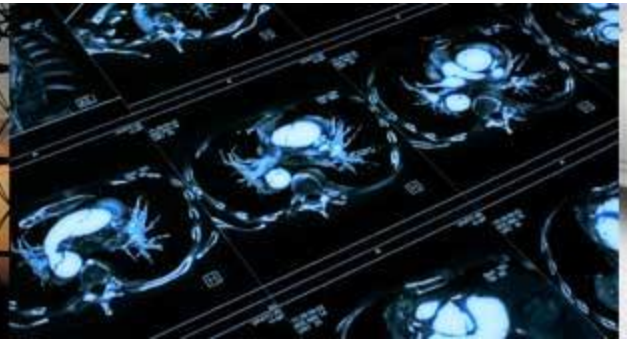
Understanding GFCIs

Developed by the NEMA 5PP Personnel Protection Technical Committee

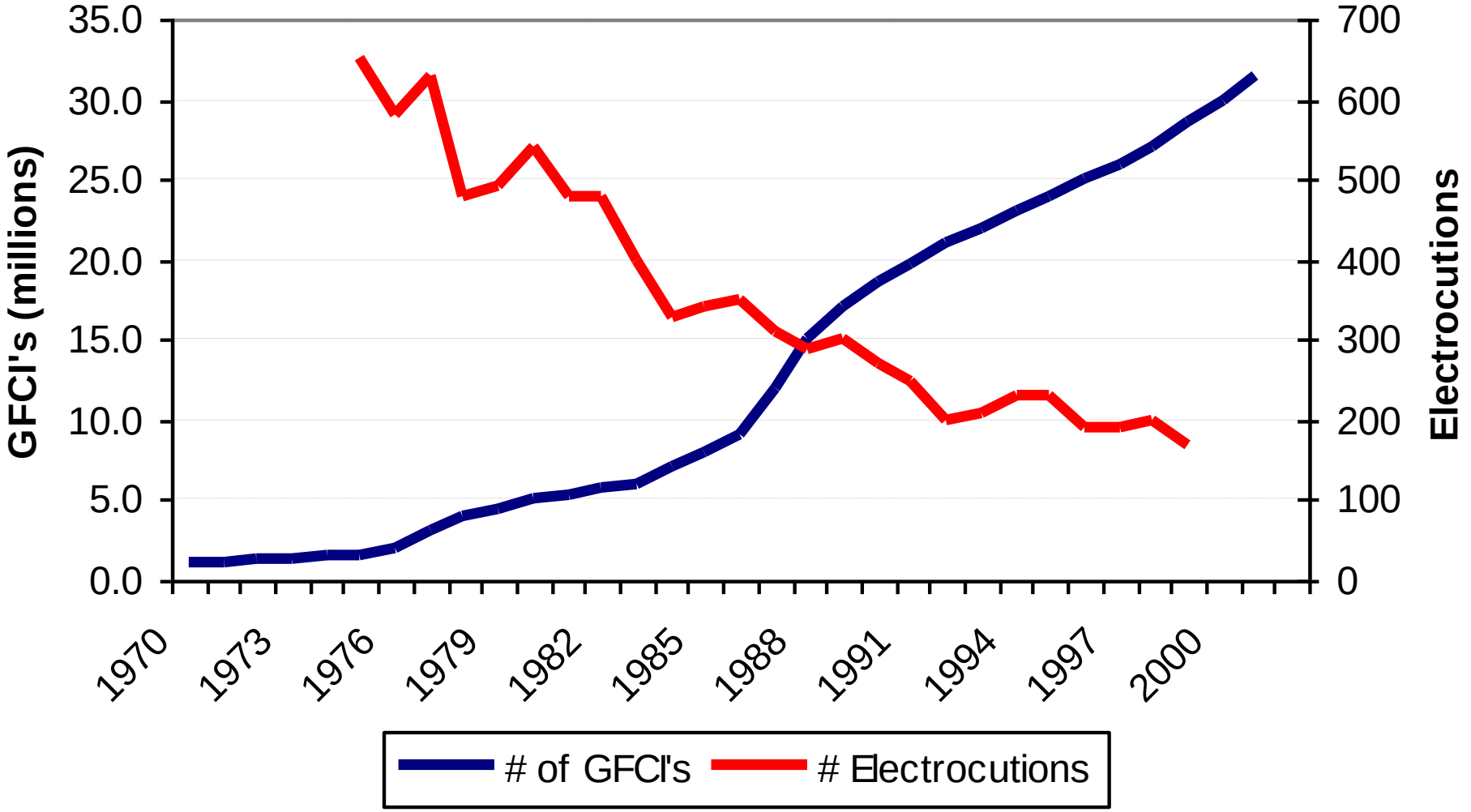
The Association of Electrical and Medical Imaging Equipment Manufacturers



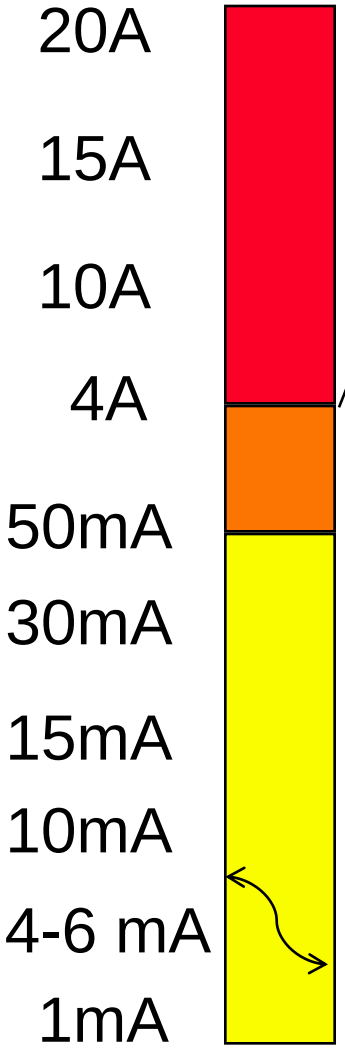
What Is to Be Covered?

- Electrical Shock - Why Have GFCIs?
- How GFCI's Operate
- Proper Installation of a GFCI
- Wiring Errors
- Grounded Neutral Detection
- Testing GFCIs

Electrocutions Associated With Consumer Products



Effects of Electric Shock



4 AMPERES AND OVER
Heart Paralysis, Serious Tissue and Organ Burning

50 mA - 4 Amps Fibrillation

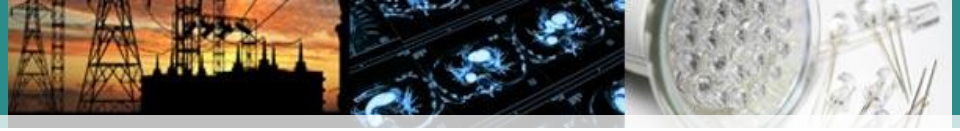
IEC RCD Standards Breathing Difficult, Fibrillation in children

Muscles “Freeze” in 50% of the Population

Let-Go Threshold

4-6 UL 943 Class A GFCI Trip Level

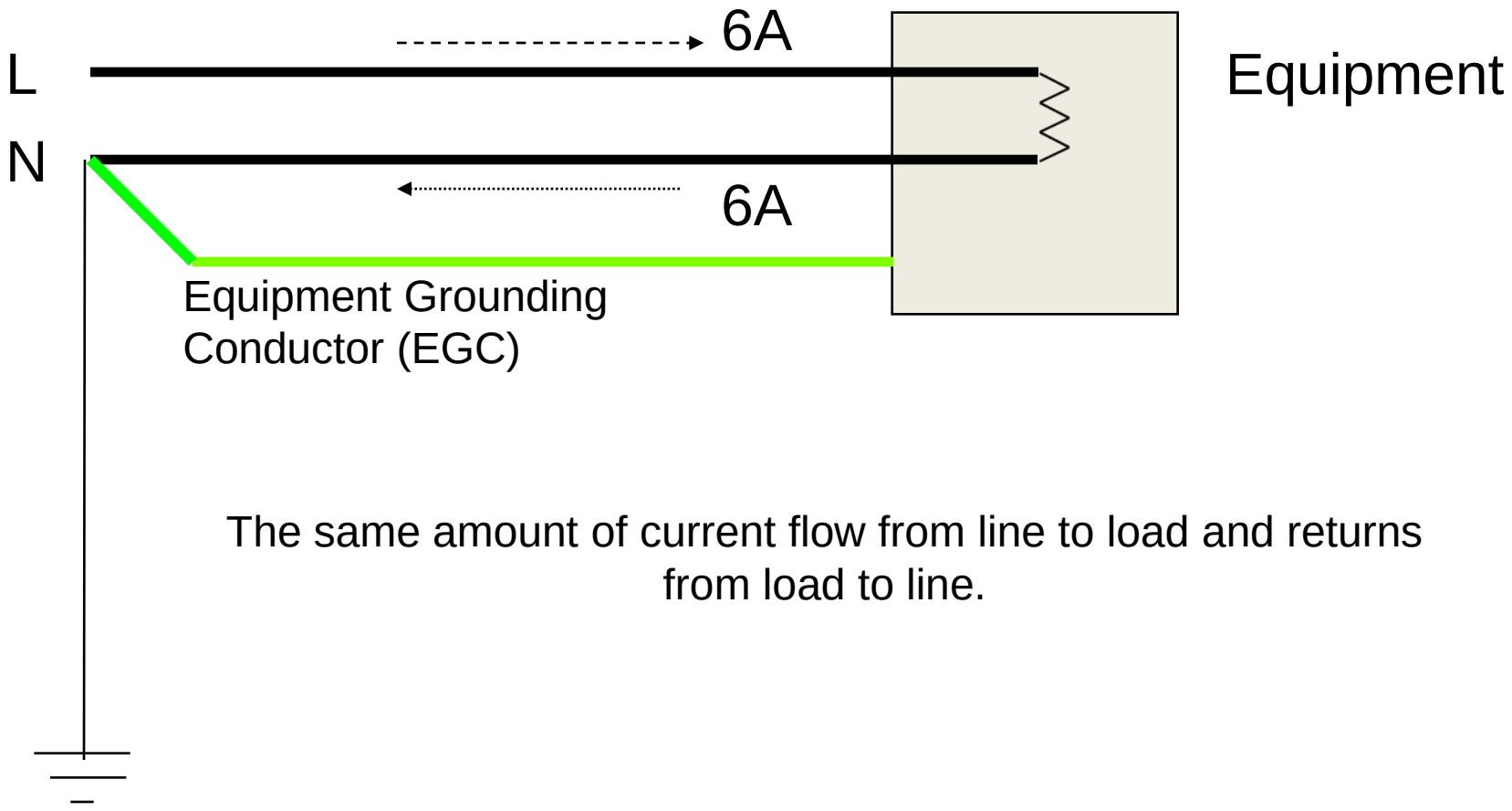
Perception Level



Electric Shock Prevention System

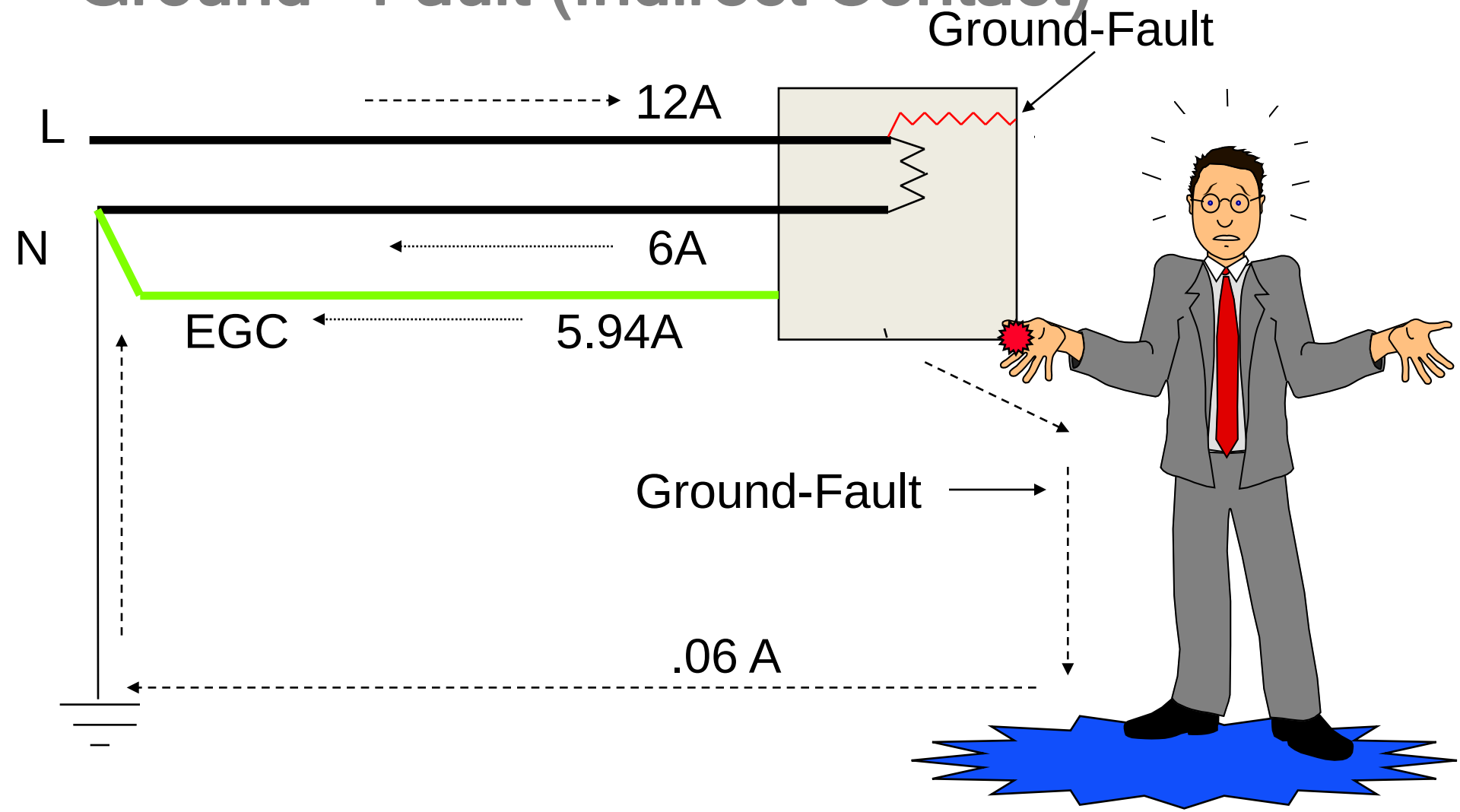
- Isolation (Physical)
- Insulation
- Double Insulation
- Equipment Grounding
- GFCI (solves shortcomings of above systems)

