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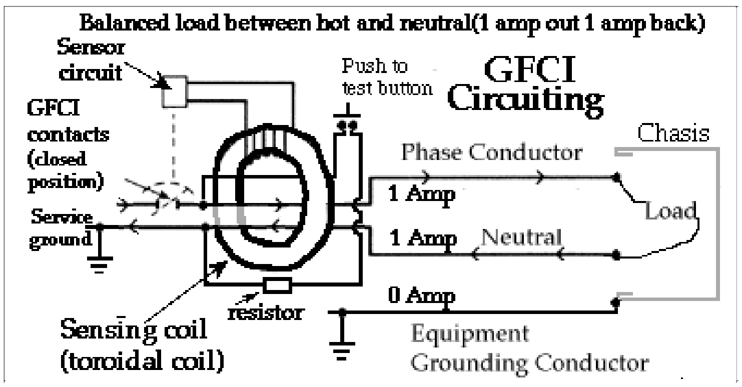
G.F.C.I. by Sam Goldwasser

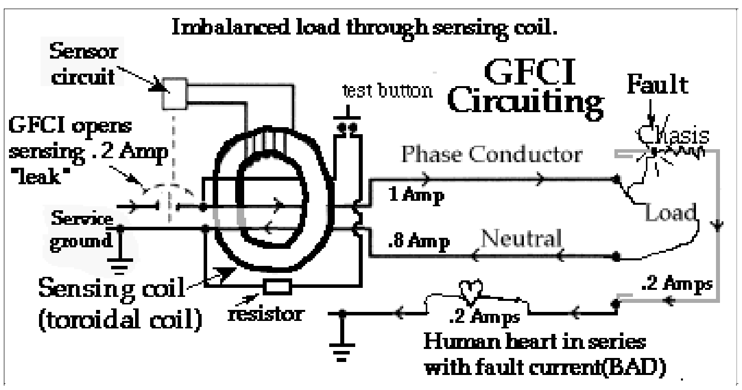
-- exerpts from: Sci.Electronics.Repair FAQ:http://www.repairfaq.org/

What is a GFCI?:

A Ground Fault Circuit Interrupter (GFCI) is a device to protect against electric shock should someone come in contact with a live (Hot) wire and a path to ground which would result in a current through his/her body. The GFCI operates by sensing the difference between the currents in the Hot and Neutral conductors. Under normal conditions, these should be equal. However, if someone touches the Hot and a Ground such as a plumbing fixture or they are standing in water, these currents will not be equal as the path is to Ground - a ground fault - and not to the Neutral. This might occur if a short circuit developed inside an ungrounded appliance or if someone was working on a live circuit and accidentally touched a live wire.



The GFCI will trip in a fraction of a second at currents (a few mA) well below those that are considered dangerous. Note that a GFCI is NOT a substitute for a fuse or circuit breaker as these devices are still required to protect equipment and property from overloads or short circuits that can result in fire or other damage.



GFCIs can be installed in place of ordinary outlets in which case they protect that outlet as well as any downstream from it. There are also GFCIs that install in the main service panel.

Note that it may be safe and legal to install a GFCI rated at 15 A on a 20 A circuit since it will have a 20 A feed-through. Of course, the GFCI outlet itself can then only be used for appliances rated 15 A or less.

Many (if not most) GFCIs also test for a grounded neutral condition where a low resistance path exists downstream between the N and G conductors. If such a situation exists, the GFCI will trip immediately when power is applied even with nothing connected to the protected outlets.

