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You'll never understand grounding by reading the Code book no matter how you arrange the sections. It's like driving an automobile, you first had to learn how to drive it before being handed the book of rules and going to take the exam for a license.

This book is written for an electrician to understand *why we ground* before we ever start explaining what the Code says.

It has been rumored that only three people have ever understood grounding, and they disagreed. I'm writing this book for the student preparing to become an electrician so the mystery of grounding will not follow them throughout their career as it has mine.

Sometimes too much emphasis is put on one's knowledge of Code rules and sizing of bonding jumpers, electrode conductors, etc. Before one can discuss proper sizing of grounding conductors, you must first understand the reasons for grounding a system, theory, Ohm's law and what takes place when a fault condition occurs in the system.

It is not possible to use electricity without involving some risk. It is impossible to prevent dangerous voltages to ground on an electrical system unless we do away with electricity completely because we cannot prevent a fault condition from occurring. The job of the electrician is to hold that risk to a minimum by installing protection which will reduce the existence of voltages to ground on equipment to a minimum and hold the fault condition to a minimum time duration.

We must understand what a circuit is. An electrical circuit is a path or route of least resistance in which electrons flow from the source of supply to accomplish the electrical work and flow through the circuit back to the source of supply.

Grounding is an electrical circuit. The grounding circuit can be conductors or in some cases a conduit system is the grounding circuit. The **mechanical** connections of fittings, conduits, boxes, etc. are just as important as the **electrical** connection of the circuit wires. Each mechanical fitting is a part of the equipment grounding circuit path and must be connected with just as much care as the electrical circuit conductors. Very few faults occur in a short-circuit between wires. The point of connection or termination is where most faults take place.

90% of all failures are from line to metal enclosure. Only 10% are between conductors of the circuit (line-to-line) (line-to-neutral) short circuit.

There are two types of grounds for the protection of electrical wiring systems:

1. The service ground
2. The equipment ground

The **service ground** is intended to limit the voltage on the circuit from lightning or other causes which may impose a higher voltage than it was designed to handle and to limit the maximum potential to ground due to normal voltage. Planet earth is a conductor, although a very poor one in dry conditions. The electrical potential of earth is considered to be zero. Therefore, when a metal object is **grounded** to earth, it is forced to take the same zero potential as earth. Any attempt to raise the potential of the grounded object will cause current to pass over the grounding connection until the potential of the object and the potential of the earth are equalized. Grounding ensures that the grounded object cannot take on a potential differing from the potential of earth.

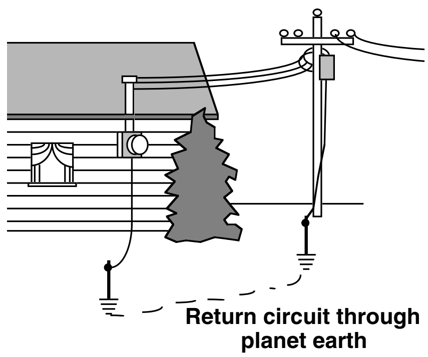
The **equipment ground** is intended to prevent an objectionable potential above ground on raceways and equipment enclosures and to provide a low-impedance path of sufficient capacity for the fault currents to travel back to the overcurrent protective device (fuse or circuit breaker).

Grounded circuits protect people and equipment. When grounding is **improperly** installed, the results can be from "dirty electricity" to the damaging of electrical equipment or minor physical harm to a person or even death in some cases.

How does a person get shocked? By exposure to two conductive surfaces which have a potential difference between them. Bonding these two surfaces together with a conductor will limit the potential difference between them to the voltage drop of the conductor.

A common fantasy is that planet earth is a magic sponge of enormous capacity. Anything undesirable, including unwanted currents and voltages will bury themselves in the earth and be forgotten. Planet earth does not have the ability to accept and store man generated currents, but acts as a conductor to return them to their source. The principles of Ohm's Law apply to this circuit as in other more common circuits.

The return circuit through planet earth is of highly variable resistance due to changing conditions, such as moisture content of the soil, temperature (conductivity of ice is less than that of water), etc.



Approximately what would be the shock exposure to a person coming into contact with a 120 volt circuit that has faulted to the equipment?