Normal Circuit Operation

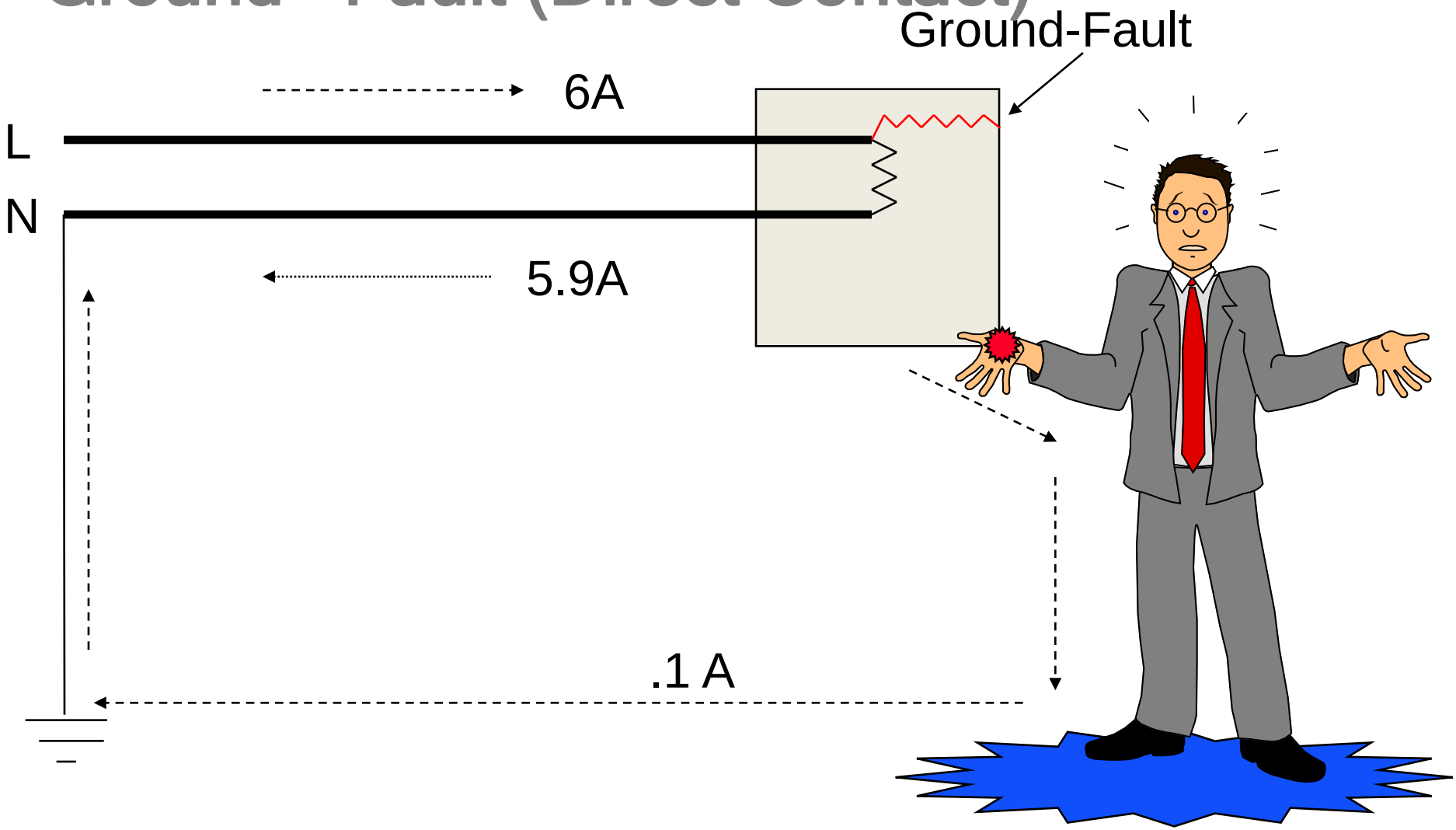


The same amount of current flow from line to load and returns from load to line.

Ground – Fault (Indirect Contact)



Ground – Fault (Direct Contact)



How GFCIs Operate

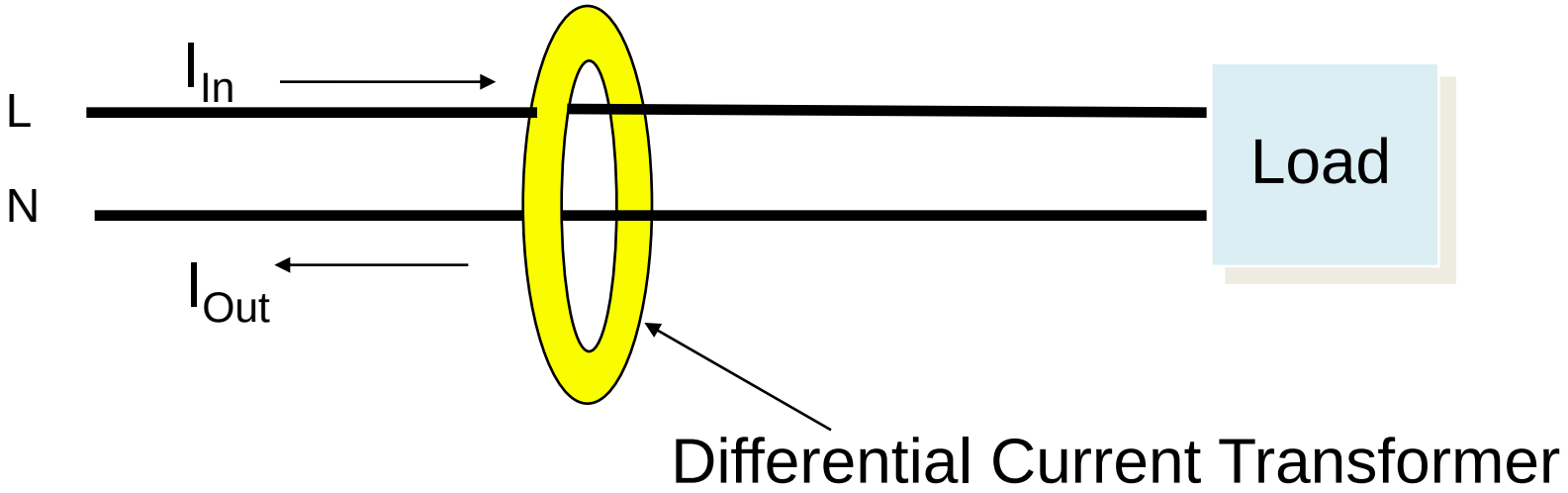
Knowing how GFCIs work will enable you to understand:

1. Why GFCIs must be installed a certain way
   - For Circuit Breaker GFCI:
     To prevent constant tripping, MUST connect Load Neutral to circuit breaker neutral terminal, NOT panelboard neutral.
   - For Receptacle GFCI:

   If line and load conductors are reversed, per 2010 edition UL 943, no power is available at:

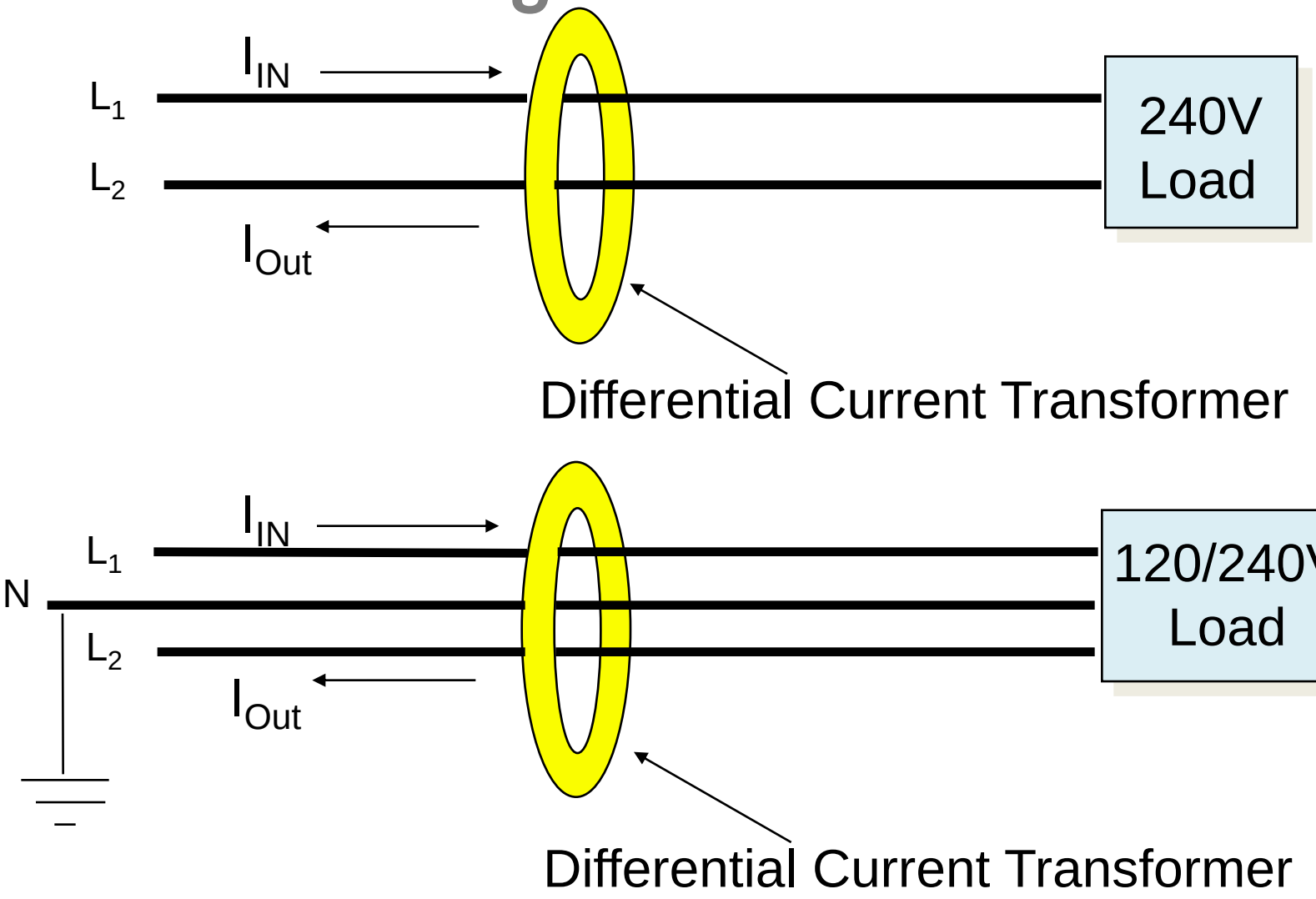
   1. Face terminals or
   2. Line terminals connected to downstream receptacles.
2. Why do GFCIs trip under various circumstances
   - Mis-wiring will cause GFCI to trip if:
     1. Ground current is flowing
     2. Neutral is grounded on load side of GFCI.
   - Portable GFCIs will trip if open neutral is present on the line side of the GFCI.
3. What conditions causes unexpected tripping
   - Ground current exceeding 6 mA when a load is applied.
   - Load neutral is not connected to correct terminals.

