



Consulting, Resource, Education, Training, and Support Services for Professional Home Inspectors
"A candle loses no light when it lights another candle."

Electrical System Bonding and Grounding

GROUNDING – BONDING – GROUNDED/NEUTRAL CONDUCTOR

EQUIPMENT GROUNDING CONDUCTOR - UNGROUNDED CONDUCTOR

GROUNDING ELECTRODE - GROUNDING ELECTRODE CONDUCTOR - FEEDER

MAIN BONDING JUMPER - BONDING JUMPER - BONDING CONDUCTOR

While these are all electrical system terms and they all relate to each other, they are nonetheless confusing to many home inspectors, in part, because many of these terms share one of two root words, "bond" and "ground." This article will define each of the terms above and, in the course of doing so, will attempt to explain how they interrelate in a typical residential electrical system.

GROUNDING

Grounding means connected to the earth and refers to the process of joining all non-current-carrying conductors in the electrical system and making a low-resistance connection between them and the earth or some conducting body that serves in place of the earth. The purpose of grounding is to stabilize voltage in relation to the earth or to another body that serves in place of the earth so that the voltage measured between an ungrounded conductor (also referred to as the "hot," "live," or phase conductor) and a grounded object is always at the same potential which is zero. For practical electrical circuits, the earth or ground potential is usually taken to be zero and everything is referenced to the earth. Electrical potential is the difference in electrical charge between two points in a circuit and it is expressed in volts. By keeping the potential at zero (no difference in potential) on the components of conductive systems such as water piping and fuel gas piping, the possibility for shock or electrocution for someone who comes into contact with such components is greatly reduced.

BONDING/BONDED

Bonding/bonded (also referred to as "equipotential bonding") means connected to establish electrical continuity and conductivity. It is the permanent joining of metallic parts to form an electrically conductive path that ensures both electrical continuity and the capacity to safely conduct any current likely to be imposed on such metallic parts. Properly bonded systems are at the same electrical potential (thus, the term "equipotential") as the grounding portion of the electrical system. Bonded systems are neither designed nor intended to carry current as part of the electrical system but they must be able to safely do so in the event that current is imposed on them. Think of bonding as "gluing" a system's parts together such that they are all electrically connected. Current flowing on any one part will flow on all parts because they are connected. The bonding of conductive systems minimizes the voltage differential between the different components in the system under both normal and atypical operating conditions.

All metal piping that is likely to become energized must be bonded to an effective ground-fault current path and the equipment grounding conductor for the circuit that has the potential to energize the piping can serve as the bonding means - NEC 250.4(A)(4). **EXPOSED** structural metal building components are also to be bonded; however, metal studs and metal siding are not required to be bonded.

GROUNDED/NEUTRAL CONDUCTOR

The term “neutral” conductor has become accepted as interchangeable with the term “grounded” conductor and in the 2008 NEC the neutral conductor will be defined as a wire “intended to carry current under normal operation.” Therefore, for the purposes of this article the term “neutral” appears after the term “grounded” as in the term “grounded/neutral conductor.”

A grounded/neutral conductor is a system or circuit wire that is intentionally grounded.

NOTE: Keep in mind that equipment grounding conductors and bonding conductors **are not system or circuit conductors** because they do not have to be present for the electrical system to function or operate; they only need to be present to make the system operate more safely. Only a grounded/neutral service conductor and an ungrounded (hot) service conductor are required in order to have an operational system.

Since the grounded/neutral service conductor serves as the effective path for ground-fault current, it has to be sized large enough to safely carry the maximum fault current that is likely to be imposed on it. The grounded/neutral service conductor cannot be sized smaller than the required grounding electrode conductor. However, it is not required to be larger than the largest ungrounded (hot) service-entrance conductor. The individual branch circuit grounded/neutral conductors carry the unbalanced neutral current in a 240 volt circuit. Therefore, they have to be sized large enough to carry the maximum unbalanced neutral current that they may be required to carry. The insulation on grounded/neutral conductors is to be white or gray in color.

NOTE: In power systems, the neutral conductors are typically the grounded conductors, but not all grounded conductors are neutral conductors. In a typical residential single-phase, 120volt 240volt (nominal) electrical system with both 120volt and 240volt circuits, only the white or gray insulated conductor in a 240volt circuit (such as the circuit for an electric clothes dryer, electric water heater, or electric range) will function as a true neutral conductor because it will carry the difference in current between the two 120volt ungrounded (hot) conductors. If one 120volt ungrounded (hot) conductor is carrying 25 amps and the other is carrying 21 amps, the 4 amp difference will run on the neutral conductor.

Most home inspectors have encountered two types of 240volt clothes dryer and cooking range receptacle outlets. Some are pre 1996 NEC 240volt receptacles which only accept 3 pin plugs and some are 1996 and later which only accept 4 pin plugs. The 3 pin type appliance pigtail (wiring with the plug end) combines the equipment grounding conductor function and the grounded/neutral conductor function in a single conductor. This practice evolved during World War II as a measure to conserve copper. However, the NEC decided that separating these conductors would decrease the potential for electrocution and the 1996 edition of the NEC and all subsequent editions reflect that position.

EQUIPMENT GROUNDING CONDUCTOR

An equipment grounding conductor is a wire that connects non-current-carrying metal parts such as raceways, enclosures, and the metal frames of equipment, appliances, motors, etc. back to the main bonding jumper (also referred to as a “bus link”). The main bonding jumper connects the grounded/neutral conductor to the distribution panel enclosure, to the equipment grounding conductors, and to the grounded/neutral conductor coming from the incoming electrical service provider’s wiring. An equipment grounding conductor establishes a conductive path both to connect normally non-current-carrying parts of equipment together and to connect to the system grounded/neutral conductor or to the grounding electrode conductor or to both.

The point of connection of the equipment grounding conductors, the grounded/neutral conductors, and the grounded/neutral conductor from the electrical service provider is typically located in the main distribution panel enclosure unless the main electrical service disconnection device/means is located upstream (on the line side) of and in a separate location from the main distribution panel enclosure.

An equipment grounding conductor doesn’t normally carry current when the electrical system is properly functioning. In the event of a ground-fault, the equipment grounding conductor is designed

and intended to provide an effective, low impedance ground-fault current path from the point of a ground-fault on the wiring system to the electrical supply source in order to cause the overcurrent protection device to open the circuit and to clear the fault. An equipment ground~~ing~~ conductor may be uninsulated or, if it's insulated, the insulation is to be green or green with yellow stripes.

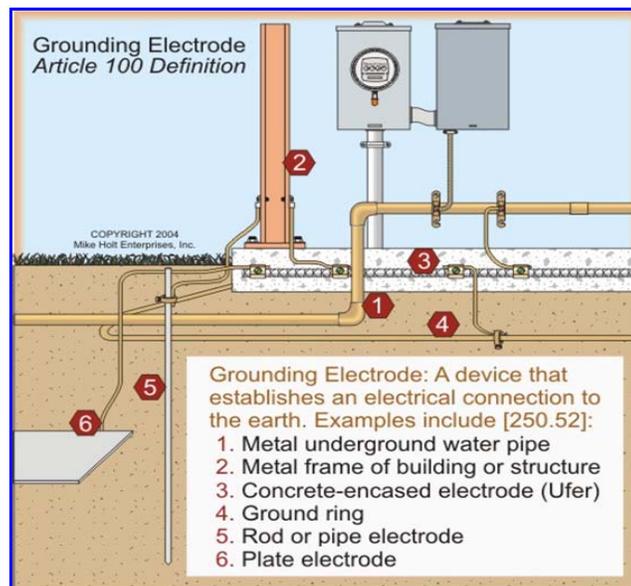
UNGROUND~~ED~~ CONDUCTOR

An unground~~ed~~ conductor (also referred to as a “hot,” “power,” or “phase” conductor) is a wire which supplies power or which carries current from a source of power to a device which uses power (a load). The insulation on unground~~ed~~ (hot) conductors must be finished to be clearly distinguishable from both ground~~ed~~/neutral conductors and equipment ground~~ing~~ conductors. Distinguishing markings shall not conflict in any manner with the surface markings required in the NEC. Branch-circuit unground~~ed~~ (hot) conductors shall be identified in accordance with the requirements of the NEC.

