric knockouts (250.92). Not very clear about other locations (250.96).

Multiple Equipment Grounds

The manufacturer determines how many conductors can be secured under a single screw.



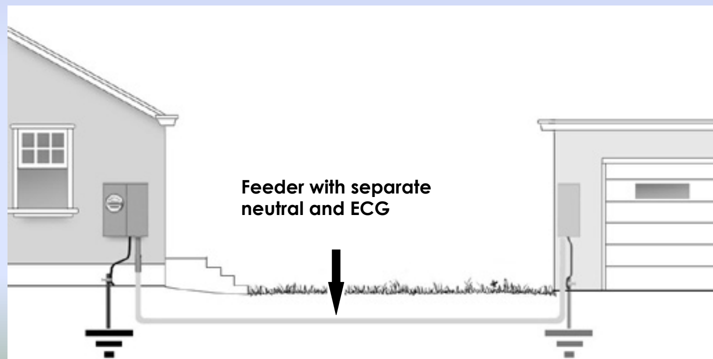
Multiple Equipment Grounds

Split-bolts are not approved for this use.

Questions

Grounding at Detached Buildings

A grounding electrode is required; however, we still have **one grounding electrode system.** This means a grounding electrode at a detached building (any piping has to be bonded as well), but the feeder cable will include an equipment ground. Except…



Grounding at Detached Buildings

250.32 Buildings or Structures Supplied by a Feeder(s) or Branch Circuit(s).

(A) Grounding Electrode. Building(s) or structure(s) supplied by feeder(s) or branch circuit(s) shall have a grounding electrode or grounding electrode system installed in accordance with Part III of Article 250. The grounding electrode conductor(s) shall be connected in accordance with 250.32(B) or (C). Where there is no existing grounding electrode, the grounding electrode(s) required in 250.50 shall be installed.

Grounding at Detached Buildings

250.32 (A) Exception: A grounding electrode shall not be required where only a single branch circuit, including a multiwire branch circuit, supplies the building or structure and the branch circuit includes an equipment grounding conductor for grounding the normally non-current-carrying metal parts of equipment.

Now we come to the tricky part…

Grounding at Detached Buildings

Prior to the 2008 NEC, an equipment ground between panels was optional if there were no "continuous metallic paths" connecting the two structures together.

A grounding electrode would be provided and the grounded (neutral terminal block would be bonded to the enclosure (similar to service equipment).

The problem is – what is a "continuous metallic path"? Phone or TV cable, buried piping, reinforcing steel, etc. Difficult to verify the absence – particularly when a homeowner makes modifications.

Grounding at Detached Buildings *(old)*

[Outdated article – from 1999 NEC]

250-32 (2) Grounded Conductor. *Where (1) an equipment grounding conductor is not run with the supply to the building or structure, and (2) there are no continuous metallic paths bonded to the grounding system in both buildings or structures involved, and (3) ground-fault protection of equipment has not been installed on the common ac service, the grounded circuit conductor run with the supply to the building or structure shall be connected to the building or structure disconnecting means and to the grounding electrode(s) and shall be used for grounding or bonding of equipment, structures, or frames required to be grounded or bonded.*

Grounding at Detached Buildings *(coming)*

[Not yet enforced - from 2017 NEC]

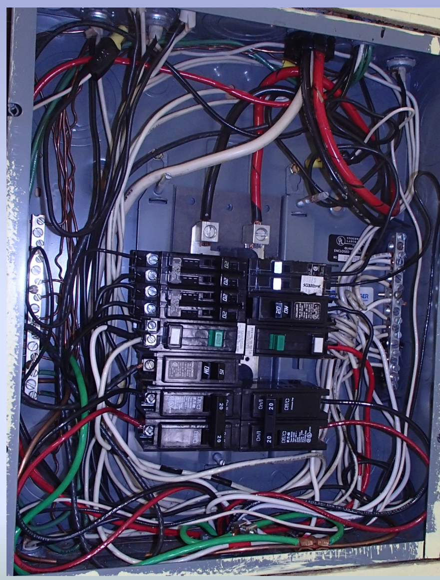
250-32 Exception: *For installation made in compliance with previous editions of this Code that permitted such connection, the grounded conductor run with the supply to the building or structure shall be permitted to be the ground-fault return path if all of the following requirements continue to be met:*

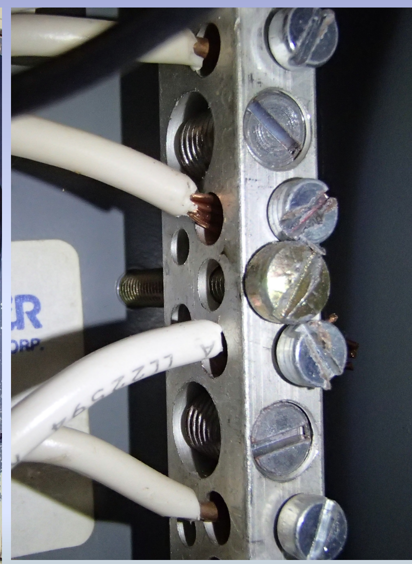
(1) An equipment ground is not run with the supply to the building or structure.

(2) There are no continuous metallic paths bonded to the grounding system in each building or structure involved.

(3) Ground-fault protection has not been installed on the supply side of the feeders.