The Current "Adding Machine"

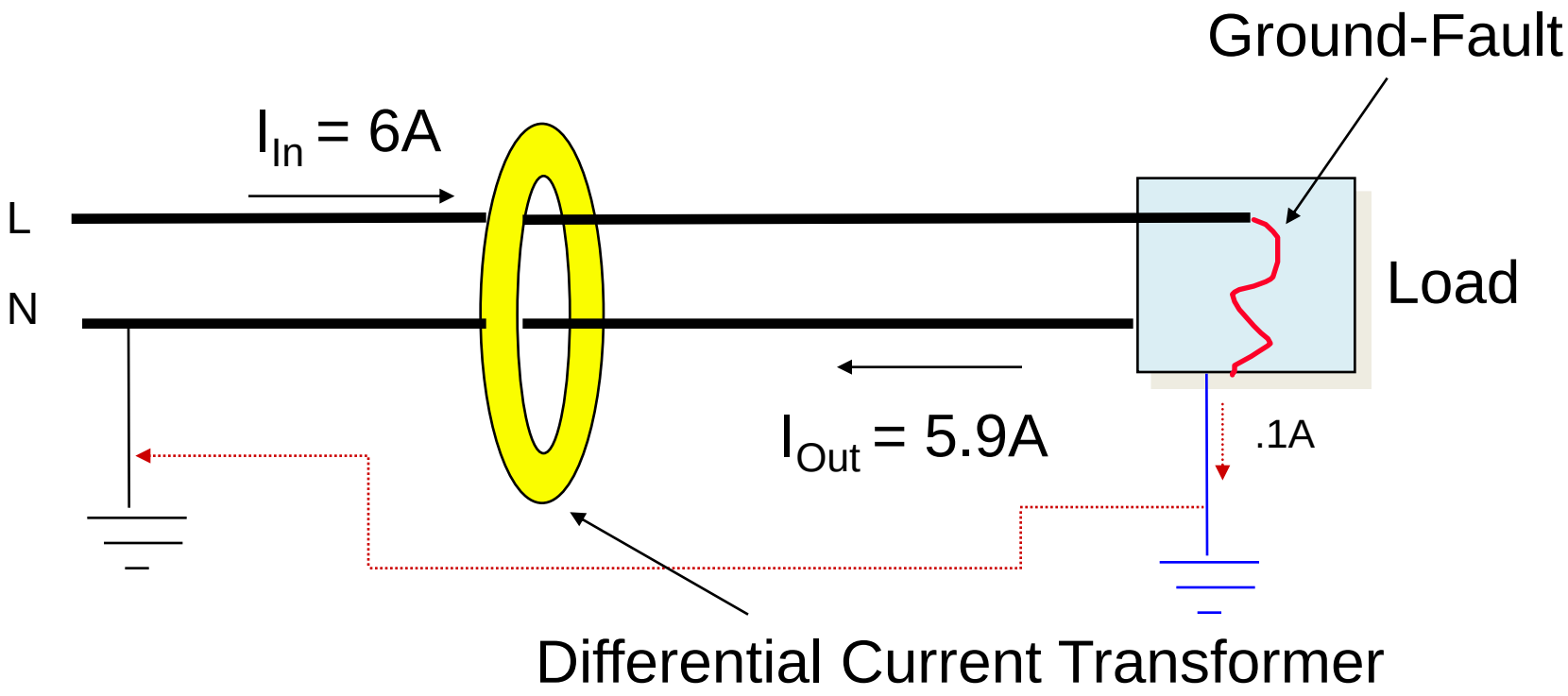


If the current out = current back, the differential current transformer shows no output.

Current "Adding Machine"



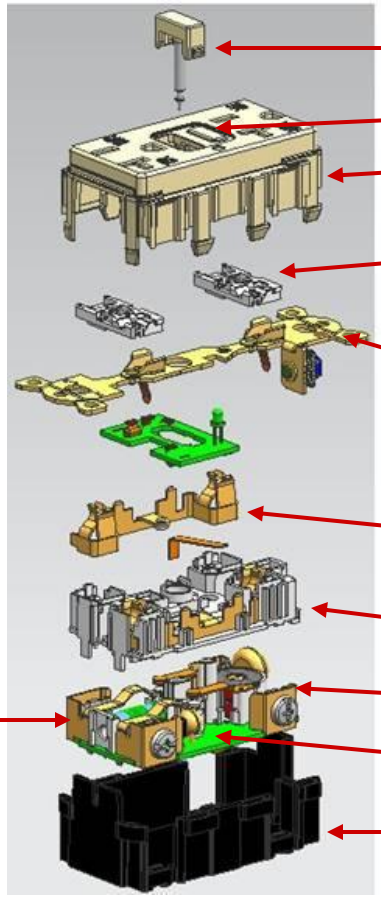
Current "Adding Machine" Under Ground Fault Conditions



If I-out does not equal I-in, the differential current transformer creates an output signal.

What's in the GFCI?

(Receptacle)



Reset Button

Test Button

Cover

Tamper Resistant Mechanism
(Optional)

Bridge

Face Contacts

Middle Barrier

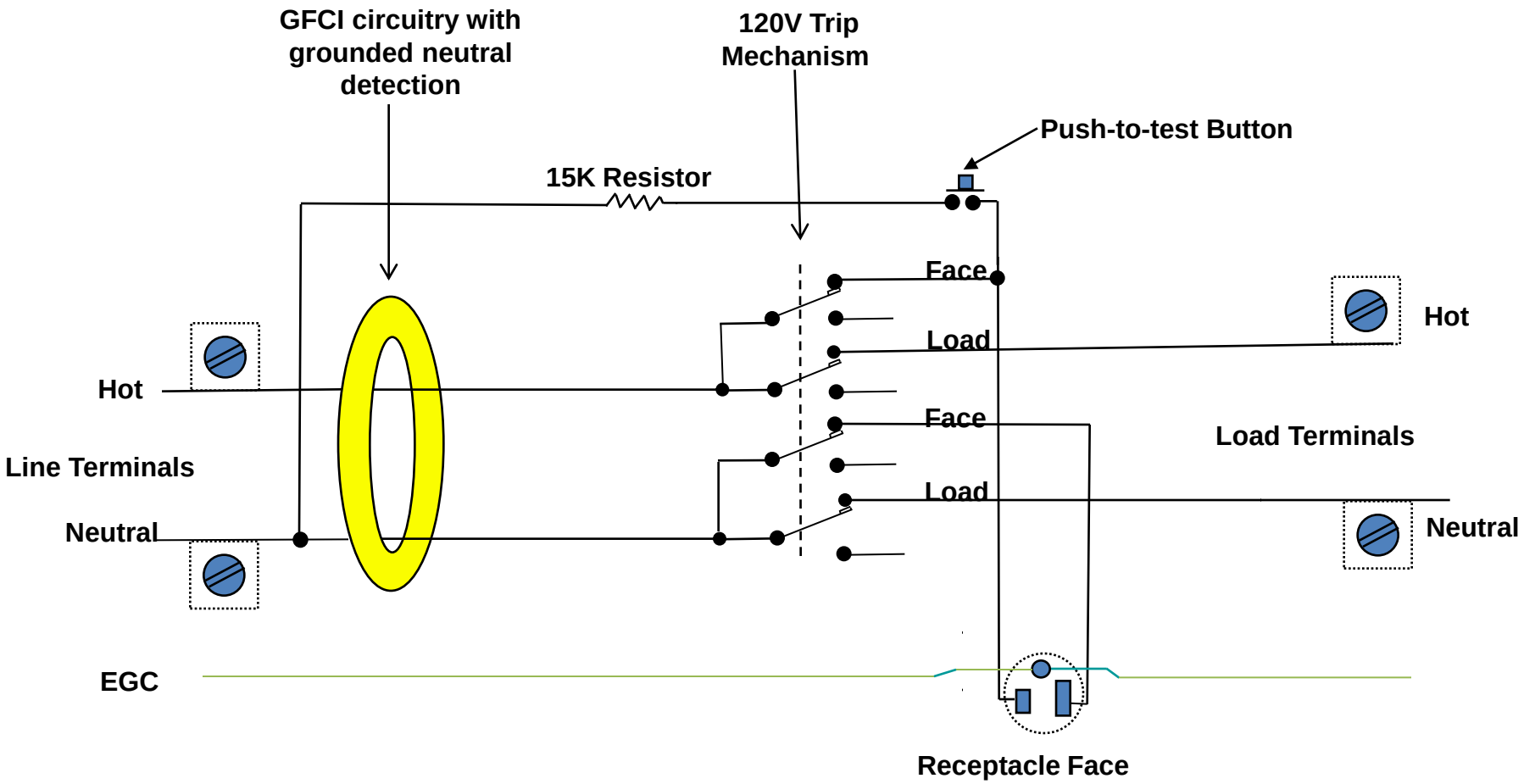
Terminals

Terminals

Printed Circuit Board

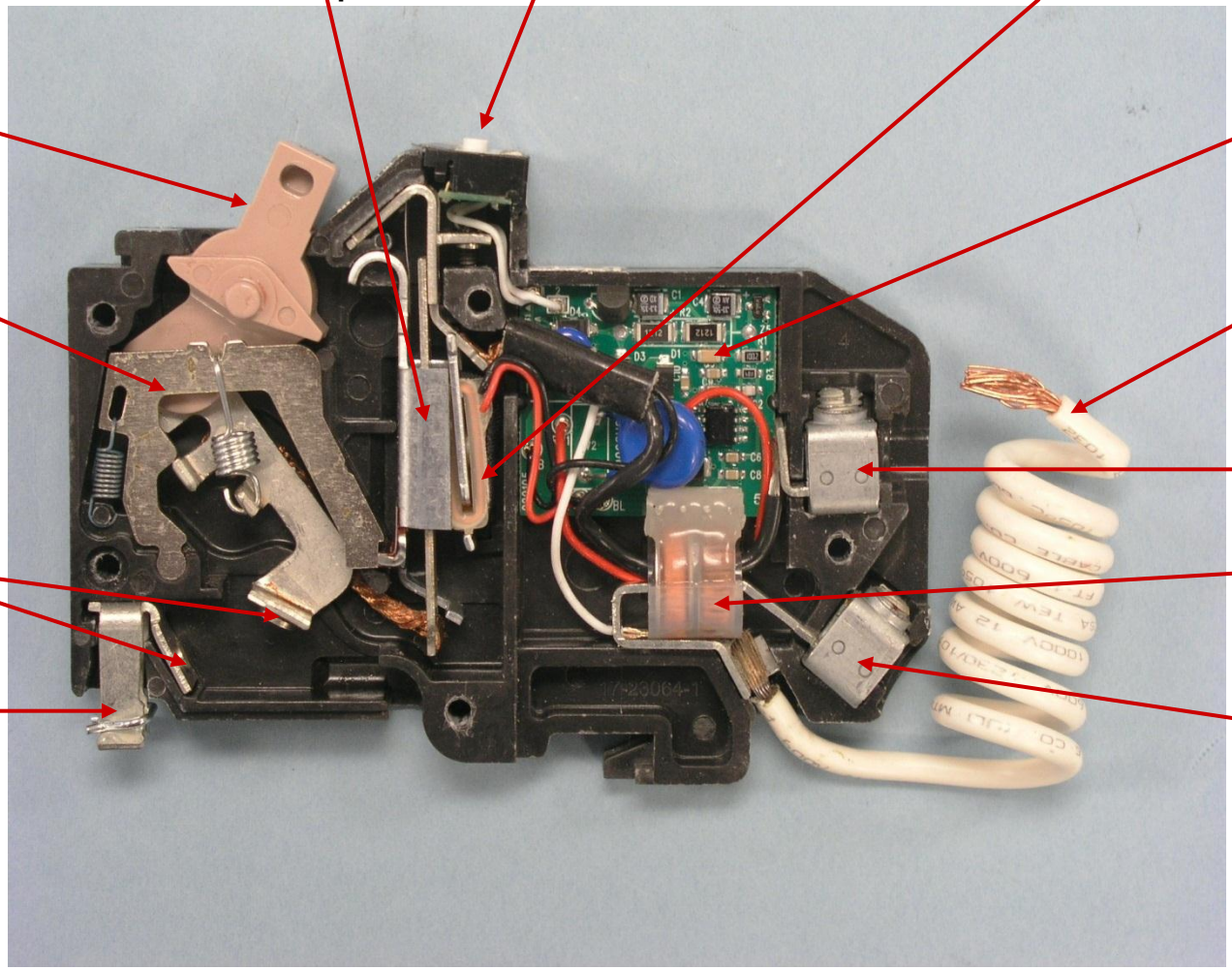
Base

What's in the GFCI?
(Receptacle)



What's in the GFCI?