GROUNDING ELECTRODE

A grounding electrode is an electrically conductive solid rod, plate, or ring (of approved materials and whose size and surface area are sufficient to permit adequate contact with the earth in which it is buried or driven. Or, in the case of a concrete-encased electrode (Ufer ground), the grounding electrode is steel rebar of sufficient size, length, and embedment in concrete foundation components which are themselves, in sufficient and substantial contact with the earth. A wire called a grounding electrode conductor connects a grounding electrode to the ground~~ed~~/neutral conductor at service equipment, to a source of a separately derived system, or to the equipment ground~~ing~~ conductor at each building or structure disconnect that is supplied by a feeder.

As pointed out above, a Ufer ground refers to an electrical system ground which utilizes the reinforcing steel rebar(s) in a concrete foundation as the grounding electrode. The system is named after Herbert G. Ufer, a consultant who worked for the United States Army in World War II. Faced with the need to ground desert bomb storage vaults in an area with little soil moisture near Flagstaff, Arizona, he devised this system of grounding. Ufer knew that concrete has the characteristics of absorbing moisture rapidly and losing moisture very slowly and that it has a high ph (it is very basic). These characteristics raise the ph of the soil with which concrete is in contact and reduce the resistance of the soil making both the concrete and the soil contacting it excellent conductors for electrical currents.



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Concrete-Encased Electrode System (Ufer Ground)

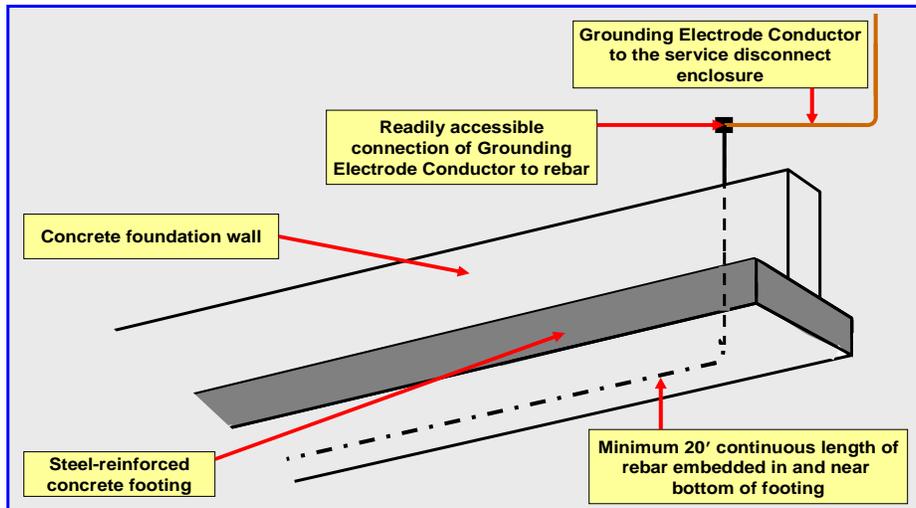


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A Concrete-Encased Electrode must be encased by at least 50 mm (2 in.) of concrete and located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth. It must consist of at least 6.0 m (20 ft.) of one or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm ($\frac{1}{2}$ in.) in diameter, or consisting of at least 6.0 m (20 ft) of bare copper conductor not smaller than 4 AWG. Reinforcing bars shall be permitted to be bonded together by the usual steel tie wires or other effective means.



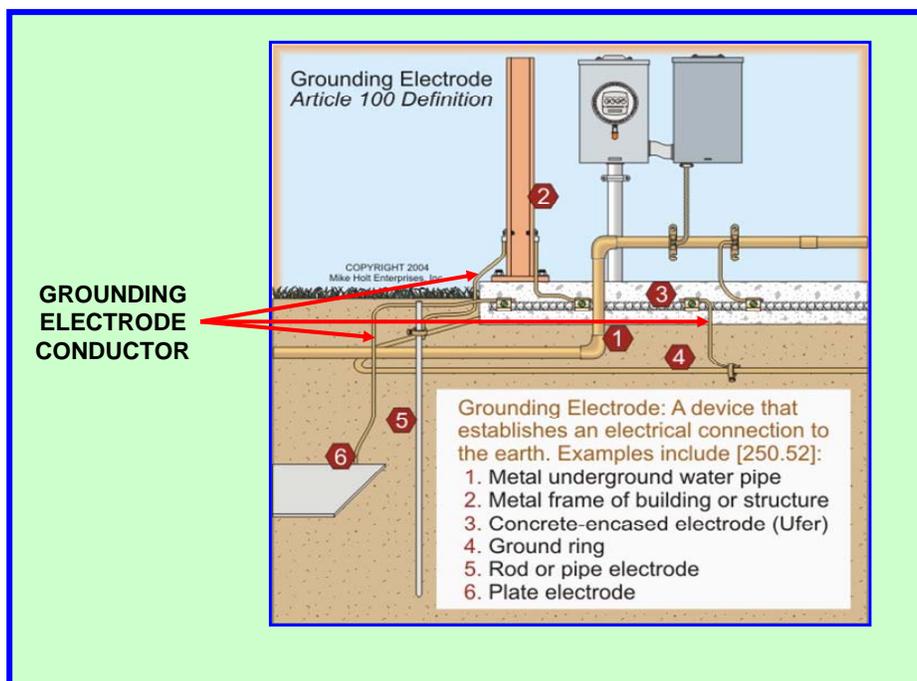
**CONNECTION OF THE GROUNDING ELECTRODE CONDUCTOR TO A CONCRETE-ENCASED
GROUNDING ELECTRODE (UFER GROUND)**

GROUNDING ELECTRODE CONDUCTOR

A grounding electrode conductor (GEC) connects equipment or the grounded circuit of a wiring system to a grounding electrode. It must be a continuous unspliced conductor from its point of attachment at the grounding electrode to its point of attachment at the service or it may be spliced under specific conditions using exothermic welding, an approved compression-type connector, connecting sections of busbars together to form a GEC, or by terminating it to a busbar sized not smaller than ¼" x 2". The exception to the requirement that a GEC be continuous and unspliced was made to permit extending the conductor when a main disconnection device enclosure has to be moved/relocated such as when an addition to a home is constructed. Together, the grounding electrode and grounding electrode conductor comprise the grounding electrode system.