Grounding at Detached Buildings

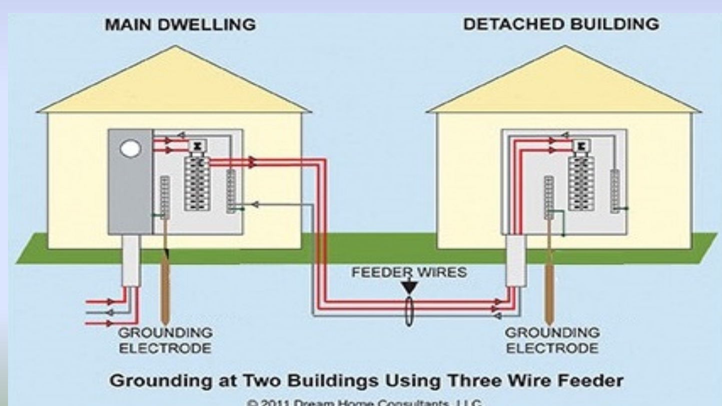




Same panel – close-up.

Grounding at Detached Buildings

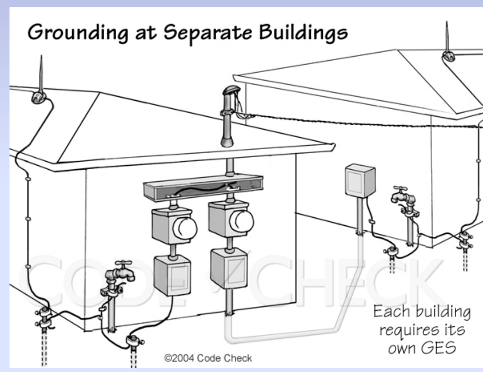
In the case of a detached building that was built to an earlier code, I would report the lack of an equipment grounding conductor (EGC) as a part of the feed, state that I was concerned that this was not properly grounded and defer.



What about cases where the Service Equipment is not at the primary structure?

Remember, grounding and "neutral" are bonded together at the Service Equipment. This means that you should see four wires exiting the service equipment to ANY panel.

Ok… maybe not ANY. Remember grounding at detached buildings prior to the 2008 NEC.



Q&A coming up

Detached Buildings - One More Time

We want to see a feeder cable with an EGC supplying a sub-panel at the detached building. Neutral & ground should be isolated. Just like any sub-panel, except we also have a grounding electrode.

If we see a feeder cable without an equipment ground, neutral & ground should be bonded and also connected to a grounding electrode and NO continuous metallic paths between.

But, you should seriously consider deferring for further review by a licensed electrical contractor because it is usually difficult to determine if there is a parallel metal path between the two structures.

Questions?

Bonding of Piping & Other Plumbing.

Water supply and gas piping systems should be bonded.

Water heaters, softeners, dielectric unions, water meters (if in basements) & plastic piping will isolate sections of the piping. These breaks in the effective ground fault current path should have bonding jumpers, but rarely do.

Bonding of Piping.

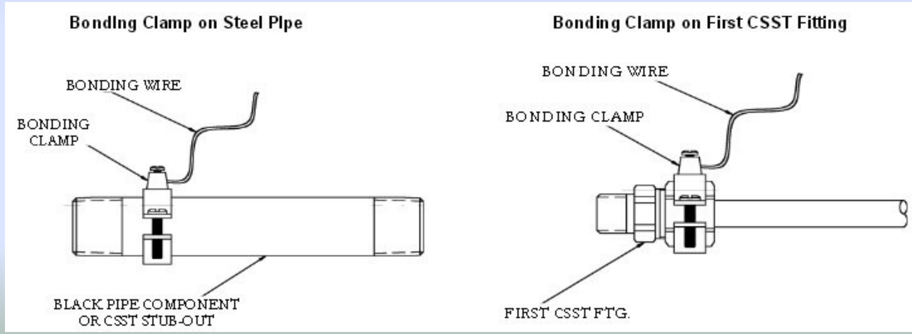
Gas piping is typically bonded at the gas meter in new construction. The EGC at the furnace should not be relied upon to bond. You may also see upgraded bonding at the water heater.

Hot & cold is typically bonded above the water heater. Only cold is present here.

Q & A coming up

Bonding of CSST

The International Fuel Gas, National Fuel Gas, Uniform Mechanical and Uniform Plumbing Codes require CSST to be bonded with a #6 at the point of delivery (after the meter) or the first downstream fitting to the GEC or Service Equipment grounded terminal. Not allowed to bond directly to the CSST.



Bonding of Other Systems

Gas-fired water heaters are isolated, but are not likely to become energized.

Electric water heaters have the equipment ground (remember EGC also performs bonding).

Hot water circulation pumps - equipment ground.

Tankless water heaters often use power, but an ECG should be a part of the appliance cord.

Metal ducting is usually bonded by the furnace EGC unless isolated by a vibration damper.

Bonding of metal gutters, drain piping, roofs, etc. seems to be up to the local jurisdiction. In lightning prone areas, these may need to be bonded.

Read the manufacturer's installation instructions.

Questions

Receptacle Outlets

Three-light receptacle outlet tester. Can be fooled by improper wiring in a number of ways.

When 3-pin/slot receptacle outlets are installed in homes that have older 2-wire NM without ground, the outlet tester should show as "open ground". This is pretty common, but still improper and worthy of mention in a report.

Receptacle Outlets

Ungrounded Receptacle outlets are not a problem as long as the equipment ground is not needed. Many household appliances (table lamps, stereos, TVs, vacuums, chargers, etc. do not have EGCs.

Appliances with equipment grounds should be plugged into properly grounded receptacle outlets or GFCI protected.

Receptacle Outlets

However, on occasion you may find that your little tester is telling you that the receptacle outlet is properly grounded, even though you know the house is too old to have equipment grounding conductors as a part of the branch circuit wiring.

In these cases, you likely have "pirated" grounds.