(Circuit Breaker)



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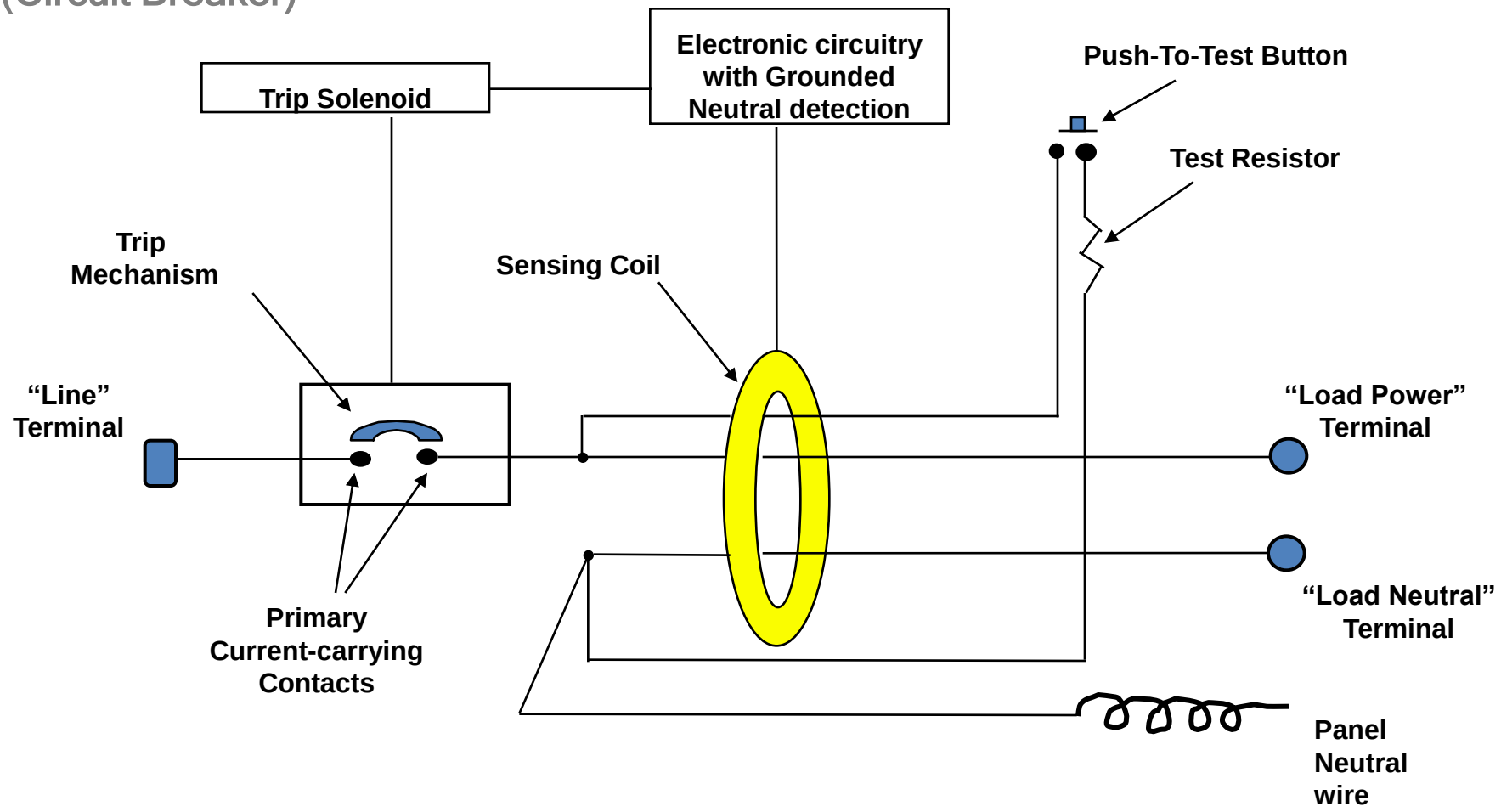
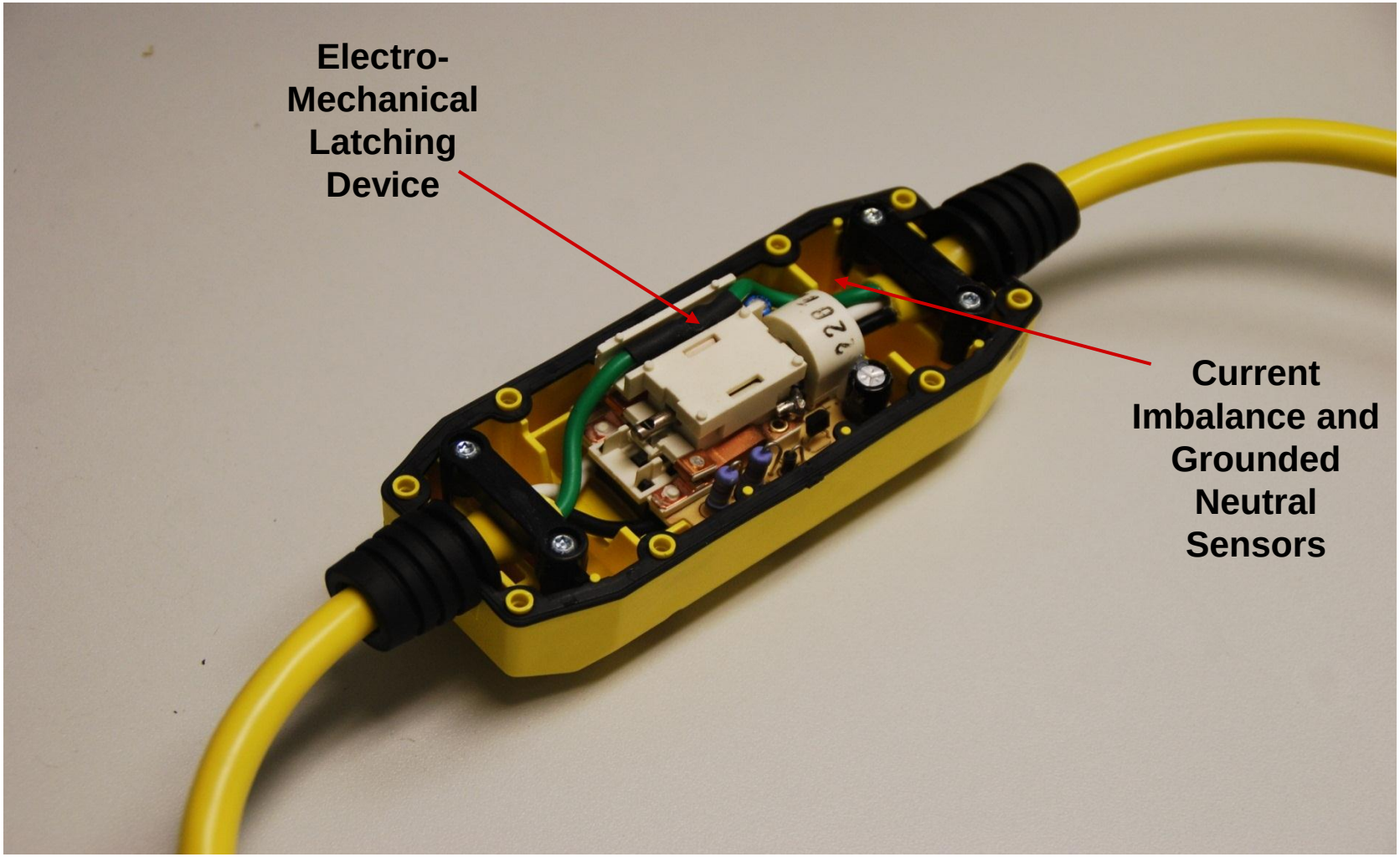


What's in the GFCI?

(Plug-in)



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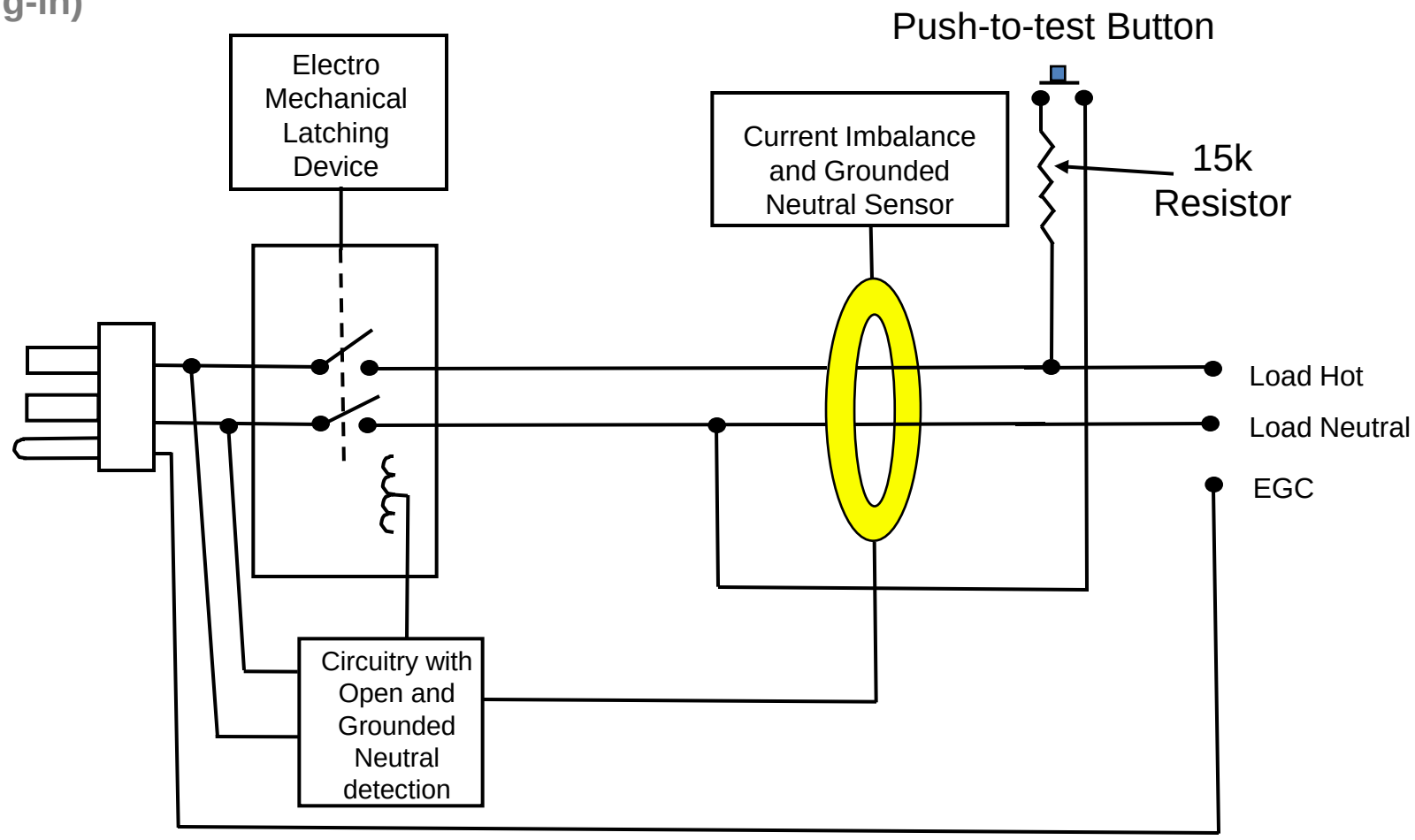
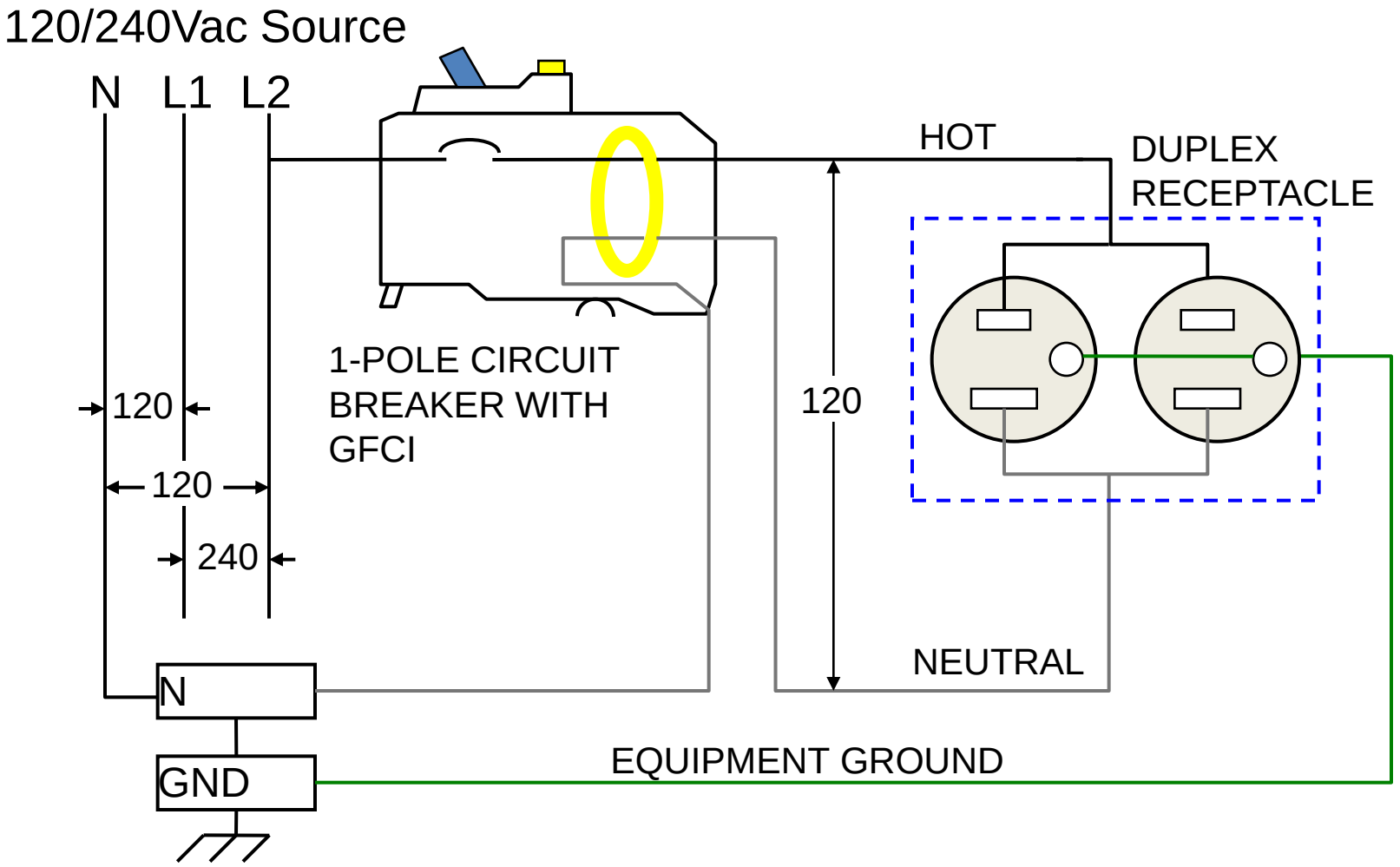