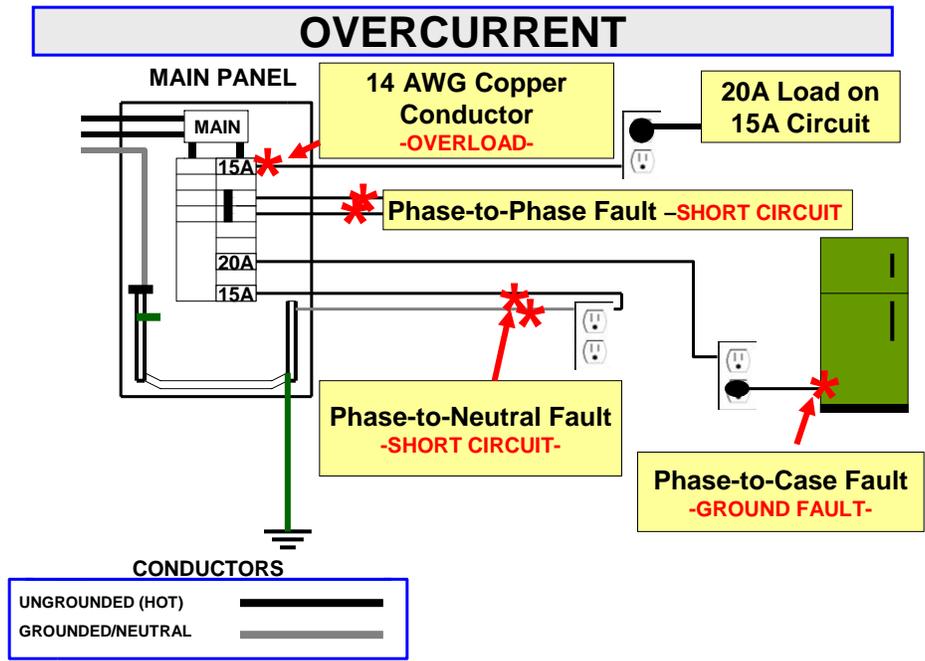
This system is not intended to conduct much current under normal circumstances. Its primary purpose is to conduct the currents generated by lightning strikes and other extremely short-duration electrical events. Because the conductivity of the grounding electrode system is relatively low and its resistance is relatively high, as much as 25 ohms, (that translates as 5 amperes at 120 volts), it is not enough to trip a 15 amp breaker and, therefore, it is not intended to be involved in causing a breaker to trip and clear a fault when a hot-to-ground, hot-to-hot, or hot-to-neutral short circuit occurs on individual circuit wiring. To operate and clear a fault, a circuit breaker relies on fault current traveling on the grounded/neutral service conductor back to the center-tap (ground) of the service transformer (transformers will be discussed in a future *ProSpex* article).

In separate buildings or structures the metal parts of the electrical system and all conductive systems such as metallic piping and exposed structural metal that are neither designed nor intended to carry current as part of the electrical system in separate buildings or structures supplied by a feeder, must be grounded to the earth through a grounding electrode/grounding electrode conductor system to reduce the potential for damage to or the destruction of electrical components from superimposed voltage from line surges, unintentional contact with higher voltage lines, and voltage transients and to help prevent the build-up of static charges on equipment and material. Failure to ground the metal parts of the electrical system through a grounding electrode/grounding electrode conductor system can result in electric shock, fire, and damage to or destruction of expensive electronic equipment from lightning or high voltage line surges.



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NOTE: A short circuit is an accidental path of low resistance which passes an abnormally high amount of current. A short circuit exists whenever there is a low resistance connection between the two conductors supplying electrical power to any circuit. In a short circuit the resistance of a circuit or the resistance of a part of a circuit drops in value to almost zero ohms. This results in excessive current flow in the power source through the short. If there is no overcurrent protection device (circuit breaker or fuse) installed in the circuit, a short circuit can cause the power source to be destroyed.



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Splicing/connecting other grounding conductors to the grounding electrode conductor is permitted by use of irreversible compression-type connectors listed for grounding or by exothermic welding.

GROUNDING ELECTRODE CONDUCTOR SPLICING

Splicing of the grounding electrode conductor is permitted by irreversible compression-type connectors listed for grounding or by exothermic welding.

Graphite Mold

Starting Powder

Welding Powder

Steel Disc

Tap Hole

Weld Cavity

Grounding Electrode Conductor

Exothermic Welding

Once utilized, an irreversible connector cannot be opened.

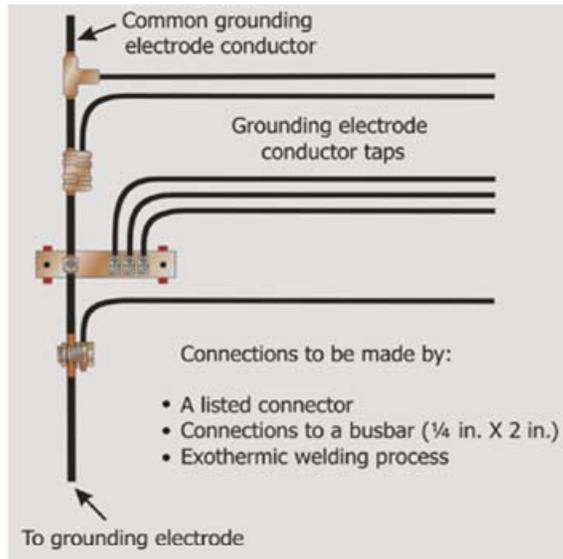


Illustration Courtesy of the International Association of Electrical Inspectors
www.iaei.org

Opening a circuit and clearing a short circuit in the electrical system relies on the manner in which equipment **grounding** conductors (when present) and **grounded/neutral** conductors are installed and how they function in the electrical system. Equipment **grounding** conductors and **grounded/neutral** conductors terminate at the **grounded/neutral** conductor bus in the main distribution panel. Short circuit currents which occur on circuits will be conducted down the equipment **grounding** conductor or down the **grounded/neutral** conductor to the point of connection with the **grounded/neutral service** conductor from the electrical service provider in the main panel (SES) (the Service Entrance Section). From there, it will travel back to the center tap (ground) of the service transformer and will cause the overcurrent device (circuit breaker or fuse) to clear the fault by opening the circuit.

Equipment **grounding** conductors, **grounded/neutral** conductors, and the **grounded/neutral** conductor from the electrical service provider terminate at the **grounded/neutral** conductor bus in the main distribution panel (SES).

**Main Electrical Distribution Panel With
 the Main Electrical Disconnection Device
 Located Within the Panel Enclosure**

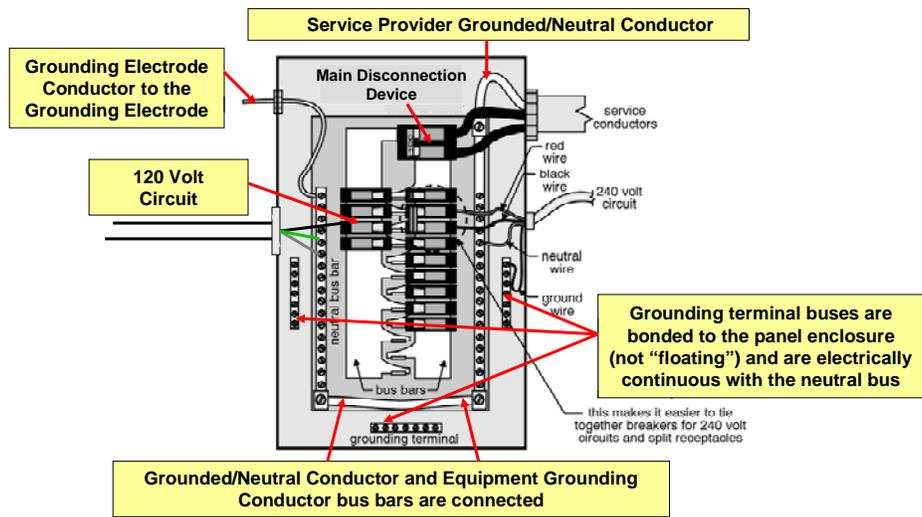


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At one time most jurisdictional building authorities permitted and encouraged the use of metal potable water supply piping as the grounding electrode because it was embedded in the earth outside of the building. In fact, prior to 1978, the National Electrical Code (NEC) specified the metal potable water supply pipe as the first choice for use as a grounding electrode and “*other electrodes*” and “*made electrodes*” were acceptable only “*where a water system (electrode)...is not available.*” If a minimum of ten (10) feet of a metal potable water pipe to a building were buried in the ground, then that water pipe had to be used as the grounding electrode and no other electrical system electrode was required.