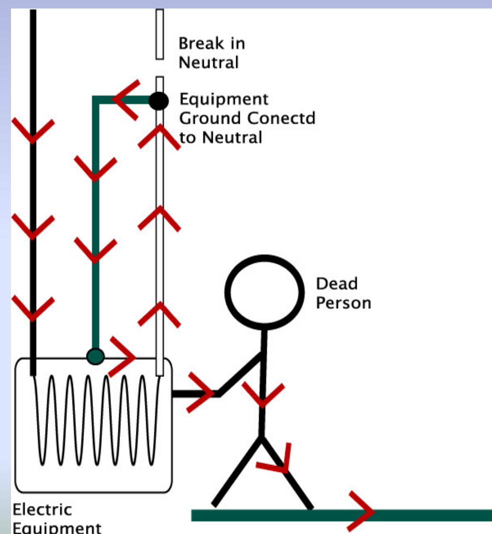
"Pirated/Bootlegged" Ground

In this case, the "neutral" has been short-circuited to the equipment grounding screw on the receptacle outlet.

Why a "Pirated" Ground is a Bad Idea

When an equipment grounding terminal is directly connected to the "neutral" terminal on a receptacle outlet, this current now has a direct connection to the chassis of the appliance. This means the chassis of our refrigerator could be "energized".

So, how do you find bootlegged grounds?



How To Find Pirated/Bootlegged Grounds

Check in the panel for EGCs. Generally, electrical systems prior to the 1960s (this depends on the code cycle in your area) do not have equipment grounding conductors, or if they do, there are a limited number.

How To Find Pirated/Bootlegged Grounds

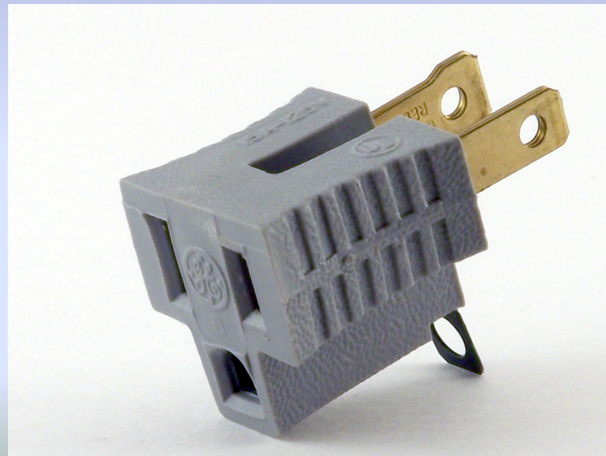
Pulling off a receptacle outlet cover plate may allow you to see the jumper between the grounded (neutral) and equipment grounding terminal.

How To Find Pirated/Bootlegged Grounds

You can also consider purchasing additional equipment. SureTest and Amprobe both make testers that run about $350.00

Of course, this is perfectly OK…

I have no idea why this thing is made. The faceplate screw is unlikely to be connected to an EGC. Potential problems? You becha!



Adding Equipment Grounds

In an older system where an Equipment Grounding Conductor is desired (i.e. refrigerator or computer), a separate equipment grounding conductor can be added to a receptacle outlet or outlets. This independent EGC can be connected to an accessible point on the grounding electrode system, to the grounding electrode conductor, to the grounding terminal bar where the circuit originates or the neutral service conductor within the service equipment. 250.130(C)

Connection to a water pipe is not acceptable unless the pipe is part of the Grounding Electrode System and within 5 feet of the water service entrance.

GFCI Devices

Ground-Fault Circuit Interrupters may be used to replace or protect older 2-slot receptacle outlets or ungrounded 3-slot receptacle outlets even if the cable does not have an equipment grounding conductor. No equipment ground is necessary for a GFCI to function.

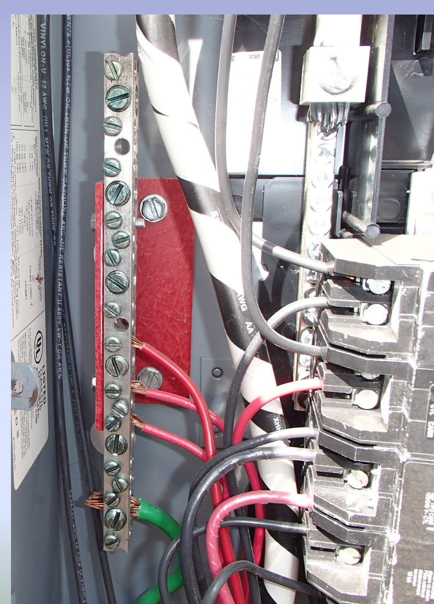
This is because the device compares the amperage at the ungrounded (hot) conductor with the amperage at the grounded (neutral). If an imbalance is detected, power is interrupted.

On an aside, surge protectors/suppressors may not function properly without an EGC.

Weird Grounding Stuff

This one threw me for a bit. This grounding terminal is isolated from the enclosure. Occasionally, electrical systems providing power to computers will have isolate the equipment grounds. It still must go back to the same grounding electrode.

I don’t know why the red wires though.



Grounding/Bonding Conclusion

The one thing that I would like for you to take away from this is that all piping as well as other metal systems should be fully bonded (interconnected with each other). The primary grounding electrode is typically at/near the Service Equipment. Any other grounding source should be bonded (connected) to the primary.

I find it helpful to read a little of the NEC as often as I can in order to learn how to interpret the code accurately. I also highly recommend reading "Electrical Inspections of Existing Dwellings" by Douglas Hansen as well as using the "CodeCheck" series of flip books for reference. All great cures for insomnia.

Article 250.4 General Requirements for Grounding and Bonding.

(A) (A) Grounded Systems.

(1) Electrical System Grounding. Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

Informational Note: An important consideration for limiting the imposed voltage is the routing of bonding and grounding conductors so that they are not any longer than necessary to complete the connection without disturbing the permanent parts of the installation and so that unnecessary bends and loops are avoided.

250.4 (2) Grounding of Electrical Equipment. Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials.

(3) Bonding of Electrical Equipment. Normally non-current-carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

250.4 (4) Bonding of Electrically Conductive Materials and Other Equipment. Normally non-current-carrying electrically conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.