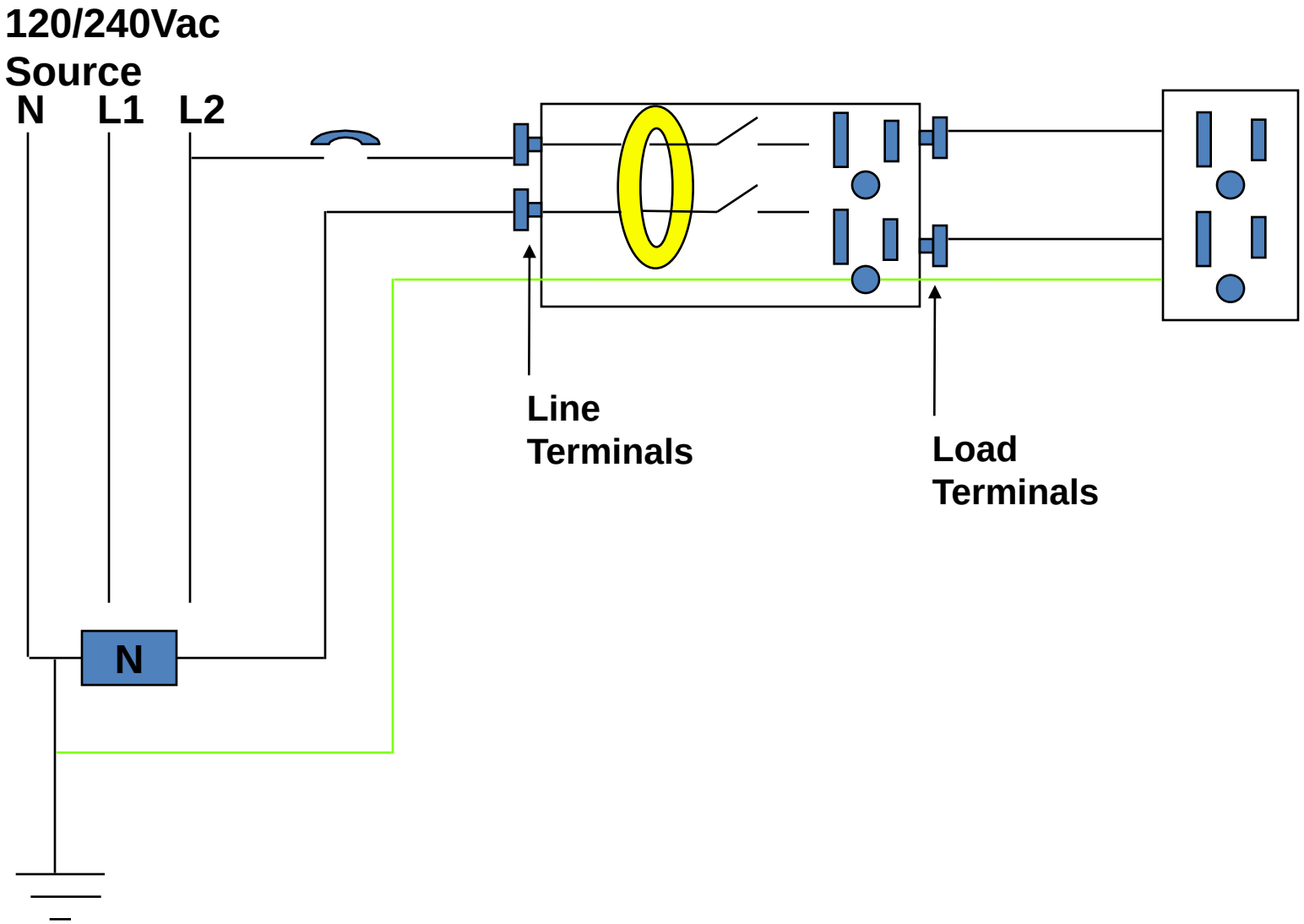
Standard 120V Connection

(GFCI Circuit Breaker)

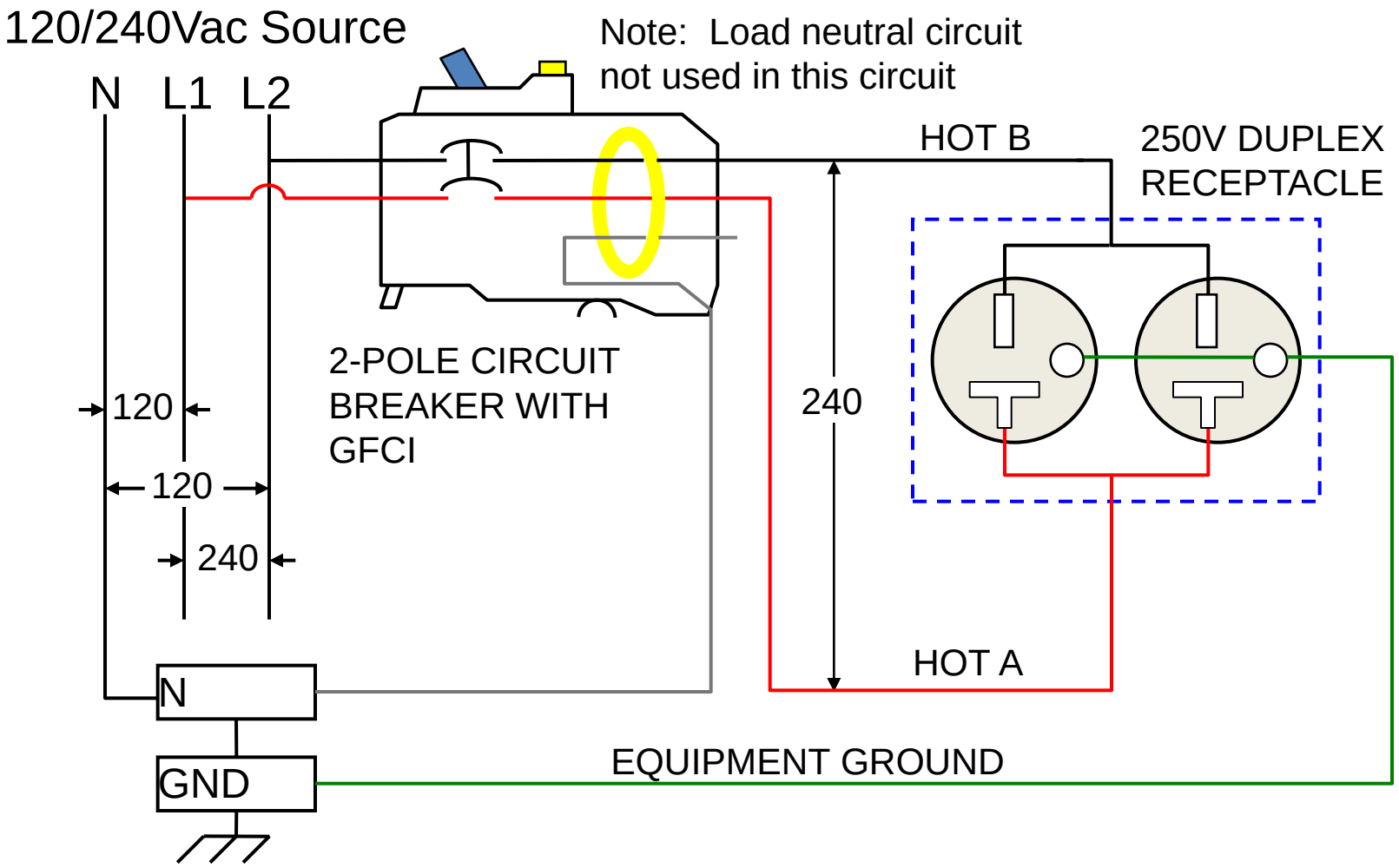


Standard 120 Volt Connection

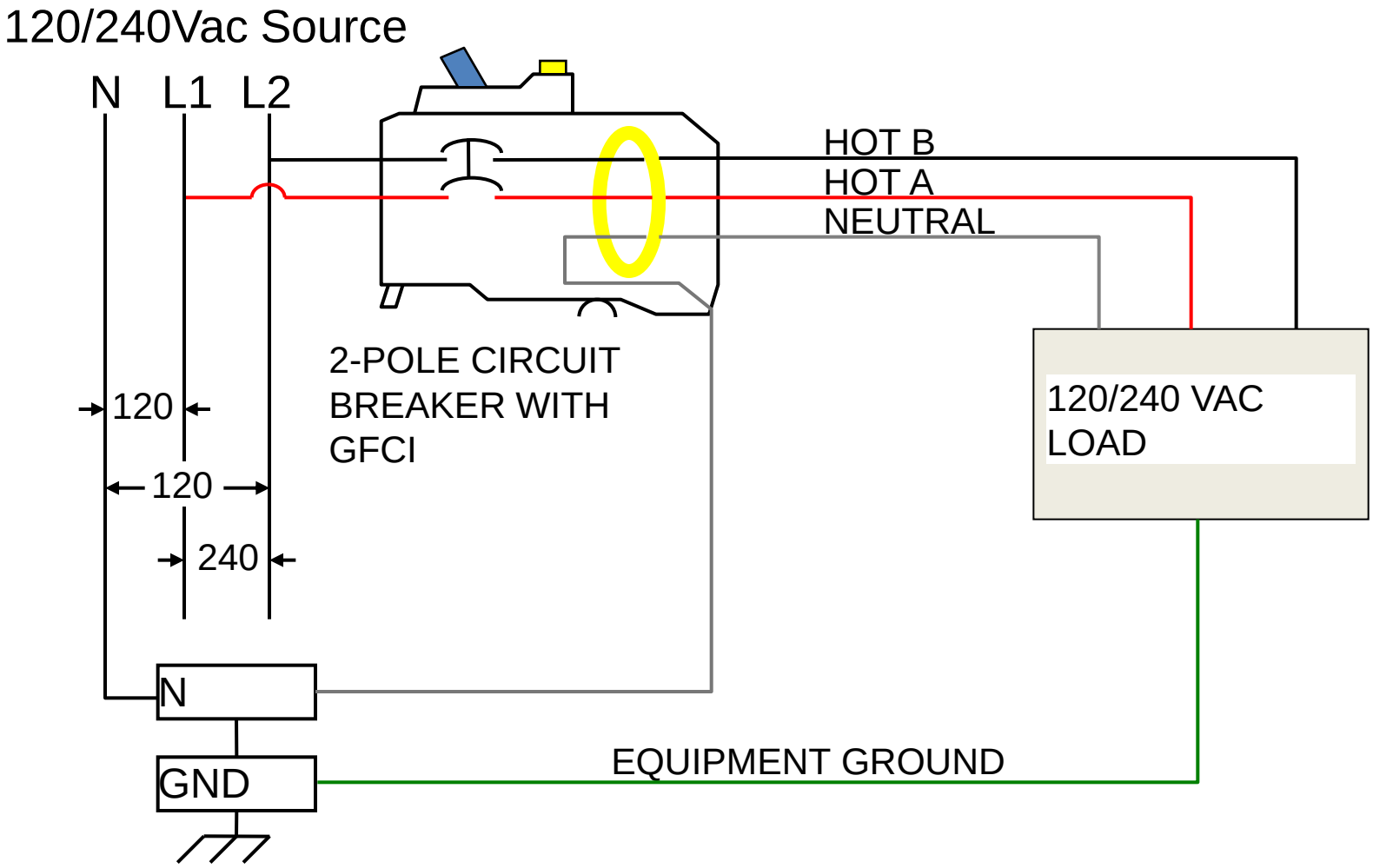
(GFCI Receptacle)