However, with the growing use of non-conductive components in such piping systems, their ability to provide an electrically continuous and reliable electrical system ground came into question. Today, buried metal potable water supply piping is considered by the NEC to be the least acceptable grounding electrode and is the only grounding electrode that may never be used as the sole grounding electrode. It must be supplemented by at least one additional approved grounding electrode. While metal fuel gas piping is to be bonded to the electrical system, it is **NEVER** to be used as a grounding electrode

The connection of a conductor from any of the following is to be accomplished by use of exothermic welding, a listed pressure connector, or other listed means (“listed” means tested and approved for the specific use by a qualified and recognized standards and testing agency such as Underwrites Laboratories or the Canadian Standards Association):

1. The piping system to the service equipment enclosure
2. The groundeded/neutral conductor at the service
3. The grounding electrode conductor where such grounding electrode conductor is of sufficient size (the grounding electrode conductor is the wire which connects the grounding bus in the main panel (SES))
4. A Ufer, to the grounding rod, to any other approved grounding electrode
5. One or more grounding electrodes used for the service

FEEDERS

A feeder is any circuit conductor between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device. Feeders are typically required to provide an equipment grounding conductor to which all equipment grounding conductors of the circuit are to be connected as specified in the appropriate section of the NEC. Feeders shall be identified in accordance with the requirements of the NEC and can be any color other than those reserved for other conductors.

MAIN BONDING JUMPER

Located at the electrical service, the main bonding jumper is the connection between the groundeded/neutral circuit conductor and the equipment grounding conductor at the service.

For a grounded electrical system, there are to be **NO** splices in the main bonding jumper. The main/system bonding jumper connects the equipment grounding conductor(s) and the service disconnect enclosure (the enclosure in which the service disconnect device is located) to the groundeded/neutral conductor within the service disconnect enclosure for each disconnect. This means that in a split bus panel with six single throw/double pole 240 volt breakers (multi-wire circuits), all of which have to be thrown to disconnect the entire system, the groundeded/neutral conductors for each of those circuits must be bonded to the enclosure by means of one of the approved methods for doing so. Typically, this would be by connecting them to a terminal bus bar that is bonded to the metal body of the enclosure.

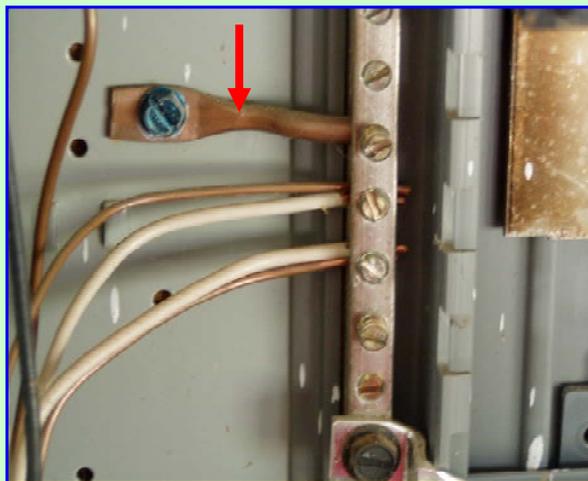
The purpose of the main bonding jumper is to provide a path for a ground-fault back to the source of supply to the service. The path for the fault current would be from the point of the fault back through the equipment ground~~ing~~ conductor system to the service disconnect enclosure, and through the equipment bonding jumper to the equipment ground bar and then to the ground~~ed~~/neutral conductor of the system. The ground~~ed~~/neutral conductor of the system may also serve as the neutral for some applications and may carry currents as well as transmit any fault current back to the utility company transformer or other source of power.

Depending on the impedance of the system, fault current levels can often be hundreds of thousands of amps relative to the normal current in the circuit. Therefore, the size of both main bonding jumpers on the supply (line) side of any overcurrent protection device and the ground~~ed~~/neutral service conductor (from the electrical service provider) must be large enough to conduct this potentially high fault current. Since the main bonding jumper is connected in series with the ground~~ed~~/neutral service conductor and is subject to the same amount of fault current, it must be sized similarly to the ground~~ed~~/neutral service conductor.

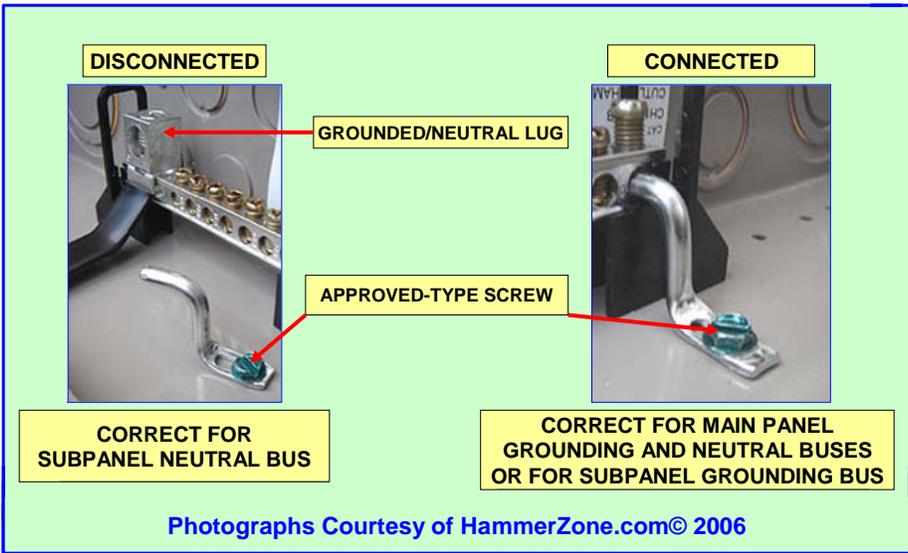
The main bonding jumper of a system, like all electrical connections, must be readily accessible and it must be connected to one of the following components of the electrical system:

1. The service equipment enclosure
2. The ground~~ed~~/neutral service conductor at the service
3. The grounding electrode conductor where such grounding electrode conductor is of sufficient size (the grounding electrode conductor is the wire which connects the grounding bus in the main panel (SES) to the
4. Ufer, the grounding rod, or other approved grounding electrode).
5. One or more grounding electrodes used for the service.
6. Since the main bonding jumper is a critical path for a ground-fault, it must be copper or other corrosion-resistant material and must not be spliced. The main bonding jumper can be a wire, screw, terminal bus, or other suitable conductor.

Main Bonding Jumper



Main Bonding Jumper



Since the main bonding jumper is a critical path for a ground-fault, it must be copper or other corrosion-resistant material and must not be spliced. The main bonding jumper can be a wire, screw, terminal bus, or other suitable conductor.

Main Panel Main Bonding Jumper

Circuit breakers and all conductors removed for clarity

For the purpose of this illustration, the panel enclosure as depicted is a main service disconnect and distribution panel.

Additional grounding terminal bus "D" bonded to the enclosure case

MAIN LUGS

Staggered "hot" buses

Terminal (lug) for incoming grounded/neutral service conductor from the utility service provider

Grounding and grounded/neutral terminal buses "B" & "C"

Main bonding jumper "A" to be connected to grounding and Grounded/neutral terminal bus "B"

When the main bonding jumper "A" is connected to the grounding/grounded neutral terminal bus "B" and the grounding and grounded/neutral terminal bus "C" is bonded to the enclosure case by an approved means, then all the terminal buses will be bonded and the main bonding jumper will be properly installed and will perform its intended function.

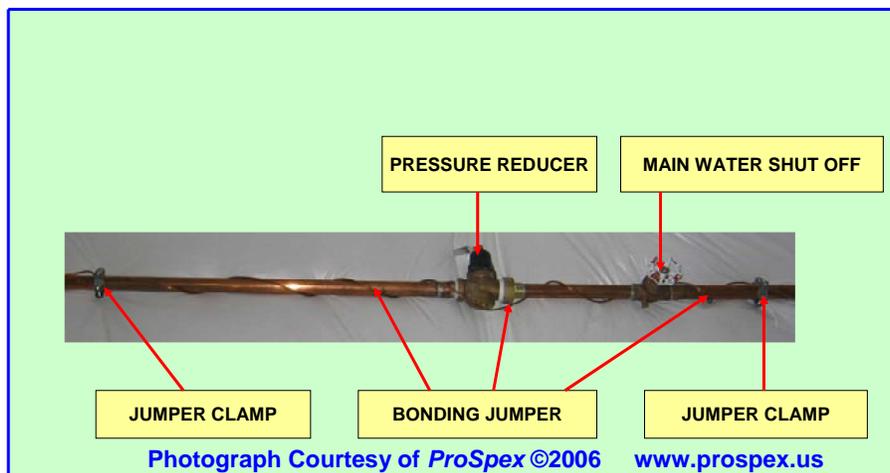
Photograph Courtesy of HammerZone.com© 2006

BONDING JUMPER

Where small sections of non-conductive components are installed in potable water piping, fuel gas piping, and other systems composed primarily of conductive metal material, it is necessary to connect the sections of metal pipe on either side of such non-conductive components by installing a bonding jumper conductor to help ensure that electrical conductivity and continuity is maintained throughout the system. An example of a non-conductive component that is commonly installed on a potable water piping system (and with which most home inspectors are familiar) is a water meter.