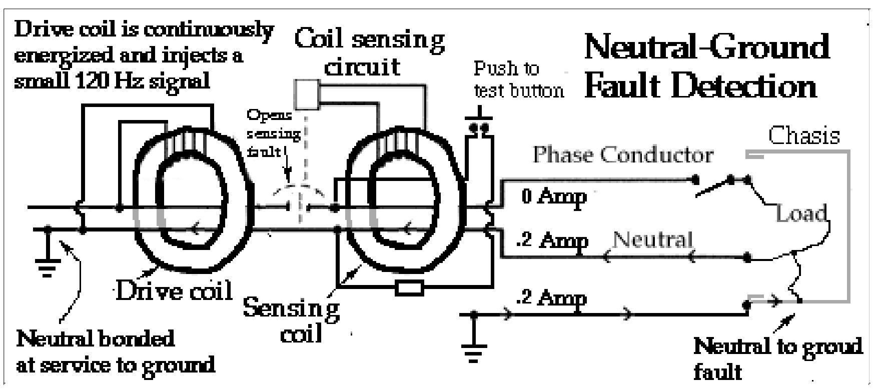
How does a GFCI work:

GFCIs typically test for the following condition:

- A **Hot to Ground**
  (safety/earth) fault. Current flows from the Hot wire to Ground bypassing the Neutral. This is the test that is most critical for safety.
- A **Grounded Neutral**
  fault. Due to miswiring or a short circuit, the N and G wires are connected by a low resistance path downstream of the GFCI. In this case, the GFCI will trip as soon as power is applied even if nothing is connected to its protected (load) circuit.

To detect a Hot to Ground fault, both current carrying wires pass through the core of a sense coil (transformer). When the currents are equal and opposite, there is no output from its multiturn sense voltage winding. When an imbalance occurs, an output signal is produced. When this exceeds a threshold, a circuit breaker inside the GFCI is tripped.

To detect a Neutral to Ground fault there is a second transformer (left toroid in the illustration below) placed upstream of the H-G sense transformer (in the illustration above). A small drive signal is injected via the 200 T winding which induces equal voltages on the H and N wires passing through its core.



- If N and G are separate downstream (as they should be), no current will be flow in either wire and the GFCI will not trip. (No current will flow in the H wire as a result of this stimulus because the voltage induced on both H and N is equal and cancels.)
- If there is a N-G short downstream, a current will flow through the N wire, to the G wire via the short, and back to the N wire via the normal connection at the service panel. Since there will be NO similar current in the H wire, this represents a current unbalance and will trip the GFCI in the same manner as the usual H-G short.
- If there is a H-H

  [Incidently, a type A GFCI will detect a "hotted hot" <G> as well as a gounded neutral. If there is a parallel path path from the load side hot back to line side hot, it will trip via the same mechanism as the load grounded neutral trip. So, a GFCI won't work on a "double ended" circuit.

  It works pretty simply when you study that circuit you pointed us to to. The second coil has as it's primary the ufiltered output of the full-wave rectifier. If a closed loop condition exists between any of the two wires going through the coil, this will induce a ~120Hz current in that closed loop. Ingenious!... "Richard G. Jones" <publius@_greenville.infi.net_>1997/08/23**]**

GFCIs for 220 VAC
applications need to monitor both Hots as well as the Neutral. The principles are basically the same: the sum of the currents in Hot1 + Hot2 + Neutral should be zero unless a fault exists.

To detect a grounded neutral fault, a separate drive coil is continuously energized and injects a small 120 Hz signal into the current carrying conductors. If a low resistance path exists between N and G downstream of the GFCI, this completes a loop (in conjunction with the normal connection between N and G at the service panel) and enough current flows to again trip the GFCI's internal circuit breaker.

GFCIs use toroidal coils (actually transformers to be mroe accurate) where the core is shaped like a ring (i.e., toroid or doughnut). These are convenient and efficient for certain applications. For all practical purposes, they are just another kind of transformer. If you look inside a GFCI, you will find a pair of toroidal transformers (one for H-N faults and the other for N-G faults as described above). They look like 1/2" diameter rings with the main current carrying conductors passing once through the center and many fine turns of wire (the sense or drive winding) wound around the toroid.