250.4 (5) **Effective Ground-Fault Current Path.** Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a low-impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. It shall be capable of safely carrying the maximum ground-fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source. The earth shall not be considered as an effective ground-fault current path.

Bonding at the Service Equipment

250.24(B) Main Bonding Jumper. For a grounded system, an unspliced main bonding jumper shall be used to connect the equipment grounding conductor(s) and the service-disconnect enclosure to the grounded conductor within the enclosure for each service disconnect in accordance with 250.28.

Exception No.1: Where more than one service disconnecting means is located in an assembly listed for use as service equipment, an unspliced main bonding jumper shall bond the grounded conductor(s) to the assembly enclosure.

(From the 2005 NEC regarding supplemental electrodes. Compare to 250.53 in the 2011 NEC)

250.56 Resistance of Rod, Pipe, and Plate Electrodes. *A single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less shall be augmented by one additional electrode of any of the types specified by 250.52(A)(2) through (A)(7). Where multiple rod, pipe, or plate electrodes are installed to meet the requirements of this section, they shall not be less than 1.8 m (6 ft) apart.*

FPN: The paralleling efficiency of rods longer than 2.5 m (8 ft) is improved by spacing greater than 1.8 m (6 ft).

(From the 1999 NEC regarding supplemental electrodes. Compare to 250.53 in the 2011 NEC and 250.56 in the 2005 NEC)

250-50 (a)(2) Supplemental Electrode Required. *A metal underground water pipe shall be supplemented by an additional electrode of a type specified in Sections 250-50 or 250-52. Where the supplemental electrode is a made electrode of the rod, pipe, or plate type, it shall comply with Section 250-56. The supplemental electrode shall be permitted to be bonded to the grounding electrode conductor, the grounded service-entrance conductor, the nonflexible grounded service raceway, or any grounded service enclosure.*

Bonding of Conduits

250.92 (B) Method of Bonding at the Service. Bonding jumpers meeting the requirements of this article shall be used around impaired connections. such as reducing washers or oversized, concentric, or eccentric knockouts. Standard locknuts or bushings shall not be the only means tor the bonding required by this section but shall be permitted to be installed to make a mechanical connection of the raceway(s).

250.96 Bonding Other Enclosures. (A) General. Metal raceways, cable trays, cable armor, cable sheath, enclosures, frames, fittings, and other metal non-current-carrying parts that are to serve as equipment grounding conductors, with or without the use of supplementary equipment grounding conductors, shall be bonded where necessary to ensure electrical continuity and the capacity to conduct safely any fault current likely to be imposed on them. Any nonconductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or be connected by means of fittings designed so as to make such removal unnecessary.

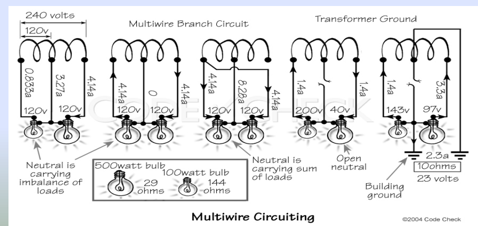
Intermission

Questions?

Multiwire Branch Circuits

Branch Circuit, Multiwire. A branch circuit that consists of two or more ungrounded conductors that have a voltage between them, and a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit and that is connected to the neutral or grounded conductor of the system. (Article 100)

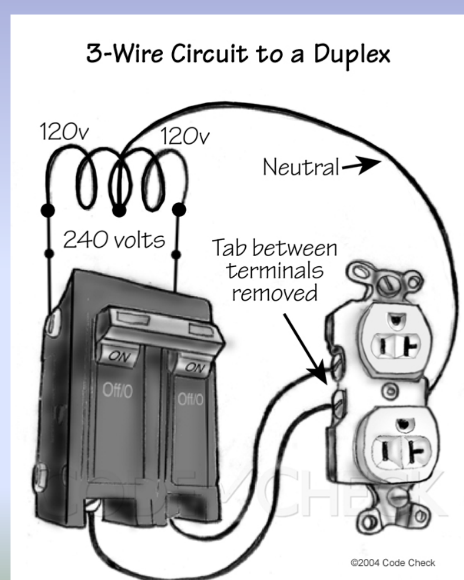
Occasionally referred to as an "Edison" circuit or "split neutral". In essence, a standard home electrical panel is a large multiwire circuit. Two ungrounded (hot) conductors that share a common grounded (neutral) conductor.



Common "Edison" Circuit Locations

There are a couple of advantages with this type of wiring. The primary consideration for a contractor is cost. Only one three-wire with ground cable needs to be pulled to handle two circuits.

This type of circuit also ends up with less voltage drop, resulting in a more efficient system.

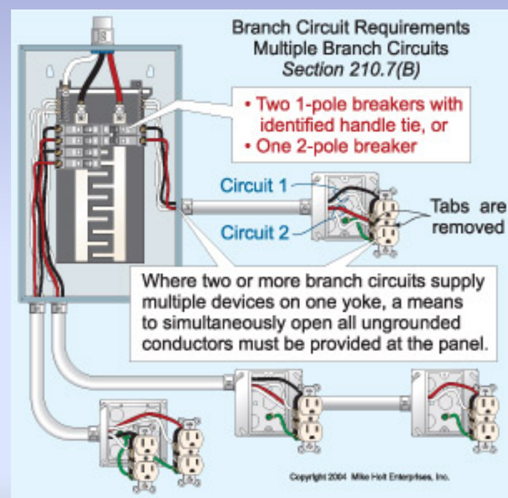


Common "Edison" Circuit Locations

Commonly found on the disposal/dishwasher duplex receptacle outlet. They can also be found on general lighting circuits.

Circuit breaker must have a handle-tie. (2008 NEC 210.4(B)). Prior to that, it was only required on a "split" duplex outlet.