A non-conductive, non-metallic piping system in which a short piece of metal pipe or other conductive material is installed is still considered a non-conductive system and the short piece of metal pipe doesn't have to be bonded.

Water Line Pressure Reducer and Bonding Jumper



BONDING CONDUCTOR

The conductor which connects a bonded system to the grounded part of the electrical system is called a bonding conductor. It is typically a large gauge solid conductor or a large multiple strand conductor often found connected to the cold water pipe at a water heater or the pipe at a hose bib when bonding the potable water piping system or connected to the metal gas pipe near the gas meter or near a gas-fired appliance when bonding the fuel gas piping system. Like all electrical connections, bonding conductor connections and bonding jumper connections are not to be concealed behind components or materials of construction and must be readily accessible.

Water Pipe Bonding Conductor and Clamp



Photograph Courtesy of the International Association of Electrical Inspectors
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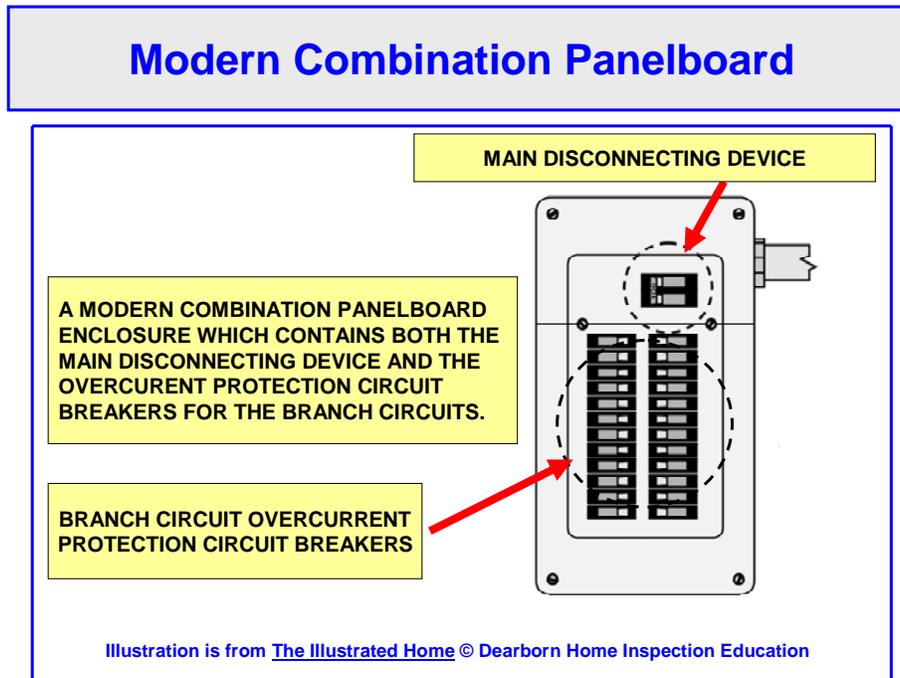
RECAP OF BONDING AND GROUNDING

Bonding and grounding work in cooperation with each other and both are essential to any safe electrical system. Failure to properly and adequately bond the potable water, drain/waste/vent, and fuel gas/oil piping systems to the electrical system increases the potential for both fire and electrocution should any one of such piping systems become energized.

Metallic piping systems other than those for potable water and other metallic systems are also required to be bonded to the electrical system for the same reasons that potable water metallic piping systems are required to be bonded. Such other systems include, but are not limited to, fuel gas and fuel oil piping, pneumatic piping, landscape irrigation system piping, fire suppression sprinkler system piping, hydromassage tub pump motors, swimming pool pump motors, and metallic components such as diving boards, ladders, fences, exposed metal structural framing, and patio roof support columns within five (5) feet of the edge of a pool.

While the term bonding is typically used to refer to “electrically tying” systems that are electrically conductive (but which are neither designed nor intended to normally carry current) to the electrical grounding system, in its broadest sense, it simply refers to the permanent joining of metallic parts to form an electrically conductive path that ensures both electrical continuity and the capacity to safely conduct any current likely to be imposed on such metallic parts. Equipment grounding conductors are wires which normally don’t carry current when the electrical system is properly functioning. They are intended to provide an effective, low impedance ground-fault current path from the point of a ground-fault on the wiring system (a short circuit between an ungrounded (hot) conductor and the chassis or case of equipment, appliances, tools. etc.) to the electrical supply source to cause the overcurrent protection device to open the circuit and to clear the fault.

In most modern single family residential electrical systems the main disconnecting device is located in the same enclosure as the main distribution panelboard as illustrated below.



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It is in this enclosure containing the main service disconnecting device, **and only in this enclosure**, that 4 (four) conductors must all be connected together.

These conductors are:

1. THE GROUNDED/NEUTRAL CONDUCTOR
2. THE GROUNDING ELECTRODE CONDUCTOR
3. THE EQUIPMENT GROUNDING CONDUCTOR
4. THE MAIN BONDING JUMPER
- 5.

EQUIPMENT GROUNDING CONDUCTORS AND GROUNDED/NEUTRAL CONDUCTORS ON THE LOAD SIDE OF THE MAIN SERVICE DISCONNECT DEVICE ENCLOSURE

What makes it more than just a bad idea to connect the grounding conductors to the grounded/neutral conductors anywhere on the load side of the main service disconnect enclosure, that is, anywhere downstream of the enclosure where the main service disconnect is installed and, therefore, why it's prohibited? This includes main distribution panels when the main service disconnect means or device is located in its own separate enclosure on the line side (upstream) of the main distribution panel enclosure instead of in the main distribution panel enclosure. This arrangement is typically found in multiple family structures such as townhouses, condominiums, and apartments where each unit is individually and separately metered and each occupant pays for her or his electrical usage.

Before starting, let's first review the concepts of "line" and "load." Sometimes it helps to think of "line" as "upstream" and "load" as "downstream." We'll begin with the transformer that supplies electrical power to a house. This is typically single phase, 120 /240 volt (nominal) service. The overhead service drop or the underground service lateral connects the power company's transformer to the electric meter by three conductors - two 120 volt (nominal) ungrounded ("hot" or "phase") conductors and one grounded/neutral conductor. Because the transformer is "upstream" of the meter, it's said to be on the "line" side of the meter. Since the meter is "downstream" of the transformer, it's said to be on the "load" side of the transformer.

Now, let's look at the main service disconnection device (the main breaker), the next component after or "downstream" of the meter. Typically, in the majority of modern residential electrical systems the main breaker is a single throw/double pole circuit breaker rated somewhere between 100 amps and 225 amps and located in an enclosure which also contains the branch circuit panelboard and circuit breakers. The conductors coming from the meter to the main breaker are connected to the "line" side of the main breaker. The two 120 volt bus bars to which the main breaker attaches are connected to the "load" side of the main breaker. The main breaker is a "load" on the meter and any circuit breakers connected to the 120 volt bus bars are "loads" on the main breaker.