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All in all, quite clever technology. The active component in the Leviton GFCI is a single chip - probably a National Semiconductor LM1851 Ground Fault Interrupter. For more info, check out the specs at National'a web site at: http://www.national.com/pf/LM/LM1851.html. or go to illustration 1851

GFCIs and safety ground:

Despite the fact that a Ground Fault Circuit Interrupter (GFCI) may be installed in a 2 wire circuit, the GFCI does not create a safety ground. In fact, shorting between the Hot and Ground holes in the GFCI outlet will do absolutely nothing if the GFCI is not connected to a grounded circuit (at least for the typical GFCI made by Leviton sold at hardware stores and home centers). It will trip only if a fault occurs such that current flows to a true ground. If the original circuit did not have a safety ground, the third hole is not connected. What this means is that an appliance with a 3 prong plug can develop a short between Hot and the (supposedly) grounded case but the GFCI will not trip until someone touches the case and an earth ground (e.g., water pipe, ground from some other circuit, etc.) at the same time.

Note that even though this is acceptable by the NEC, I do not consider it desirable. Your safety now depends on the proper functioning of the GFCI which is considerable more complex and failure prone than a simple fuse or circuit breaker. Therefore, if at all possible, provide a proper Code compliant ground connection to all outlets feeding appliances with 3 wire plugs.

Testing installed GFCIs: [**More** on GFCI testing]

The built-in tester is supposed to actually introduce a small leakage current so its results should be valid. Therefore, testing a single GFCI outlet with an external widget is not really necessary except for peace-of-mind. However, such a device does come in handy for identifying and testing outlets on the same circuit that may be downstream of the GFCI.

An external tester is easy to construct - a 15 K ohm resistor between H and G will provide a 7 mA current. Wire it into a 3 prong plug and label it "GFCI Tester - 7 mA"[Caution see **GFCI testing** article. rk]. The GFCI should trip as soon as you plug the tester into a protected outlet. On a GFCI equipped for grounded neutral detection, shorting the N and G conductors together downstream of the GFCI should also cause it to trip.

I suppose you can purchase suitable low cost testers as well. Try your local home center or electrical supply distributor.

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Determining wiring of a 2-wire outlet: [**More** on GFCI testing]

Connect a wire between one prong of a neon outlet tester and a known ground - cold water pipe if copper throughout, heating system radiator, ground rod, etc.

(Experienced electricians would just hold onto the other prong of the tester rather than actually grounding it. Their body capacitance would provide enough of a return path for the Hot to cause the neon to glow dimly but you didn't hear this from me :-). Yes, they survive without damage and don't even feel anything because the current is a small fraction of a mA. DON'T try this unless you are absolutely sure you know what you are doing!)

With one prong grounded, try the other prong in the suspect outlet:

- The Hot should glow brightly and the Neutral should not light at all. This is the normal situation.
- If neither side glows, the fuse is blown, the circuit breaker is tripped, this is a switched outlet and the switch is off, or there is a wiring problem elsewhere - or your ground isn't really ground.
- If both sides glow and using the tester between the slots results in no glow, then you have an open Neutral and something else on the circuit that is on is allowing enough current to flow to light the neon tester.
- If both sides glow and using the tester between the slots results in an even brighter glow, the outlet is wired for 220 V, a dangerous violation of the NEC Code unless it is actually a 220 V approved outlet. It is unlikely you will ever see this but who knows what bozos worked on your wiring in the past!

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For a **computer**
or other 3 wire appliance, you should really install a proper 3 prong outlet wired correctly. Otherwise, any power line filters and surge suppressors will not have the safety ground (which a GFCI does NOT create). Some UPSs may get away without one but then their surge suppressor and/or line filters will not work correctly.

Some appliances like microwave ovens MUST have a proper safety ground connection for safety. This not only protects you from power line shorts to the case but also a fault which could make the case live from the high voltage of the microwave generator.

Testing for fault in branch circuit:

This may trip the breaker or blow a fuse - or trip a GFCI if so protected. The procedure below is specifically for GFCI tripping. You will need a multimeter.