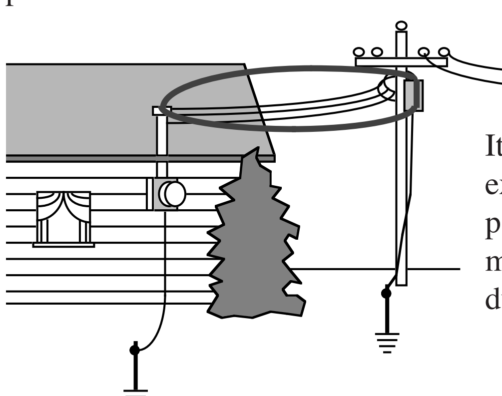
If each ground rod is assumed to have a resistance of 100 ohms, the total resistance of the ground return circuit would be 200 ohms. By Ohm's Law 120v ÷ 200Ω = .6 amp flowing. E = I x R = .6 amp x 100Ω (ground rod earth resistance at the house) = 60 volt shock hazard.

If a second ground rod is driven and connected in parallel with the first ground rod at the house and the earth resistance is reduced to 50 ohms, 120v ÷ 150Ω = .8 amp flowing. E = I x R = .8 amp x 50Ω = 40 volt shock hazard. The shock hazard has been reduced but is still too high to be considered acceptable. The fault current is so low that it will not open any overcurrent device (fuse or breaker).

The earth connections are of primary value in protecting the electrical system from lightning and high voltage involvement. The earth resistance should be as low as possible for this reason.

Most of the protection provided by the so-called ground system has nothing to do with planet earth. It's called the equipment grounding system (**the green or bare wire**). This is the part of the ground system that carries the **faults** to open the overcurrent device (fuse or circuit breaker).

Planet earth carries very little fault current as the equipment grounding circuit will provide a return path of much less resistance back to the source than the high resistance of planet earth.



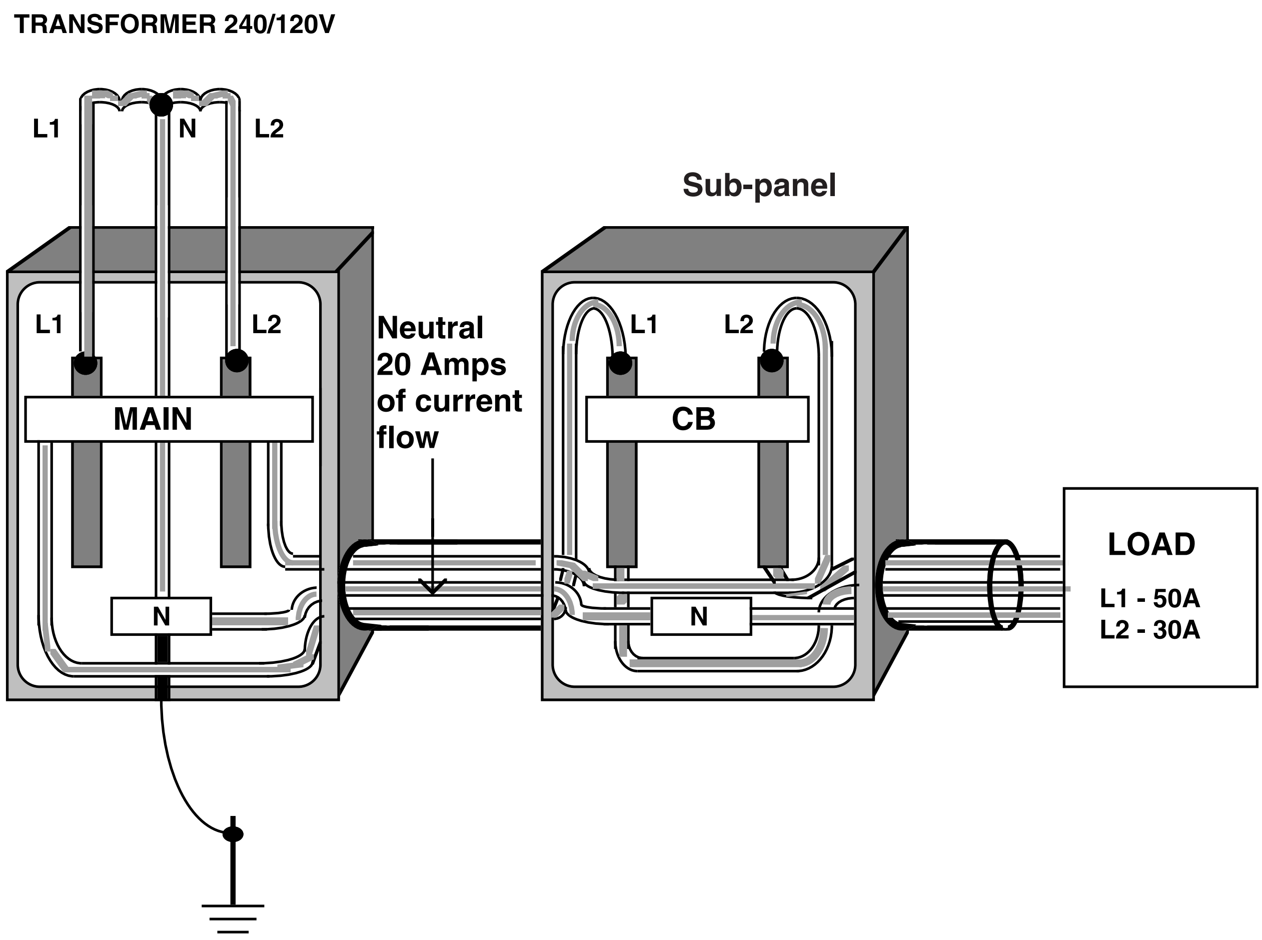
It should be emphasized that extreme care should always be exercised to maintain the integrity of the **equipment grounding** path. Failure to maintain this grounding path of least resistance may lead to a shock hazard for people, destruction of equipment due to arcing, and a fire hazard to property.