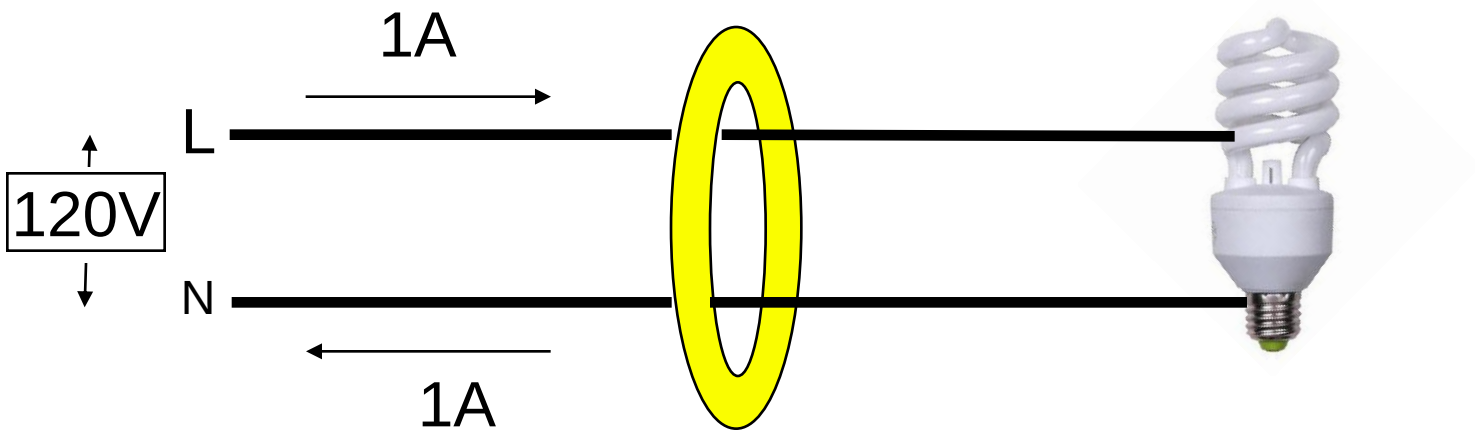
240 Volt Load – No Neutral



120/240 Volt Load

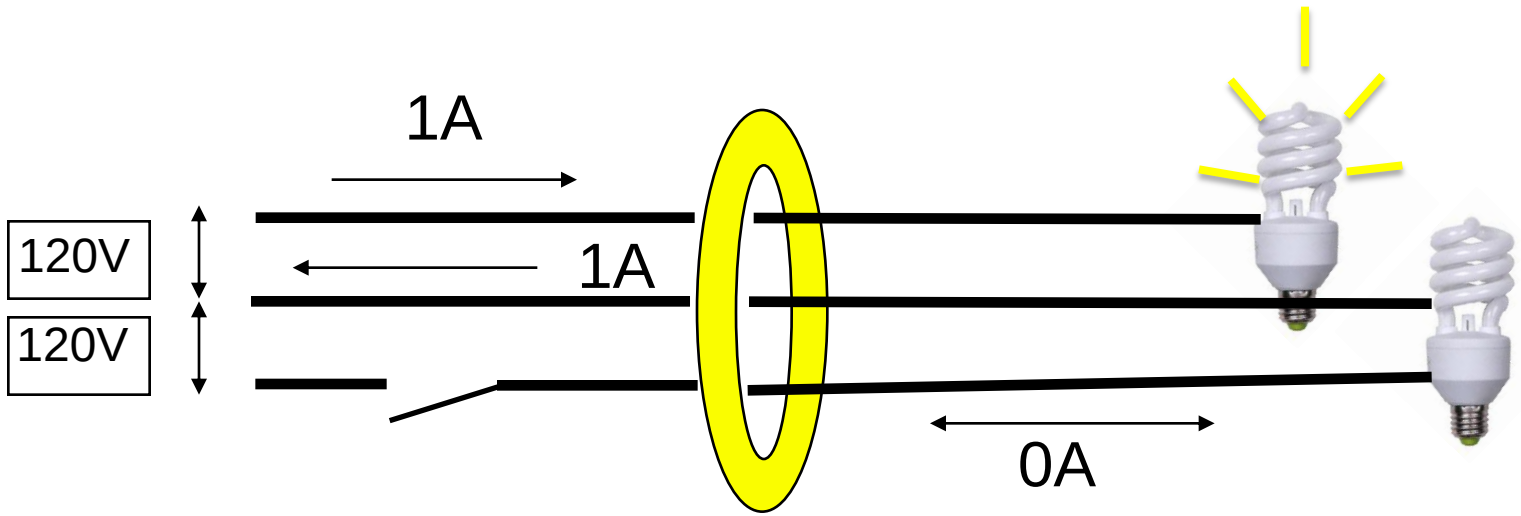


Single Phase 120V Circuit



Multi-Wire Circuits

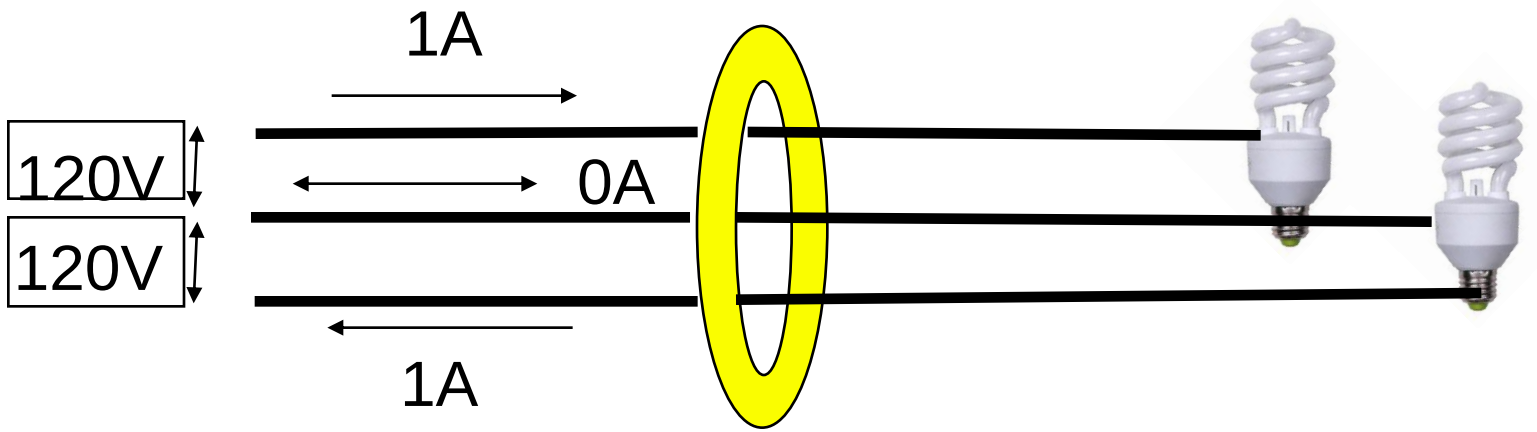
One leg of multi-wire circuit in use



Switch Open

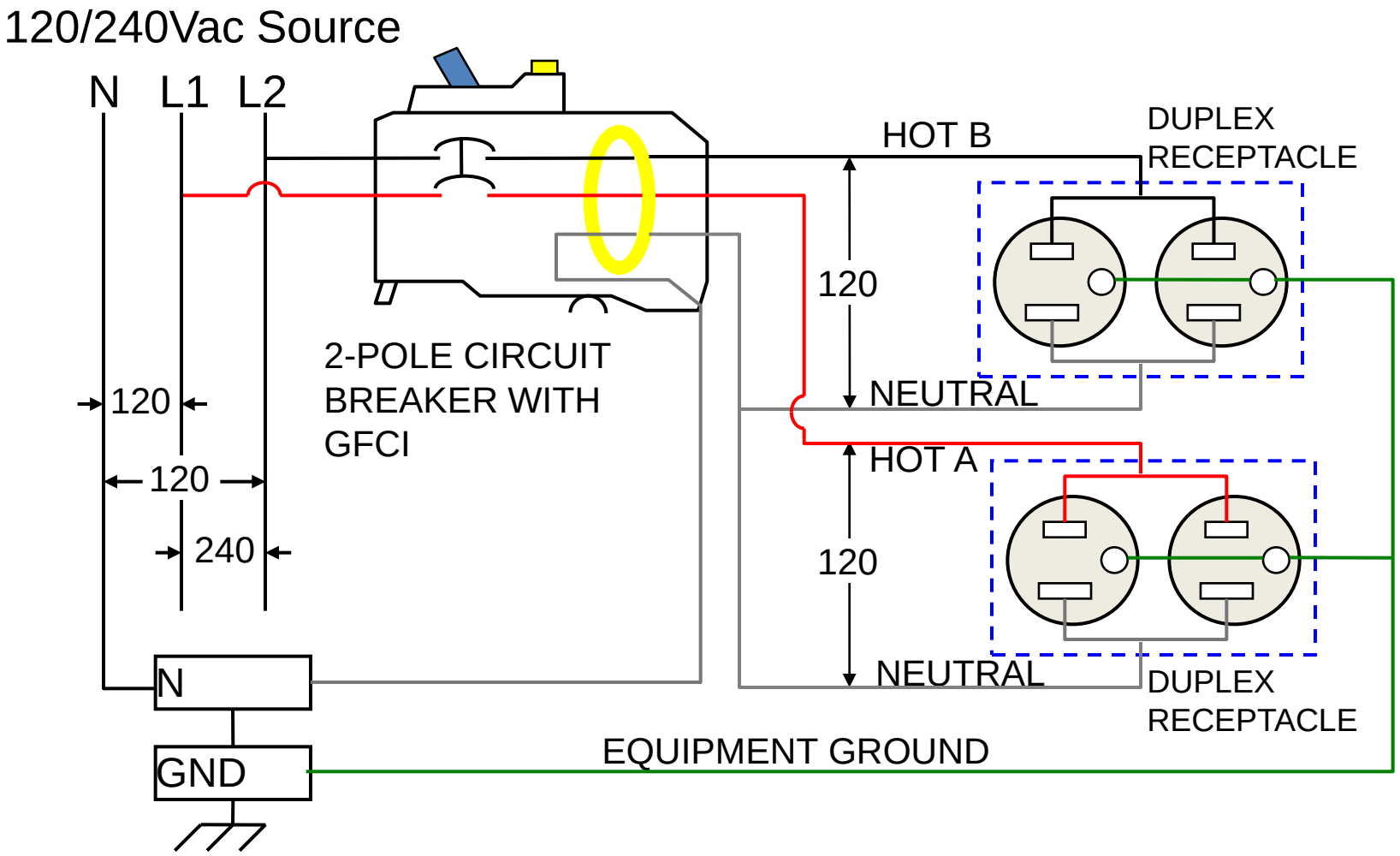
Multi-Wire Circuits

Both legs of multi-wire circuit in use

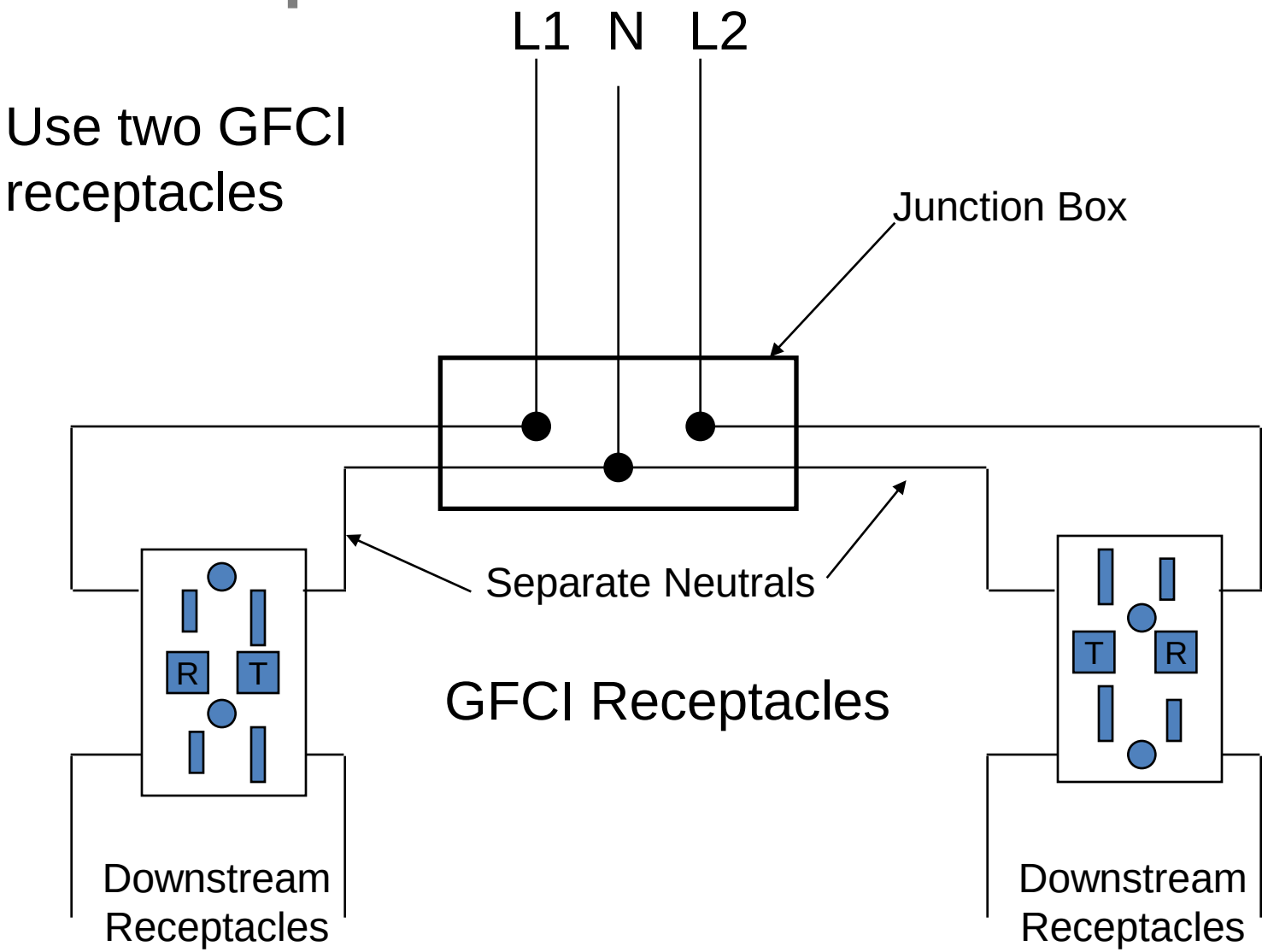