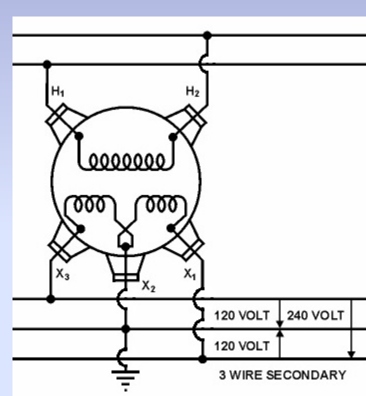
Neutral splices must be pigtailed in receptacle outlet boxes to prevent disconnecting the neutral from the circuit.



How a multiwire circuit works

Each ungrounded (hot) conductor is 120 volts to ground and 240 volts to each other. A helpful visual might be a "knob & tube" electrical system.

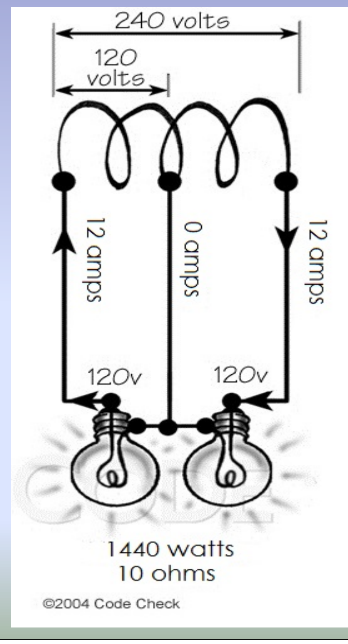
The voltage in an AC system alternates 60 times per second and is 180° out of phase with each other. In a 240 volt, single-phase system or a balanced multiwire circuit, as electrons leave one pole of the transformer, they return on the opposite pole. No current would flow down the "neutral" conductor.



How a multiwire circuit works

If a load is present only on one conductor from the transformer, current will return to the transformer through the grounded (neutral) conductor.

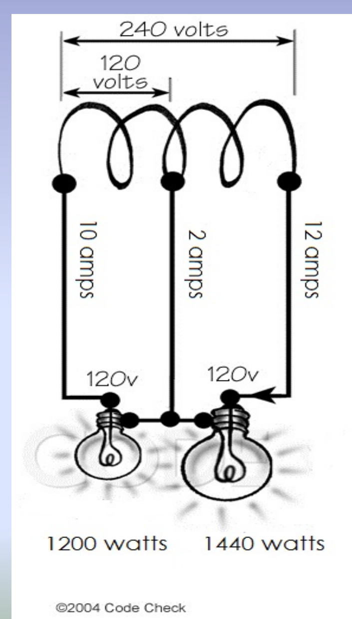
If an equal load is placed on the opposite pole, the current will return through the ungrounded (hot) conductors rather than the neutral (grounded).



How a multiwire circuit works

If an unequal load is placed on the two (correctly wired) conductors, only the difference in current will return through the grounded conductor. It does not carry the sum of the two loads.

A GFCI device may not function reliably on a multiwire branch circuit. The amperage running through the hot and neutral conductors are often not going to be equal, resulting in nuisance tripping.



From the NEC

210.4 Multiwire Branch Circuits (2008 NEC)

(B) Disconnecting Means. Each multiwire branch circuit shall be provided with a means that will simultaneously disconnect all ungrounded conductors at the point where the branch circuit originates.

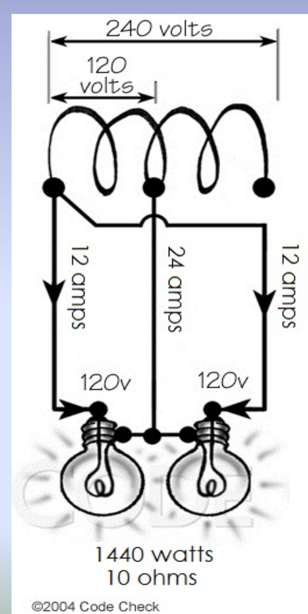
210.4 Multiwire Branch Circuits (2005 NEC)

(B) Devices or Equipment. Where a multiwire branch circuit supplies more than one device or equipment on the same yoke, a means shall be provided to disconnect simultaneously all ungrounded conductors supplying those devices or equipment at the point where the branch circuit originates.

Questions?

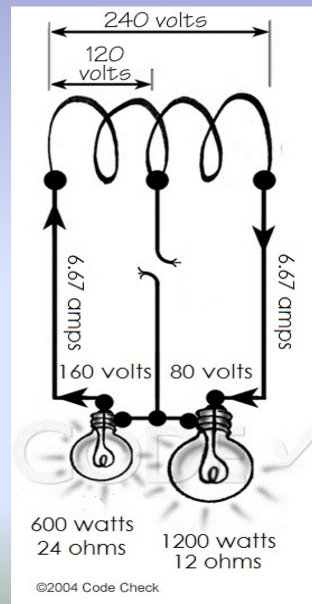
What can go wrong with a multiwire circuit?

A common problem arises when both "hot" conductors are connected to the same pole rather than opposite. As a result, there is no voltage difference between the two "hot" conductors and the grounded (neutral) conductor takes all of the current. This could result in doubling the rated current on the grounded conductor, without tripping the circuit breaker.



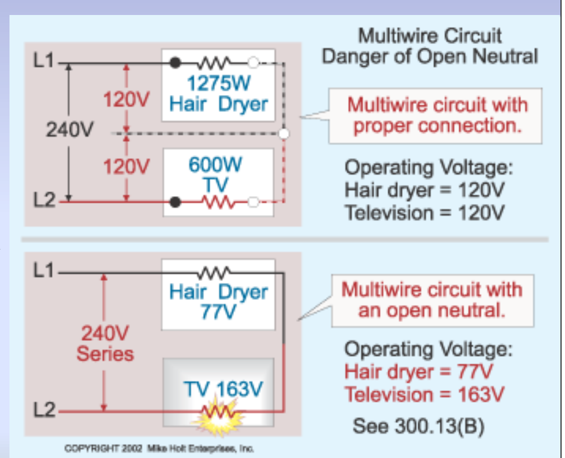
What can go wrong with a multiwire circuit?