System grounding means that the service neutral conductor, grounding electrode conductor, service entrance equipment, and all metallic pipes, must be **bonded** together at the **service**. The **equipment grounding conductor** or raceway is bonded to the neutral and grounding electrode conductor at the neutral block in the **service equipment panel only.**

The number one **violation** of grounding is the bonding of the grounded neutral at sub-panels and other locations throughout the electrical system.

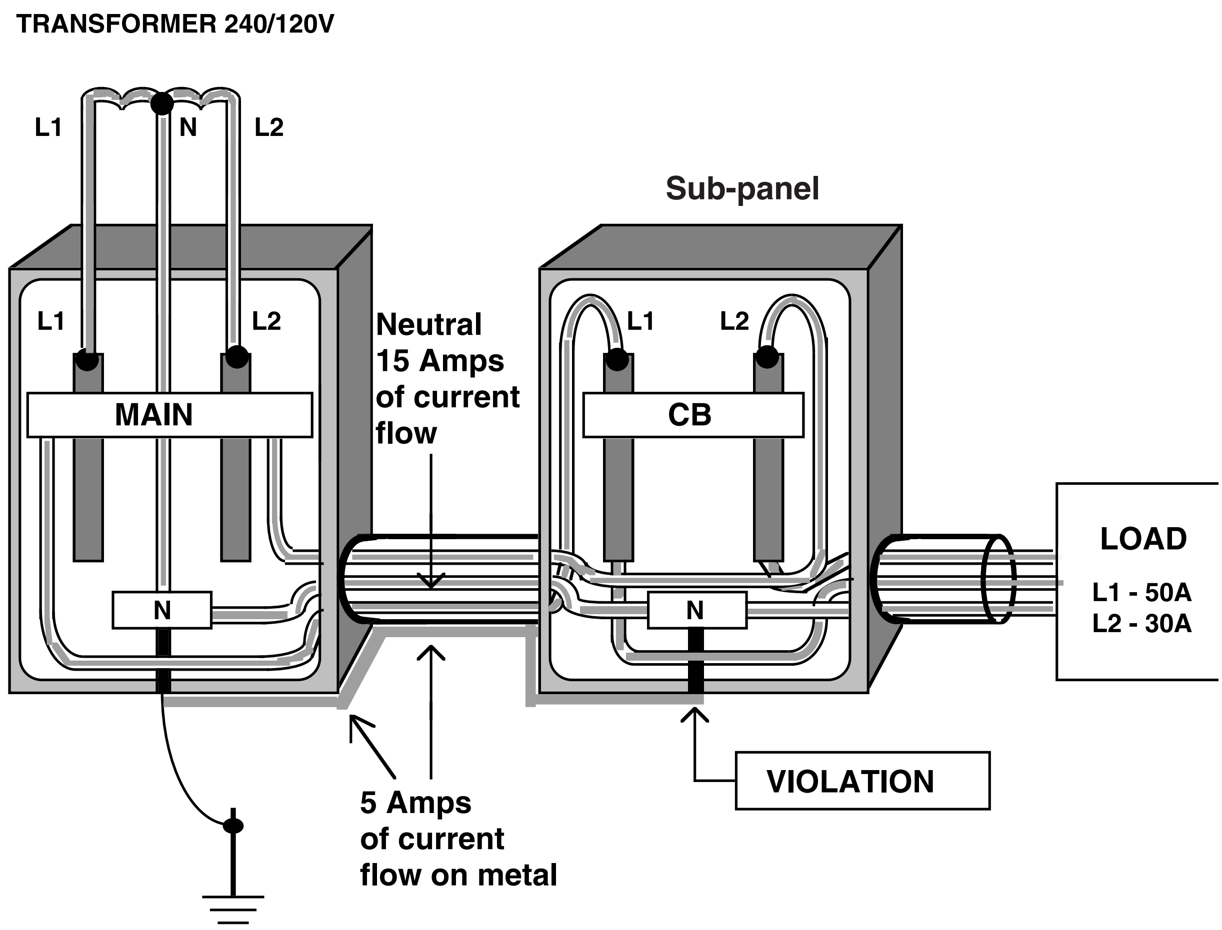
The main bonding jumper in the service equipment panel may be a wire, bus, screw or similar connector. Generally, installing the **bonding screw** through the neutral block to the service panel is the most common main bonding jumper used.