If what goes out…. Comes back.. The GFCI sees zero total current on the circuit.

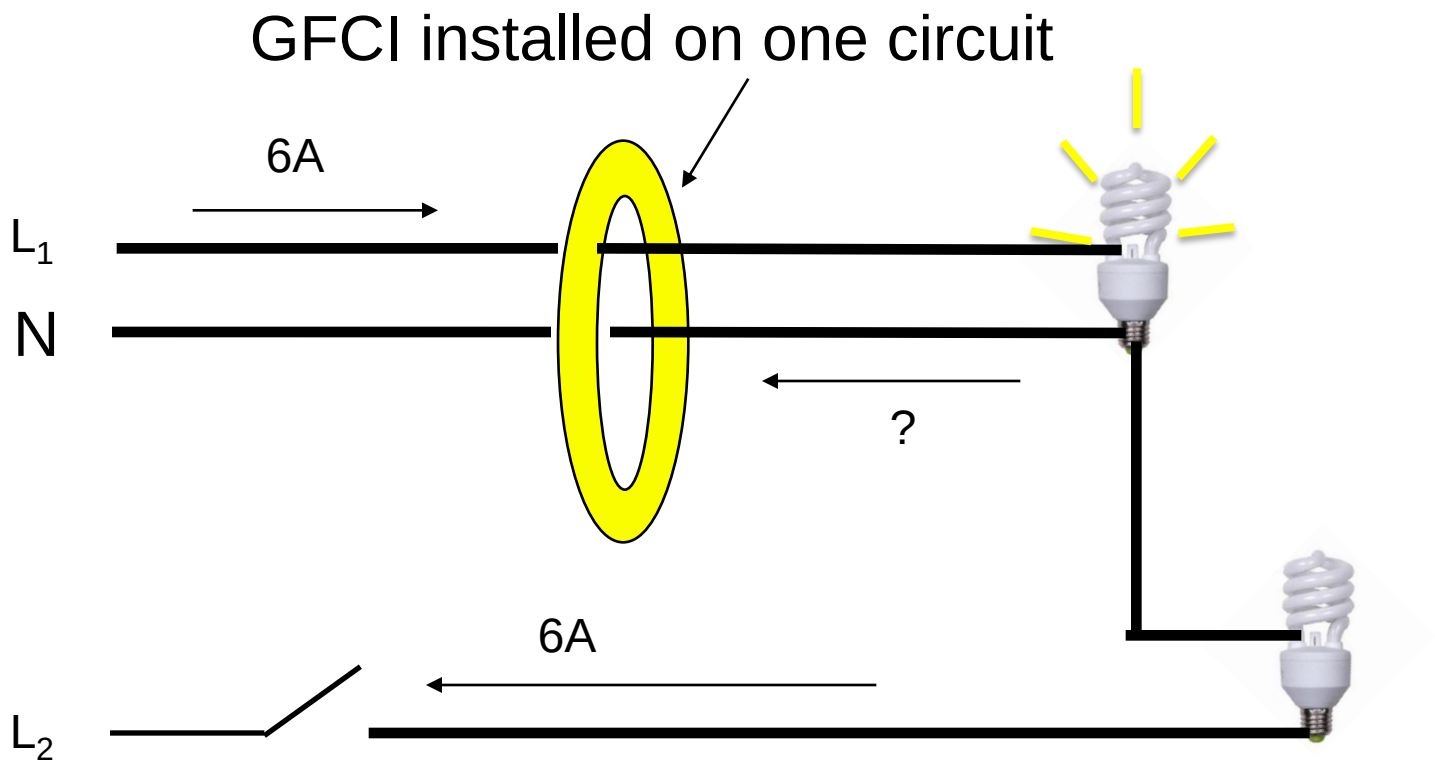
GFCI Circuit Breaker on Multi-Wire Circuits



GFCI Receptacle on Multi-Wire Circuits



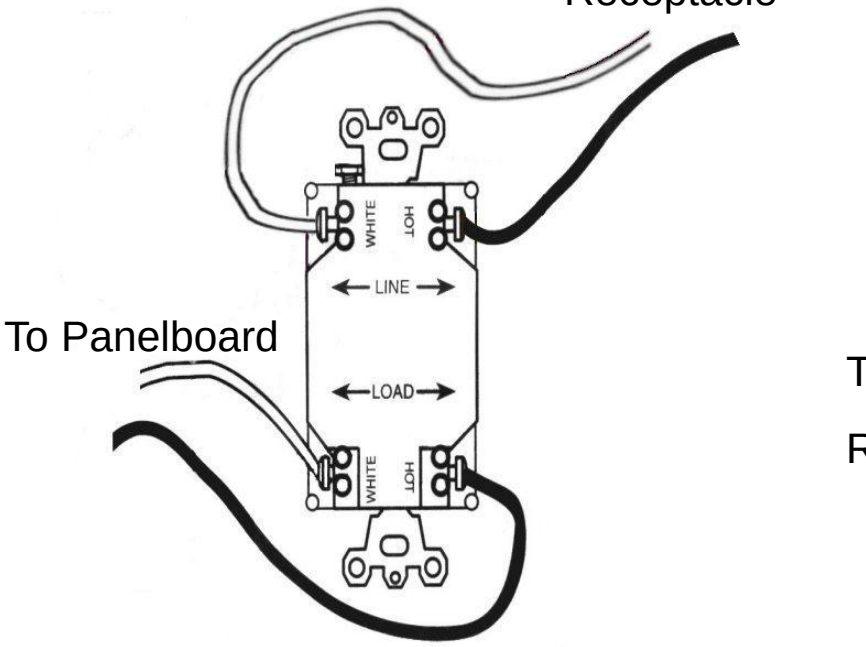
This "Old House" Problem



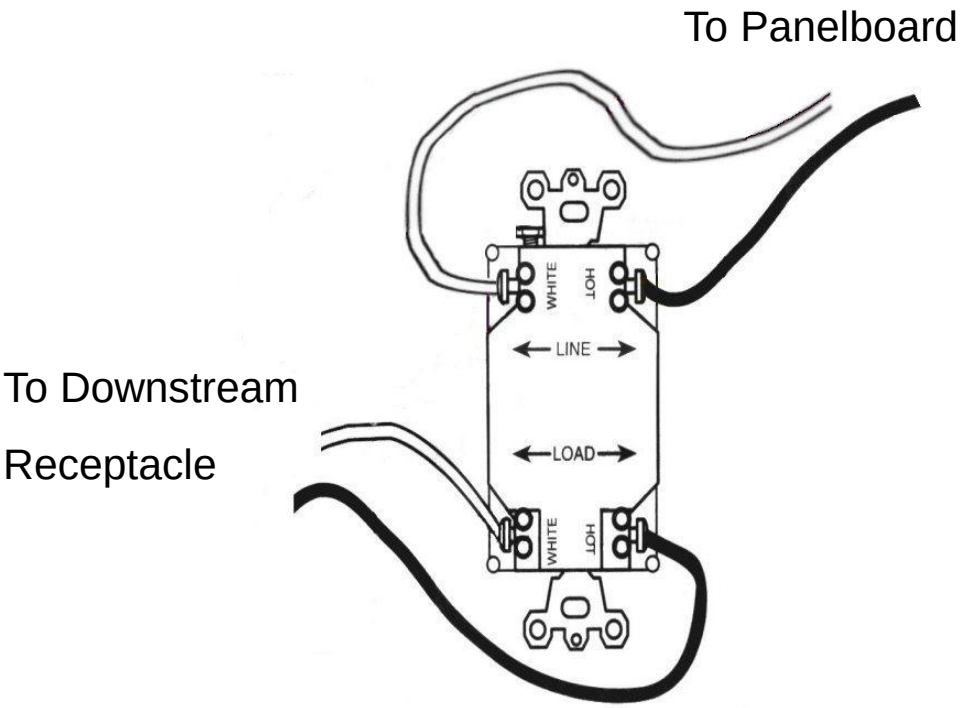
Second circuit installed and neutral "stolen" from a close-by circuit