Another issue, although less common, is a disconnected grounded conductor (open neutral). Since current can return along the 240 volt circuit, you end up with 240 volts in series. Depending on the resistance, this means that you will have widely variable voltage that can result in erratic bright/dim lights, resulting in bulbs that burn out quickly. It can also play havoc with sensitive electronics.



What can go wrong with a multiwire circuit?

If a tenant or occupant mentions going through a lot of light bulbs at a particular light fixture or area, you might have a disconnected or loose "neutral", either at a specific circuit or between the service equipment and the transformer.



Questions

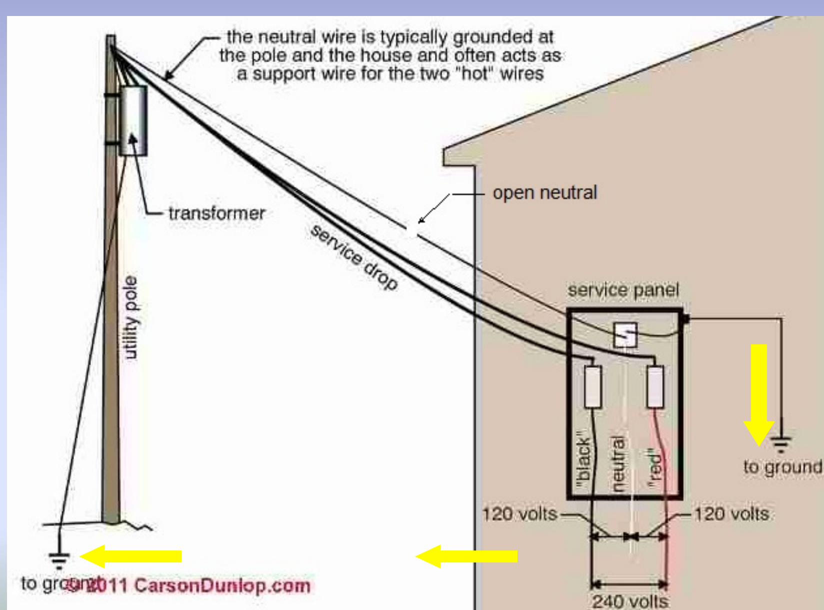
Where Multiwire Meets Grounding

In a case where we have lost the service neutral (between service equipment and the transformer), the imbalanced current will try to return via the grounding electrode. Remember, the service is essentially a multiwire circuit.

This means we would have current traveling down our GEC, throughout the metal piping and through the (high resistance) soil.

If someone disconnects the GEC or bonding, they could end up being electrocuted by neutral current.

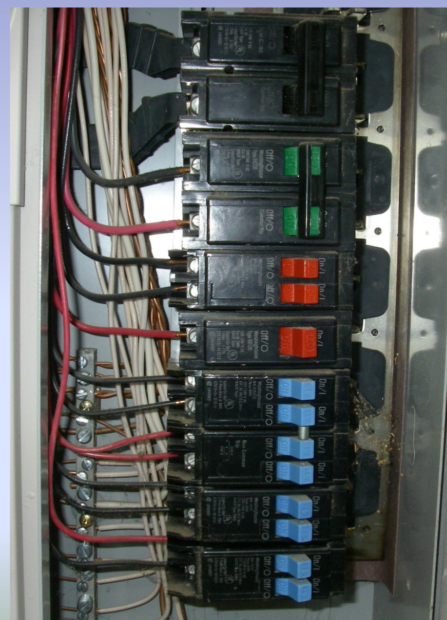
Where Multiwire Meets Ground



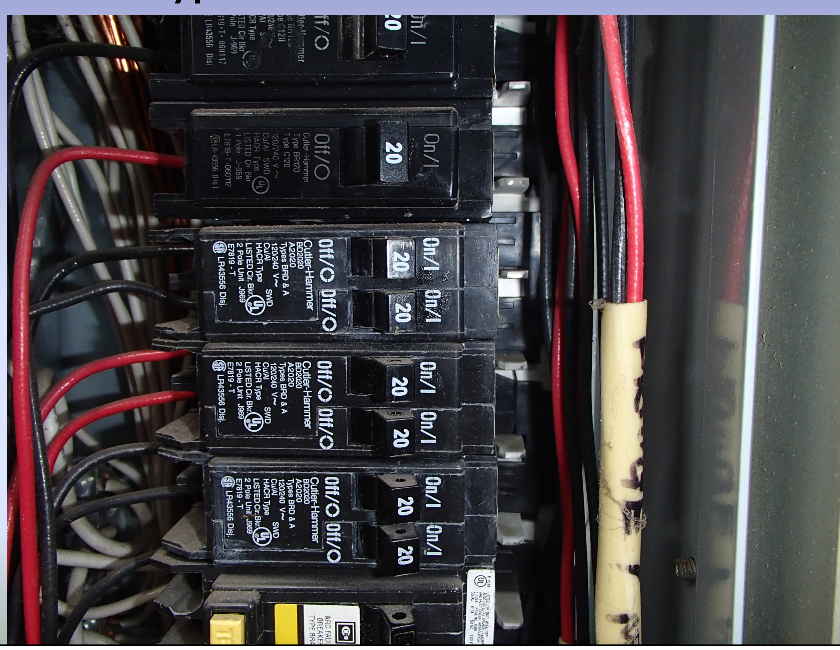
Identifying a multiwire circuit

When looking at wires from a cable, the conductors will have black, red and white insulation.