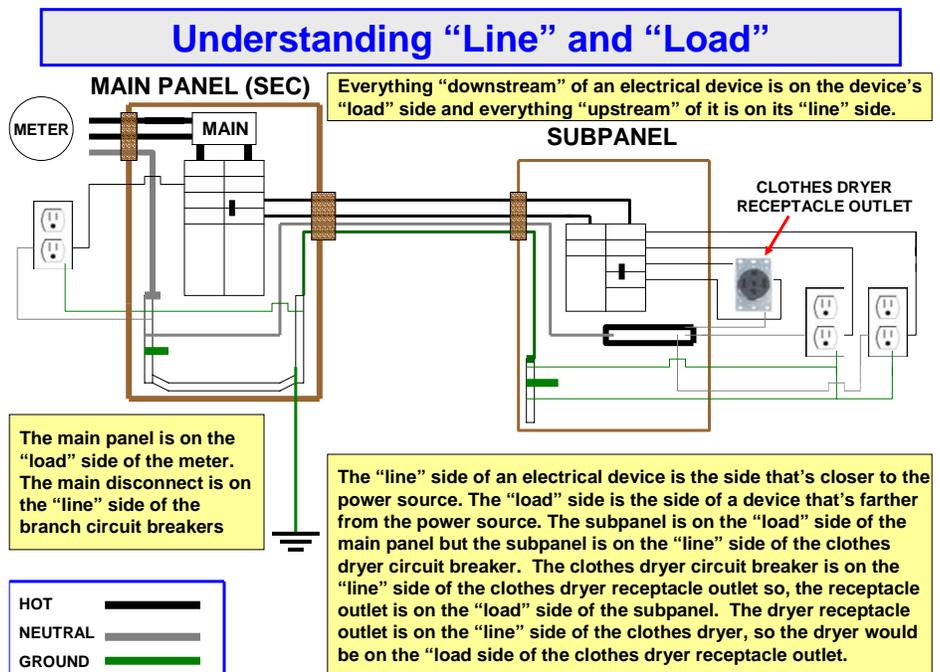


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Devices or equipment that receive/use power are on the "load" side ("downstream") of devices or equipment from or through which the power comes and those devices or equipment through which the power comes are on the "line" ("upstream") side of the devices or equipment that receive power (that are "downstream").

A receptacle outlet on a branch circuit is on the "load" side of the circuit breaker that feeds that circuit because it's "downstream" of the circuit breaker so, it's a "load" on the circuit breaker. Any receptacle outlets "downstream" of this receptacle outlet are on the "load" side of not only the first outlet and the circuit breaker but also of the main breaker, the meter and the transformer. In other words, every electrical device (component, fixture, appliance, etc.) is on the "load" side of every electrical device that's "upstream" of it and on the "line" side of every device that's "downstream" of it.

Technical jargon is a useful shortcut when everyone is familiar with and understands the jargon. Therefore, when you speak with electricians, try to get used to using “line” and “load.” However, since very few of your customers will understand the concepts of “line” and “load,” when you’re explaining electrical conditions to them, you’ll communicate more effectively by using “upstream” and “downstream.”

Now, we’re ready to discuss neutral-ground bonds on the load side of the main service disconnect device. Load side neutral-ground bonds allow any neutral current to flow on conductive metal parts of electrical equipment that are connected to the electrical system by equipment ground~~ing~~ conductors. This is because current doesn’t take the path of least resistance to ground; it takes every available path to ground.

For example, bonding the ground~~ed~~/neutral conductor to the equipment ground~~ing~~ conductors in a subpanel creates more than just a path to ground for neutral currents on the ground~~ed~~/neutral conductor; it creates parallel paths for those currents on both the equipment ground~~ing~~ conductors and on any conductive components fed by that subpanel such as metal cases and frames of appliances that are connected to the equipment ground~~ing~~ conductors. If you’re touching one of those appliances and you’re grounded, well, then, you’ve just become part of one of those parallel paths to ground. The neutral currents not only can cause lethal electric shock, they increase the potential for arcing/flashovers, overheating of equipment, and other problems stemming from electricity where it doesn’t belong. The idea behind proper bonding is to reduce the potential these conditions to occur.

The only place in the electrical system that the ground~~ed~~/neutral conductors and the equipment ground~~ing~~ conductors should come together is in the enclosure in which the main service disconnect device is located. At all other points throughout the electrical system, there should be no connection between the bare or green insulated equipment ground~~ing~~ conductor and the white or gray ground~~ed~~/neutral conductor. Under normal conditions, the equipment ground~~ing~~ conductor carries no current. No current means that there is no voltage drop along it. Therefore, anything grounded to this conductor is at the same potential (voltage) as ground – zero potential.

If the ground~~ed~~/neutral conductors and equipment ground~~ing~~ conductors are bonded at the subpanel, stray currents from the ground~~ed~~/neutral return could go through the equipment ground~~ing~~ conductors on the electrical devices that are fed from the subpanel. When the ground~~ed~~/neutral conductors are separated from the equipment ground~~ing~~ conductors and isolated/insulated from any contact with any metal or other electrically conductive components in a subpanel or at any other point on the load side of the main service disconnect enclosure (“floating neutral”), then current in the system cannot return to the main panel (SES) and then to the service ground on the equipment ground~~ing~~ conductors or any components connected to an equipment ground~~ing~~ conductor such as electrical system metal boxes, conduits, etc. or the chassis or case of an appliance or other equipment.

Remember, current doesn’t take the path of least resistance to ground; it takes every available path to ground. The idea behind bonding is to reduce the potential for a person to become part of that path.

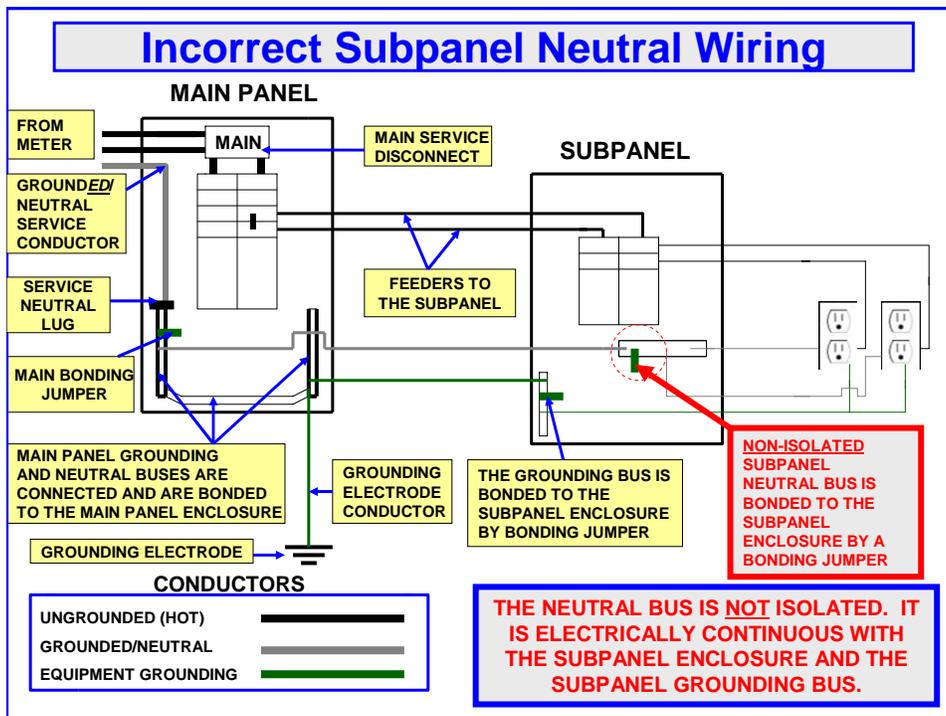


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Bonding of the neutral terminal to the enclosure case of a panelboard, which is not part of service equipment or separately derived systems, creates a parallel path for return neutral current. The result is neutral current (net current) flowing on the metal parts of electrical equipment as well as the grounding and bonding conductors.