- First, unplug everything from the circuit and see if it still trips. If it now does not trip, one of the appliances was the problem. Try them one at a time to see which is the problem and then check the section for that or a similar appliance elsewhere in this document.

Assuming the circuit is at fault:

- You need to determine whether this is a H-G leakage fault (which is what most people think is the only thing GFCIs test for) or a shorted G-N fault.
- A H-G fault that doesn't trip the normal breaker might be due to damp wiring (an outside outlet box that gets wet or similar) or rodent damage.
- A shorted G-N fault means that G and N are connected somewhere downstream of the GFCI - probably due to incorrect wiring practices or an actual short circuit due to frayed wiring or wires touching - damage during installation or renovation.

Assuming the line is separate from any other wiring:

- With the line disconnected from the service panel (all three wires), first test between each pair of wires with the multimeter on AC to make sure it is truly dead - there should be virtually no voltage. H-G, N-G, and H-N should all be close to 0 (say, less than a volt).
- If this passes, test across the dead line's H and G for leakage on the resistance range. It should be greater than 15 K ohms (it should really be infinity but to trip the GFCI requires around 15 K ohms or less).
- Then, test for resistance between H and G - this too should be infinity.

One of these will show a fault - possibly the N-G test indicating a short or improperly wired outlet since this would not result in any operational problems until a GFCI is installed (though it does represent a safety hazard).

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Lightning storm trips GFCIs protecting remote outdoor outlets:

"I have several outdoor 110V outlets, protected by GFCI breakers. These circuits nearly always trip when there are nearby lightening strikes. I am satisfied that there is no short circuit caused by water as :

- A lightning storm without rain will still trip the GFCI.
- Water from the sprinklers does not cause a problem.
- I can immediately reset the GFCI when it is still raining and it comes back on.

The electrical cables buried underground run for about 600 feet.

Is GFCI tripping caused by electrical storms normal ? Are my GFCI breakers too sensitive ? Is there any way to modify the circuits to avoid this?"

This doesn't surprise me. Long runs of cable will be sensitive to the EM fields created by nearby lightning strikes. Those cables probably have 3 parallel wires: H, N, G. The lightning will induce currents in all three which would normally not be a problem as long as H and N are equal. However, I can see this not being the case since there will be switches in the Hot but not the Neutral so currents could easily unbalance.

These are not power surges as such and surge suppressors will probably not help.

Since it happens with all of your GFCIs, it is not a case of a defective unit. Perhaps there are less sensitive types but then this would reduce the protection they are designed to provide.

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GFCI trips when it rains (hard):

Most likely, moisture/water is getting into some portion of the GFCI's protected wiring (at the GFCI or anywhere downstream) and the GFCI is simply doing its job. You will have to trace the wiring through all junction boxes and outlets to determine where the problem is located. Yes, I know this may not be your idea of fun!

Why a GFCI should not be used with major appliances:

A Ground Fault Circuit Interrupter is supposed to be a valuable safety device. Why not use them everywhere, even on large appliances with 3 wire plugs?

- A properly grounded 3 prong outlet provides protection for both people and the appliance should a short circuit develop between a live wireand the cabinet.
- Highly inductive loads like large motors or even fluorescent lamps or fixtures on the same circuit can cause nuisance tripping of GFCIs which needless to say is not desirable for something like a refrigerator.

Toasters and GFCIs:

The following is a reason to use GFCIs on kitchen outlets that may not be obvious:

(From: David Buxton (David.Buxton@tek.com)).

In addition to the usual explanations dealing with safety around water, another reason why kitchen outlets need a GFCI is the toaster. All too often people stick a butter knife in there to dislodge some bread. If the case was grounded there would be short from the element to the case. So toasters are two wire instead of 3-pronged. So, you must have a GFCI for any outlet that might take on a toaster.