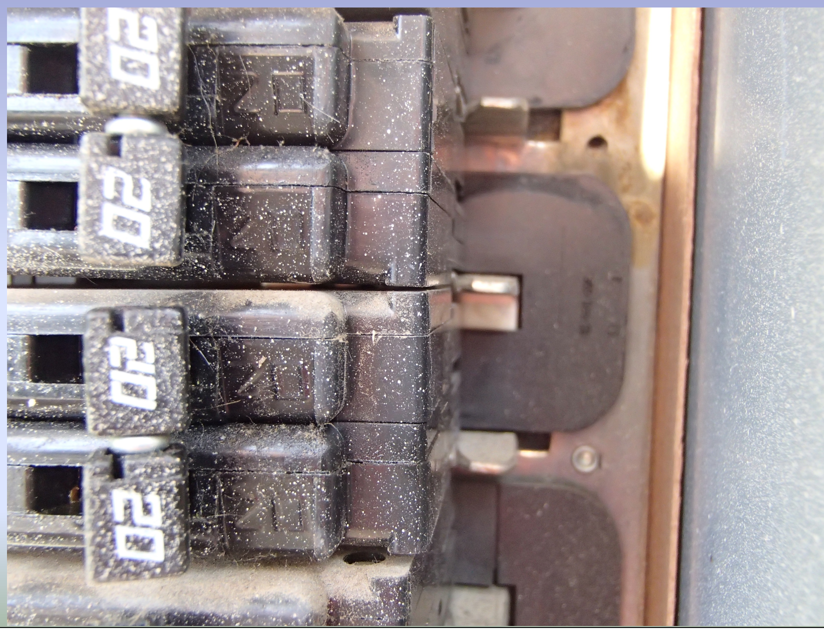
Finding improper circuits in a panel is a bit of a mixed bag. If you are looking at a wide panel with a generous amount of open space, it's typically a cinch. In a narrow panel filled with conductors, pretty much impossible without disassembly.



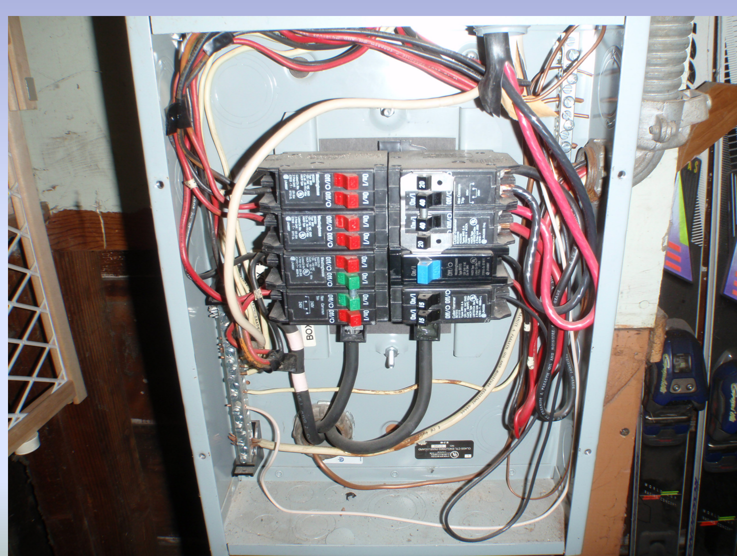
The typical circuit breaker connection



A different circuit breaker connection



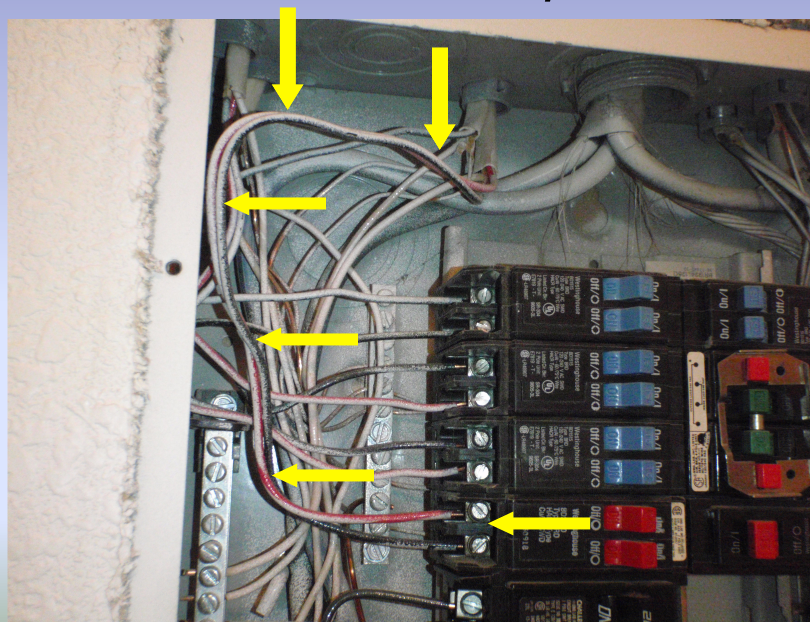
Good luck in finding improper multiwire circuits here