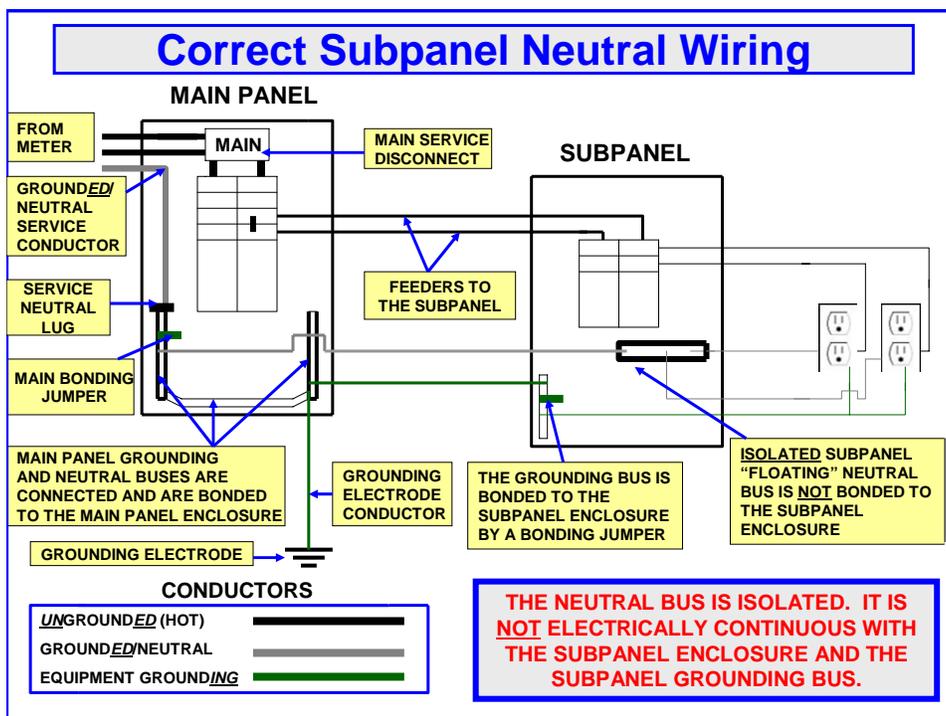


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NOTE: There are specific installations in which neutral-ground bonding is permitted on the load side of the main service disconnect enclosure. These are:

1. Separately derived systems when the requirements of 250.30(A)(1) of the NEC are followed
2. Separate buildings when the requirements of 250.32(B)(2) of the NEC are followed.

It is number **2** above which is of concern to home inspectors. It is common for home inspectors to examine detached garages in which there is a separate panelboard (a subpanel) supplied from the the main panel (SES), at the house. **If, upon removing the cover from the subpanel in the detached building, you determine that ALL of the following conditions, 1 – 4, are present:**

1. An equipment ground~~ing~~ conductor **has not** been run with the feeder (supply) wiring coming from the main panel (SES),
2. There are **no** shared electrically continuous metallic systems such as plumbing or fuel gas piping from the house to the separate building that are bonded to the grounding system for the main panel (SES), and
3. Ground-fault protection of equipment **has not** been installed on the common alternating current service,

then, the ground~~ed~~/neutral conductor that has been run with the feeder (supply) wiring to the separate building must be connected to the detached building disconnecting means and to a separate grounding electrode/grounding electrode conductor system. This is because when an equipment ground~~ing~~ conductor **has not** been run with the feeder (supply) wiring from the main panel (SES) to the separate building, then a separate grounding electrode/grounding electrode conductor system for the subpanel must be used to provide the required effective path for short duration, high electrical current events such as lightning strikes. As **ProSpex** subscriber and licensed electrician, John Branham, points out, the additional grounding electrode/grounding electrode conductor system bonded to the grounding bus and to the subpanel enclosure in the subpanel in the separate building are necessary to create **a completely separate and independent path to ground.**

Remember, it was pointed out earlier in this article that the grounding electrode/grounding electrode conductor system is not intended to conduct much current under normal circumstances. Its primary purpose is to conduct the currents generated by lightning strikes and other extremely short-duration electrical events. The conductivity of the grounding electrode system is relatively low and its resistance is relatively high, as much as 25 ohms, (that translates as 5 amperes at 120 volts). It is not enough to trip a 15 amp breaker and, therefore, it is not intended to be involved in causing a breaker to trip and clear a fault when a hot-to-ground, hot-to-hot, or hot-to-neutral short circuit occurs on individual circuit wiring. The operation of overcurrent protection devices to clear faults relies on the connection of the ground~~ed~~/neutral conductor(s) and the equipment ground~~ing~~ conductor(s) to the ground~~ed~~/neutral service conductor and its connection to the service transformer center tap (ground) and not to the grounding electrode/grounding electrode conductor system.

Because, in this case, an equipment ground~~ing~~ conductor **has not** been run from the main panel (SES) to the subpanel in the separate building, a separate grounding electrode/grounding electrode conductor system for the subpanel in the separate building must be installed in order to provide a means for connecting conductive systems such as metallic piping and exposed structural metal that are neither designed nor intended to carry current as part of the electrical system but which must be able to safely do so in the event that lightning or electrical system current is imposed on them. It must also be connected to the subpanel enclosure, to the subpanel branch circuit ground~~ed~~/neutral conductors, to any subpanel branch circuit equipment ground~~ing~~ conductors, and to the ground~~ed~~/neutral feeder from the main panel (SES).

If a separate grounding electrode/grounding electrode conductor system were not installed, then the grounded~~ed~~/neutral feeder conductor would provide the only path for hot-to-case faults back to the service transformer center tap (ground) and to the main panel (SES) grounding electrode/grounding electrode conductor system in the event that lightning or electrical system current is imposed on the subpanel system. However, in a modern system with equipment grounding conductors, that is not the primary function of the grounded~~ed~~/neutral conductor. That is the function of the equipment ground~~ing~~ conductor(s) – the conductor that **has not** been run with the feeder (supply) wiring from the main panel (SES) to the subpanel and its connection to the grounded~~ed~~/neutral service conductor.

In older electrical systems without equipment ground~~ing~~ conductors, a hot-to-case fault current (such as that imposed when a short between the ungrounded (hot) conductor and the chassis of a refrigerator occurred) had no path to ground - back to the grounding electrode/grounding electrode conductor system, the grounded~~ed~~/neutral service conductor, and the service transformer center tap (ground). Therefore, there was no means of causing an overcurrent protection device (a fuse or circuit breaker) to operate and to clear the fault. All of the metal parts of the refrigerator that were in contact with the refrigerator chassis were the equivalent of an exposed, live 120 volt wire. If someone touched the refrigerator and were grounded through their feet or by touching a metal plumbing system component, that person would become part of a path to ground for the fault current. The result would be shock or electrocution.

The addition of equipment ground~~ing~~ conductors for appliance and equipment wiring and the use of grounding-type receptacle outlets connected by equipment ground~~ing~~ conductors back to the grounding bus in the main panel (SES) provides the effective path for hot-to-case fault current back to the grounding electrode/grounding electrode conductor system, to the grounded~~ed~~/neutral service conductor, and to the service transformer center tap (ground) necessary to cause an overcurrent device to operate and to clear the fault – hopefully before someone comes into contact with the appliance or equipment (properly installed and functioning GFCI devices are the only effective means for significantly reducing the potential for shock or electrocution). In addition, hot-to-case faults can create conditions which result in electrical fires. Properly installed equipment ground~~ing~~ conductor systems are intended to rapidly clear the hot-to-case fault reducing the potential for the occurrence of an electrical fire.

Since there is no equipment ground~~ing~~ conductor from the main panel (SES) and there are no shared electrically continuous systems that bond the main panel (SES) to the subpanel, the subpanel becomes, in effect, a separate SES and that makes all applicable main panel (SES) bonding and grounding requirements apply to the subpanel.