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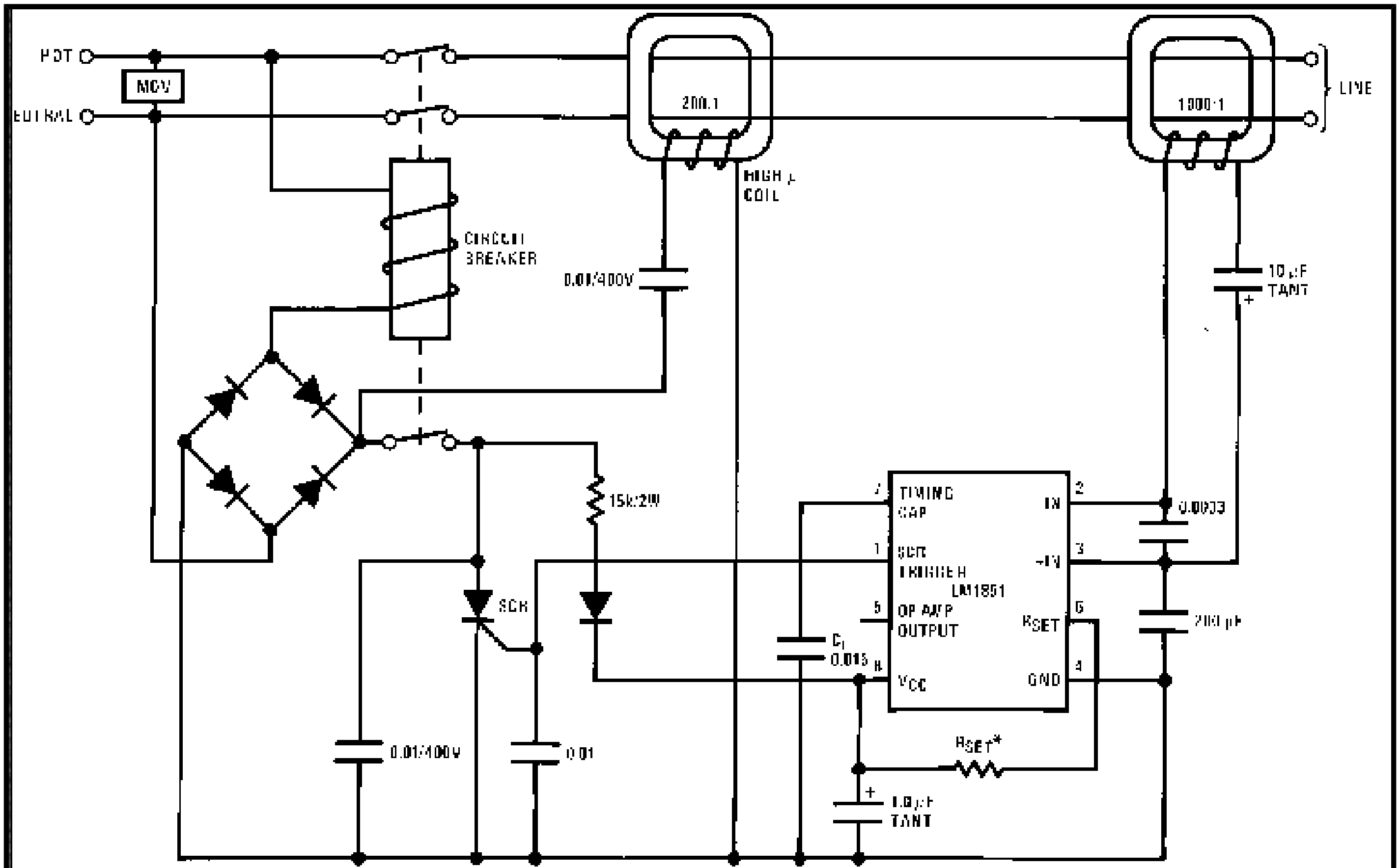
National Semiconductor LM1851



*Adjust R_{SET} for desired sensitivity

TL/H/5177–6

FIGURE 2. 120 Hz Neutral Transformer Approach