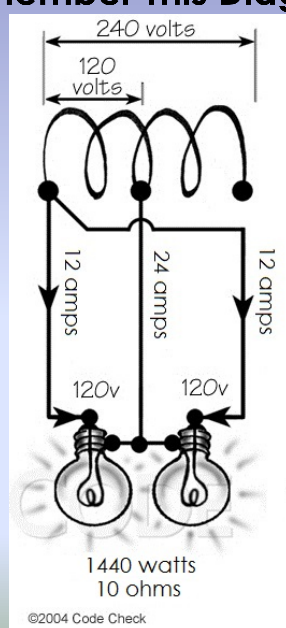
This is why

Not a chance

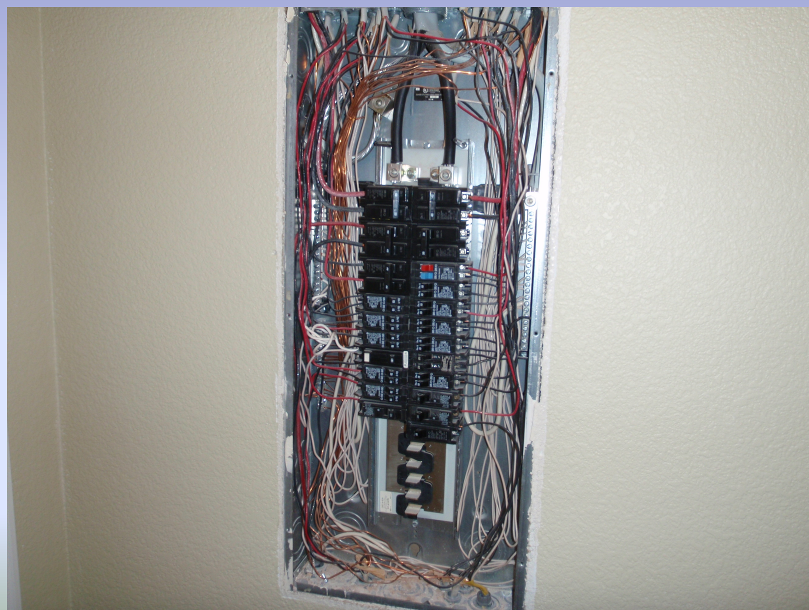
This one is easy



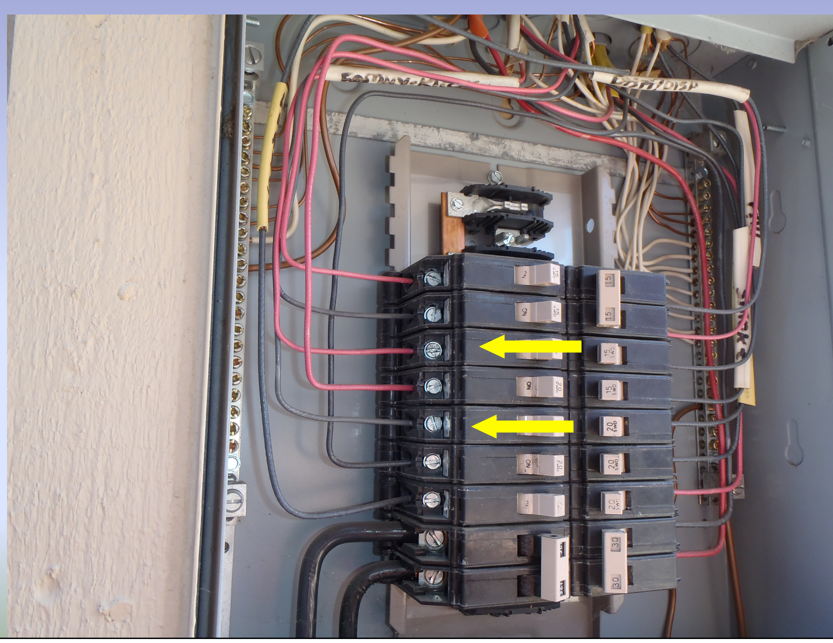
Remember This Diagram?



It can be done



I find these about twice a month



Identifying a multiwire circuit

210.4(D) Grouping. The ungrounded and grounded circuit conductors of each multiwire branch circuit shall be grouped by cable ties or similar means in at least one location within the panelboard or other point of origination.

Exception: The requirement for grouping shall not apply if the circuit enters from a cable or raceway unique to the circuit that makes the grouping obvious.

Is this within the scope of an inspection?

The inspector shall:

A. inspect:

1. service drop.
2. service entrance conductors, cables, and raceways.
3. service equipment and main disconnects.
4. service grounding.
5. interior components of service panels and sub panels.
6. conductors.
7. overcurrent protection devices.
8. a representative number of installed lighting fixtures, switches, and receptacles.
9. ground fault circuit interrupters.

ASHI's SOP

B. describe:

1. amperage and voltage rating of the service.
2. location of main disconnect(s) and sub panels.
3. presence of solid conductor aluminum branch circuit wiring.
4. presence or absence of smoke detectors.
5. wiring methods.

ASHI's SOP

The inspector is NOT required to:

A. inspect:

1. remote control devices.
2. alarm systems and components.
3. low voltage wiring systems and components.
4. ancillary wiring systems and components not a part of the primary electrical power distribution system.

B. measure amperage, voltage, or impedance.

CREIA' s SOP

A. Items to be *inspected*:

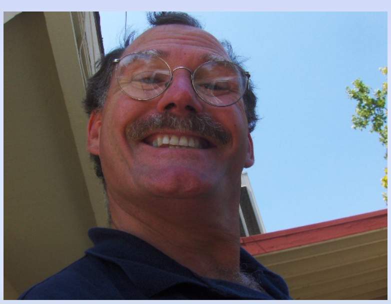
1. Service equipment
2. Electrical panels
3. Circuit wiring
4. Switches, receptacles, outlets, and lighting *fixtures*

B. The *Inspector* is not required to:

1. *Operate* circuit breakers or circuit interrupters
2. Remove cover plates
3. *Inspect* de-icing *systems* or *components*
4. *Inspect* private or emergency electrical supply *systems* or *components*

Sources

NFPA 70: 2011 NEC (www.nfpa.org)
Electrical Inspections of Existing Dwellings (Douglas Hansen)
CodeCheck (www.codecheck.com)
Carson Dunlop
Mike Holt (www.mikeholt.com)
Ken Risling (electrical contractor extraordinaire)



Thanks for your support