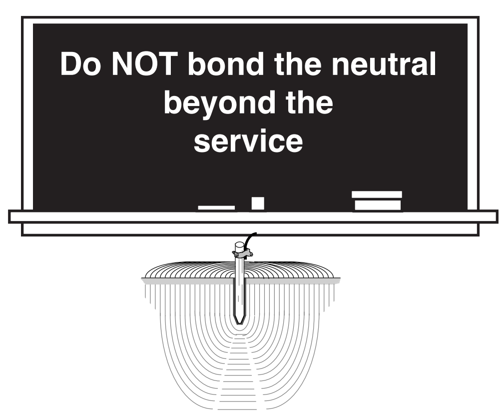
The sketch below shows the neutral bus in the service panel properly **bonded** to the panel and electrode. The sub-panel has the neutral bus isolated from the panel. This is the correct procedure. L1 has a load of 50 amps, L2 a load of 30 amps. The neutral will carry the **unbalance** of 20 amperes.



The sketch below shows a common **violation** of bonding. The neutral bus in the sub-panel is bonded to the panel. When the neutral is bonded beyond the service, it puts the neutral and the conduit in a parallel path, both carrying current. Some current flows in the neutral conductor and some current flows over the metal conduit and panel. The resistance of the conduit is approximately three times greater than the neutral conductor, this allows 1/4 of the current (5 amps) to flow over the conduit with 15 amps flowing in the neutral conductor.

This is a **VIOLATION.** No current except ground-fault current is permitted to flow through metallic equipment.



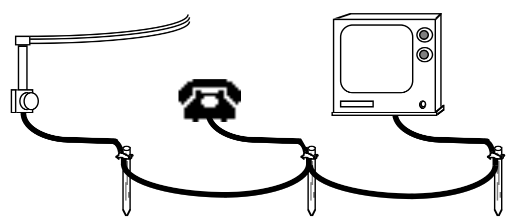


PART III Grounding Electrode System and Grounding Electrode Conductor

250.50. If available on the premises at each building or structure served, each item in 250.52(A)(1) through (A)(7) shall be bonded together to form the grounding electrode system. Where none of these electrodes are available, one or more of the electrodes specified in 250.52(A4) through (A8) shall be installed and used.

Interior water piping over 5' away from the building entrance is **no longer** permitted to serve as the grounding electrode.

All electrodes on the premises **shall be bonded together**. This is an often violated section of the Code by telephone and cable TV installers who insist on having a separate isolated ground rod to eliminate interference noise. They can have their own separate electrode, but **all** electrodes shall bond together forming the grounding electrode system. If separate electrodes on a premises are **not** bonded together, there is a potential difference between each electrode creating a possible hazard.

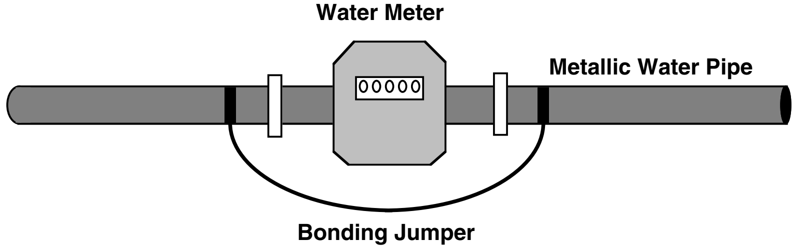


The **unspliced** grounding electrode conductor shall be permitted to run to any convenient grounding electrode available. It shall be sized from Table 250.66.