Line and Load Reversal on Receptacles

Incorrect Wiring

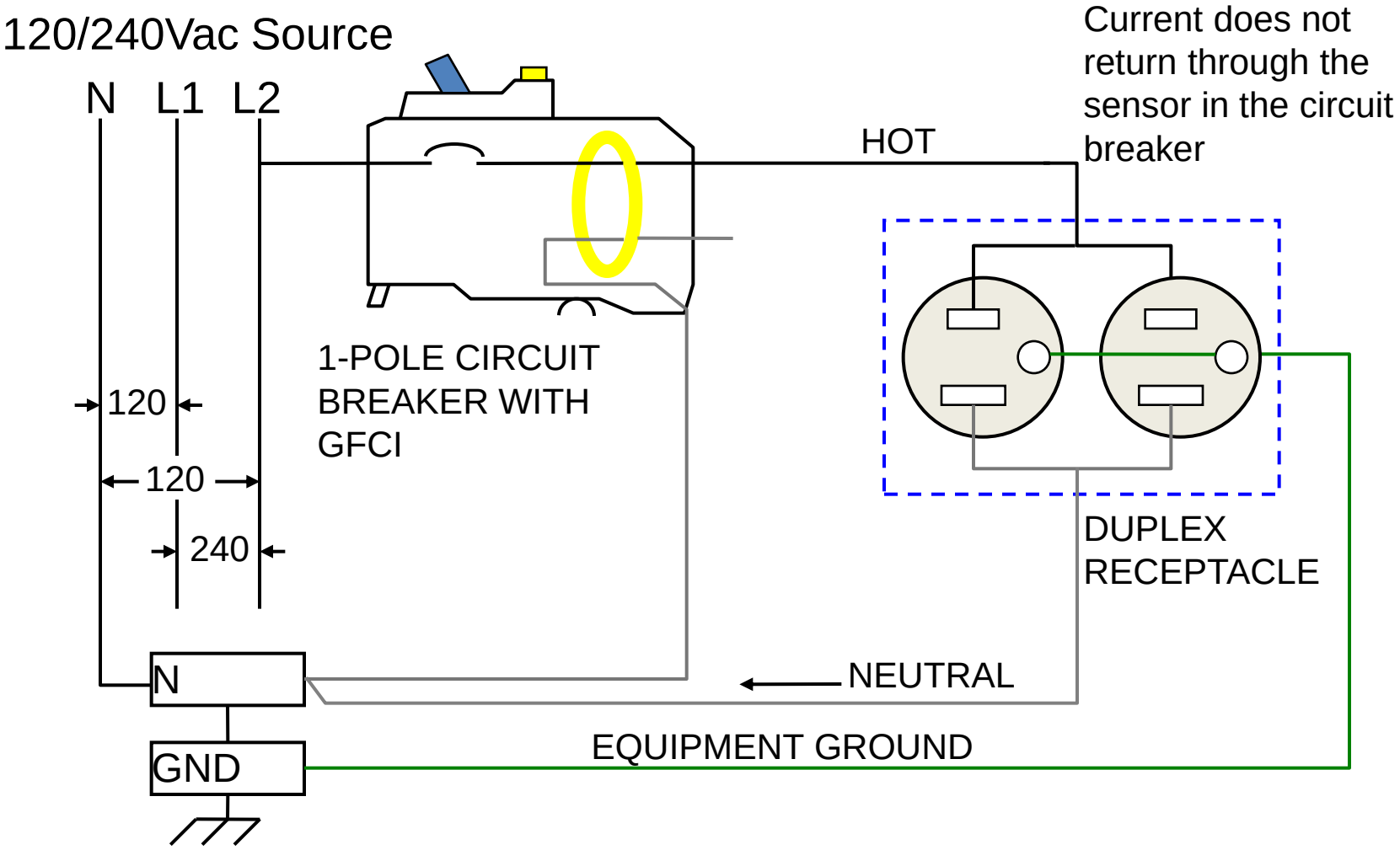


Correct Wiring

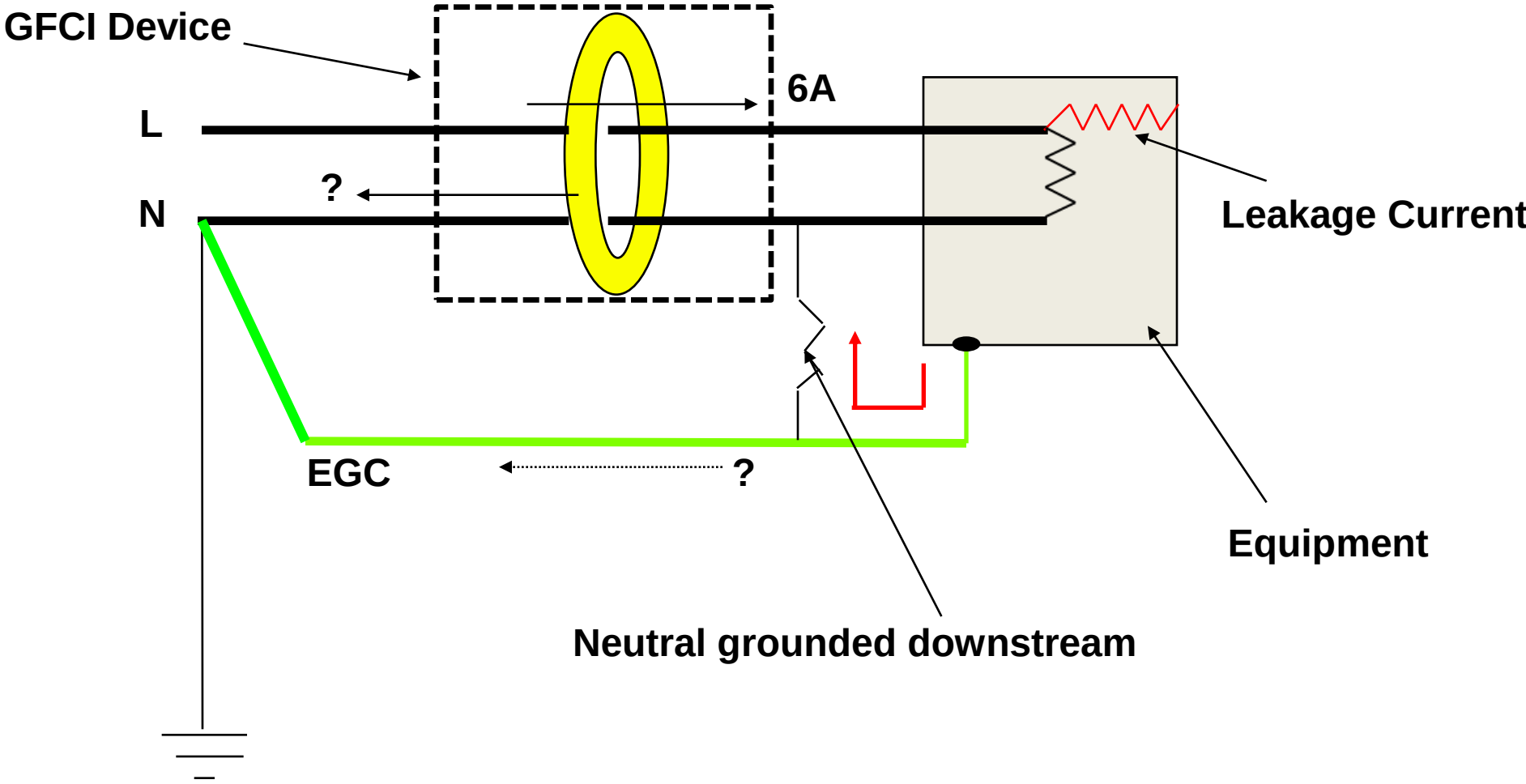


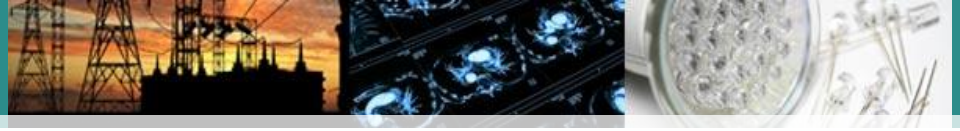
In the case of incorrect wiring there will be no power at the face or downstream.

GFCI Circuit Breaker Miswiring



Grounded Neutral Detection





UL GFCI Tests

Every GFCI must pass the following end-of-line manufacturing tests:

1. no trip below 4mA (no load)
2. must trip at 6mA (no load)
3. no trip below 4mA (with load) at rated voltage
4. must trip at 6mA (with load) at rated voltage
5. must trip with 2 ohm grounded neutral
6. must trip within 25 ms with a 500 ohm fault
7. must trip with test button at +10/-15% rated voltage
8. must not trip with noise test of GFCI Standard
9. calibration test at +10/-15% rated voltage

GFCI Testers

Why are testers used?

- verify operation of the GFCI
- check protection of downstream receptacles

Will not test:

- GFCI calibration
- ALL types of improper installation
- Danger on 2-wire circuits

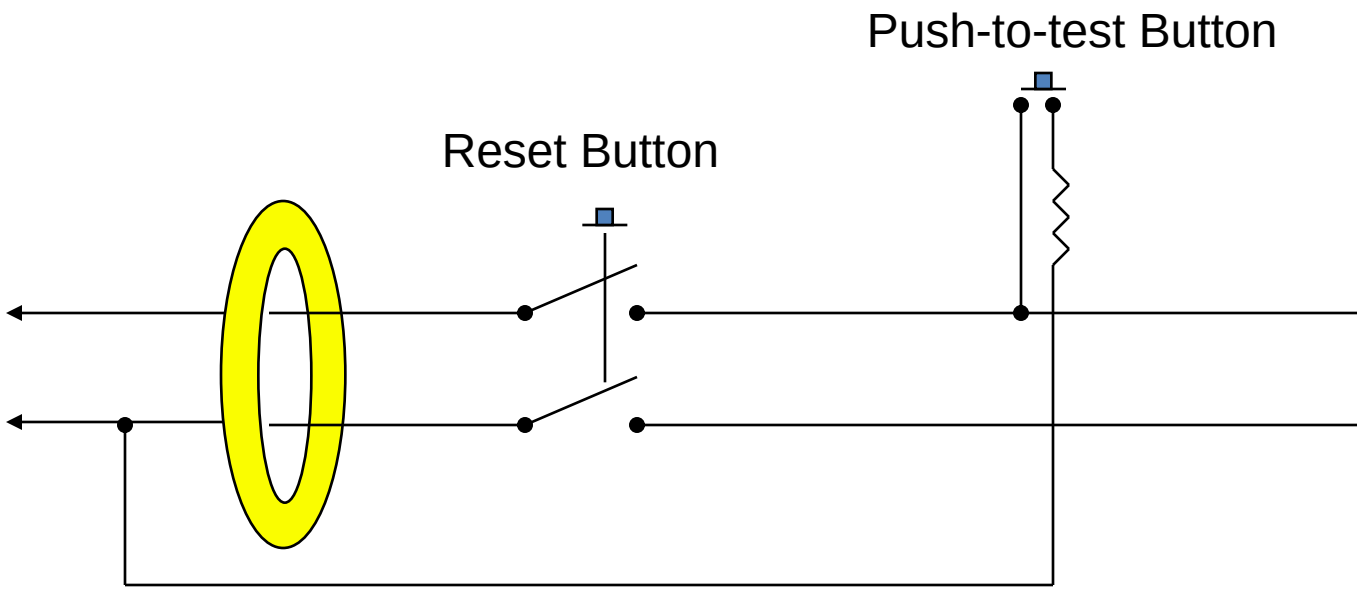
Will test for some types of improper installation:

- line/load reversal
- which outlets are protected by GFCI
- reverse polarity
- presence of the equipment ground

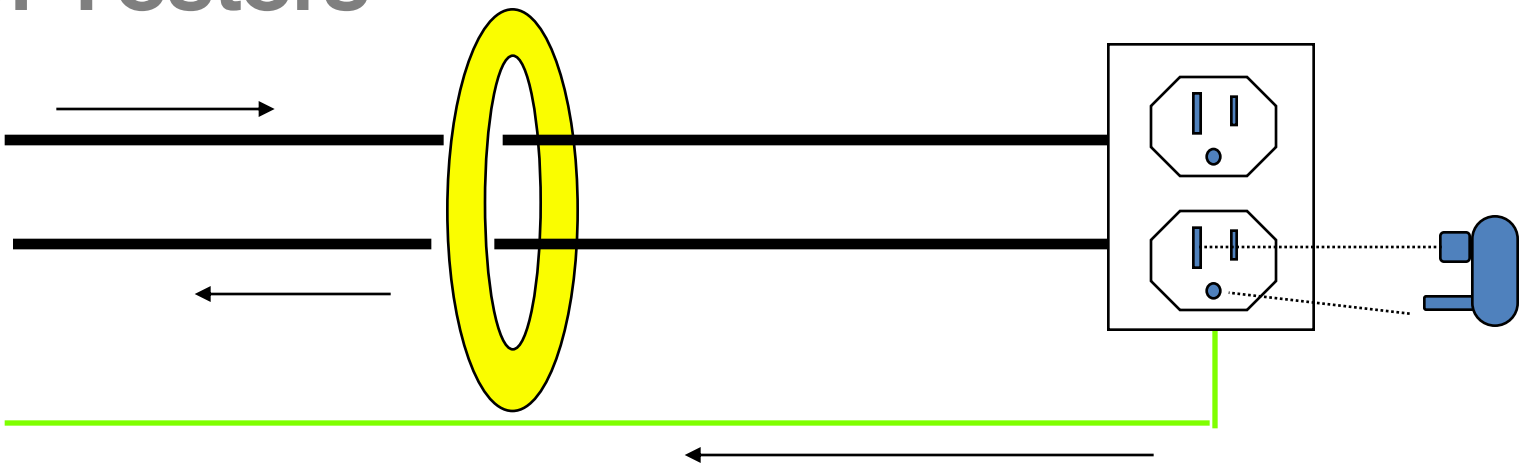
Test and Reset Buttons

(Receptacle)

- Test and reset buttons verify proper functioning of the GFCI
- Test button will initiate end-of-life indication or power denial if product is no longer operational



GFCI Testers



Plug-in testers divert current to the equipment grounding conductor

What if there is not equipment ground....? Such as in a 406.3(D)(2)(b) and 406.3(D)(2)(c) application?

The GFCI will not trip with the external tester. The test button must be used.

Benefits of UL943 (GFCI) vs. IEC (RCD)

Increased Safety Benefits

- UL943 Max 6 mA - threshold for “let-go” current.
  IEC Min 20 mA - threshold current for ventricular fibrillation.
- Receptacle End of Life indication
- Grounded Neutral protection
- Portable units - Load protection if both supply neutral and ground conductors are open together.

Summary

- GFCIs have contributed significantly to the reduction in the number of deaths due to electric shock
- GFCIs look at the current going out and compare it to the current coming back
- Remember that GFCIs detect ground to neutral connections downstream
- Test the GFCI by using the test button and a load
- GFCIs will not protect between line and neutral
- Only Class A GFCIs (6mA) protect from electrocution from “let-go” situations