It is important to understand this particular situation to reduce the potential for incorrectly identifying a non-floating grounded~~ed~~/neutral conductor in a subpanel in a separate building as an **ADVERSE CONDITION if all of the specific conditions outlined above are present.**

SEE THE ILLUSTRATION AND INFORMATION ON THE FOLLOWING PAGE

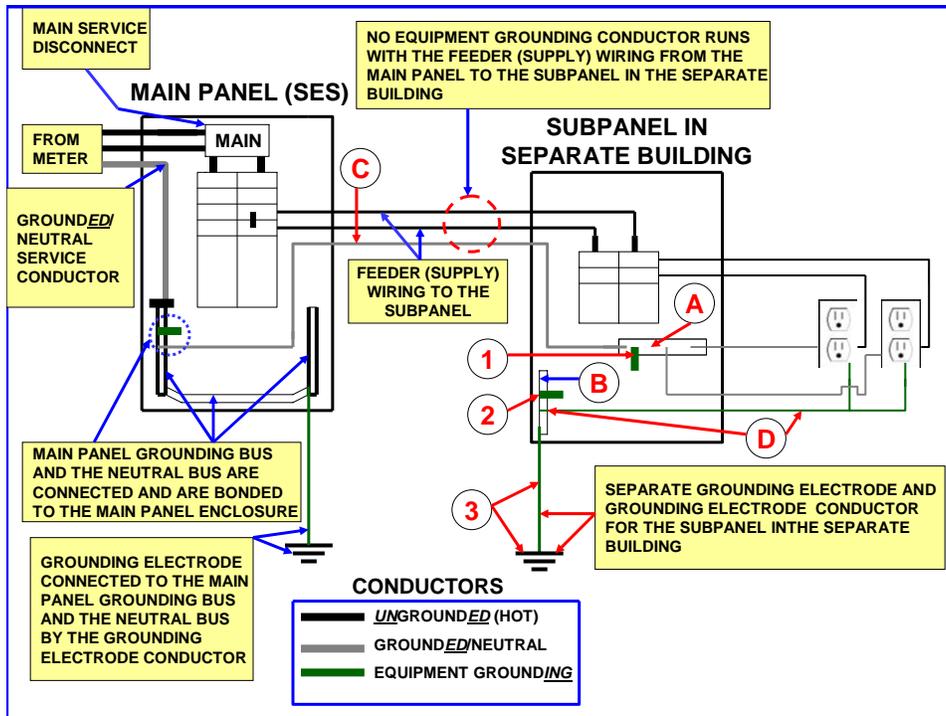


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In the above illustration **there is no** equipment ground~~ing~~ conductor running with the feeder (supply) wiring from the main panel (SES) where the main service disconnecting means is located, **there are no** shared electrically continuous metallic systems such as plumbing or fuel gas piping from the house to the separate building that are bonded to the grounding system for the main panel (SES), ground-fault protection of equipment **has not** been installed on the common alternating current service, and there is a separate grounding electrode/grounding electrode conductor system for the subpanel bonded to the subpanel grounding bus.

Follow along in the illustration above:

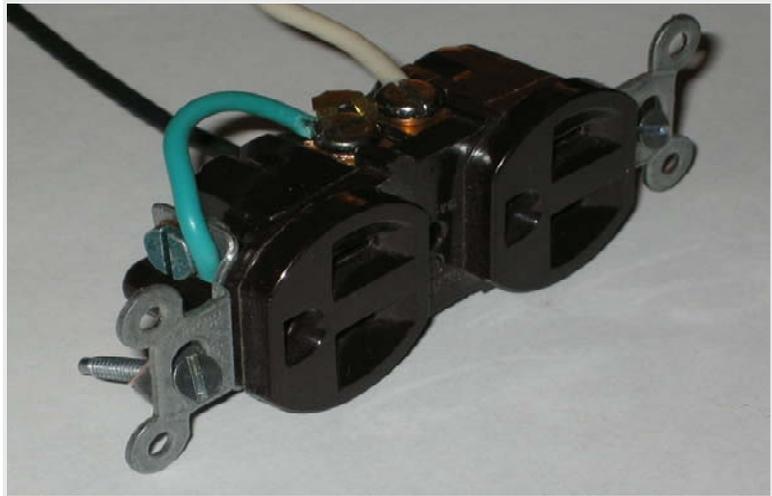
The subpanel neutral bus **A** is bonded to the subpanel enclosure at **1** and the ground~~ed~~/neutral conductor **C** that runs with the feeder (supply) wiring from the main panel (SES) to the subpanel in the separate building is connected to the subpanel neutral bus at **1**. This makes the subpanel neutral bus **A**, the subpanel enclosure, and the ground~~ed~~/neutral conductor **C** electrically continuous.

The subpanel grounding bus **B** is bonded to the subpanel enclosure at **2** and the grounding bus **B** and the equipment ground~~ing~~ conductors **D** from the 120 volt (nominal) receptacle outlets are connected to the subpanel grounding bus **B**.

Together, **A**, **B**, **1**, and **2**, are bonded to the separate grounding electrode/grounding electrode conductor system **3**. Thus, the ground~~ed~~/neutral conductor that runs with the feeder (supply) wiring from the main panel (SES) to the subpanel, the equipment ground~~ing~~ conductors from the 120 volt (nominal) receptacle outlets in the subpanel, and the subpanel enclosure, are all bonded to the separate grounding electrode/grounding electrode conductor system at **3**. They are all electrically continuous.

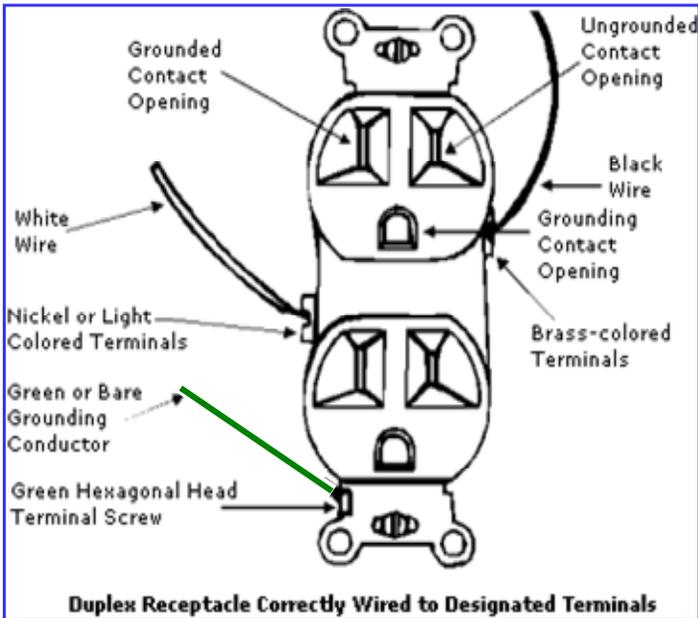
Now, there is an effective path for fault current on the ground~~ed~~/neutral conductor to clear any ground-faults (line-to-case faults) in addition to carrying any unbalanced neutral current.

Ground to Neutral Connection



Photograph Courtesy of ProSpex© 2006 www.prospex.us

In older two-wire electrical systems, two-slot, ungrounded receptacle outlets have often been replaced with grounding-type receptacle outlets. In some instances, the equipment ground^{ing} conductor terminal may have been connected to the ground^{ed}/neutral conductor terminal on the receptacle outlet as in the photograph below. This receptacle will typically test as correctly wired with most receptacle outlet testers; however, it clearly is not correctly wired. While it exceeds established and accepted home inspection standards, professional home inspectors may want to consider removing some receptacle outlet cover plates to visually examine the wiring of grounding-type receptacles if they know or suspect that two-wire receptacle outlets have been replaced with grounding-type receptacles.



The equipment ground^{ing} conductor may run back to the distribution panel or, if the receptacle outlet box is metal and is grounded, it may be connected to the box using an approved method.

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