The grounding electrode conductor can be spliced by means of irreversible compression-type connectors or by exothermic welding.

250.52(A)(1). Metal underground water pipe in direct **contact with earth** for 10 feet or more and electrically continuous is an acceptable electrode.

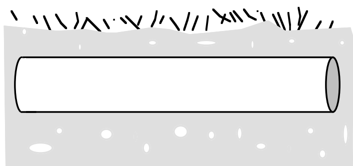
All water meters, filtering devices, and similar equipment must have a bonding jumper to keep the ground path electrically continuous. The bonding jumper must be long enough to permit removal of the water meter without interrupting the continuity of the grounding path.



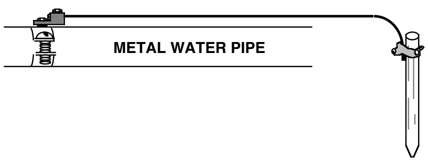
The underground water pipe at one time was considered to be the best grounding electrode for a system. Today with the use of PVC being installed in existing metal piping systems, the continuity of the grounding path is lost. Now the Code requires the underground metal water pipe to be **supplemented** by an additional electrode. The metal water pipe went from being the best electrode to it's the **only** electrode that requires a supplement electrode.

If the supplement electrode is a **rod, pipe or plate,** the portion of the bonding jumper from the water pipe to the ground rod is not required to be larger than a #6 copper or a #4 aluminum. As we learned in Chapter 5, a ground rod has only the capacity to dissipate into earth the electrons that a #6 copper conductor can carry at a given time. There is little benefit in running a larger conductor to the ground rod, because the ground itself is limiting resistance to earth.

UNDERGROUND WATER PIPE



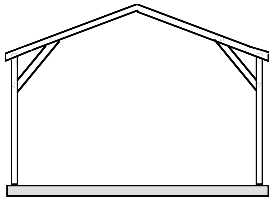
#6 copper maximum required



250.52(A)(2). Metal In-ground Support Structure(s). One or more metal in-ground support structure(s) in direct contact with earth vertically for 10 feet or more, with or without concrete encasement. If multiple metal in-ground support structures are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Metal in-ground support structures include, but are not limited to, pilings, casings, and other structural metal.

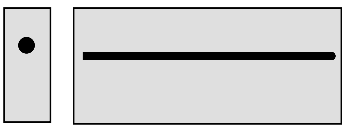
METAL FRAME OF A BUILDING



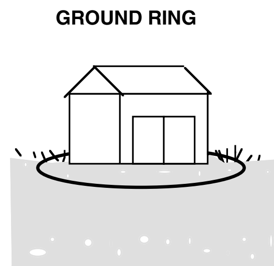
The metal frame of a building is considered an electrode when it is **effectively** grounded.

250.52(A)(3). One or more bare or zinc galvanized, or other electrically conductive coated steel rebars not less than 1/2" diameter and 20 feet in length, or a minimum #4 bare copper conductor 20 feet in length encased by at least 2" of concrete located near the bottom of the footing that is **in contact** with earth (no plastic sheeting or gravel between concrete and earth) is a **very good electrode** as we learned in Chapter 5.

CONCRETE-ENCASED ELECTRODE



250.52(A)(4). A minimum #2 bare copper at least 20 feet in length can be used as a ground ring when in direct contact with earth, encircling the building at a depth of not less than 2 1/2 feet.



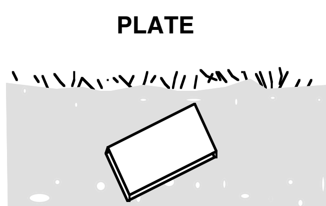
250.52(A)(5). Ground rod and pipe electrodes shall be at least 8 feet in length.

(a) Pipe or conduit electrodes shall be at least 3/4" trade size and coated with galvanize for corrosion protection where made of iron or steel.

(b) Rod-type grounding electrodes of stainless steel and copper or zinc coated steel shall be at least 5/8" in diameter, unless listed.

250.52(A)(6). Other listed grounding electrodes shall be permitted.

250.52(A)(7). Plate electrodes made of bare or conductively coated iron or steel shall be at least 1/4" thick. Electrodes of solid, uncoated nonferrous metal (copper or brass) are required to be at least .06" in thickness. Each plate electrode shall expose at least 2 square feet of surface to earth. A plate 12" x 12" would have 2 square feet exposed to earth when buried. The top and bottom of the 12" plate would be making contact with earth; this is 2 square feet.



250.52(A)(8). Other metal underground piping systems or underground tanks can be used.