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STANDARDS PUBLICATION/NO. 280-1984

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Application Guide for Ground Fault Circuit Interrupters

NEMA

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Foreword

This *Application Guide for Ground Fault Circuit Interrupters* was developed by the NEMA Joint Sections Committee on Ground Fault Personnel Protection. The committee was comprised of the Ground Fault Personnel Protection Section, the Molded Case Breaker Section, and the Wiring Device Section of NEMA.

In the preparation of this application guide, input of interested individuals and organizations has been sought and evaluated. Inquiries, comments, and proposed revisions are welcomed and should be submitted to:

Manager, Engineering Department
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Washington, DC 20037

Scope

This application guide covers ground fault circuit interrupters (GFCI's) which are intended to provide electrical shock hazard protection from line-to-ground fault currents on grounded circuits of 120, 120/240, and 208Y/120 volt two-, three-, and four-wire supplies.

GFCI's are designated as Class A or Class B in accordance with UL Standard 943 (Jan. 1977), *Ground Fault Circuit Interrupters.*[1] Unless otherwise indicated, this application guide applies to Class A GFCI's.

Covered in this guide are characteristics of the various types of GFCI's, construction details, marking data, installation guidelines, field testing recommendations, and field troubleshooting information.

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APPLICATION GUIDE FOR GROUND FAULT CIRCUIT INTERRUPTERS

Section 1
TERMINOLOGY

Ambient temperature is the temperature of the surrounding medium that comes in contact with the device or equipment. (For an enclosed device, it is the temperature of the medium outside the enclosure.)

An *electrical shock hazard* is a condition which could result in injury or electrocution to a person caused by the flow of electrical current through the body.

An *endurance test* is a test made to determine compliance with specified mechanical and electrical life requirements.

A *ground fault* is an unintentional electrical path between a part operating normally at some potential to ground, and ground.

A *ground fault circuit interrupter (GFCI)* is a device intended for the protection of personnel. It de-energizes a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

1. *Class A GFCI*—A ground fault circuit interrupter that is designed to trip when fault current to ground is 6 milliamperes or more.
2. *Class B GFCI*—A ground fault circuit interrupter that is designed to trip when fault current to ground is 20 milliamperes or more.

A *GFCI test means* is a means integral with a GFCI to check the ground fault sensing and tripping function of the device.

Ground fault current is current that flows through a ground fault.

Ground fault trip time is the elapsed interval between the time when the ground fault current is first applied and the time when the circuit is interrupted.

A *nuisance trip* is tripping caused by conditions other that those for which the device is intended to respond.

Rated continuous current is the maximum rms current which a device or an assembly is designed to carry.

Rated frequency is the frequency for which the device is designed.

Rated interrupting current is the value of the available rms symmetrical current at a specified voltage that the device is capable of interrupting under prescribed test conditions.

Rated maximum ambient temperature is the maximum ambient temperature at which the device is designed to carry rated continuous current.

Rated voltage is the nominal rms design voltage for which the device is designed to be used.

Service conditions are the conditions under which a device is designed to be used.

A *trip free* device is a device wherein the tripping operation cannot be overridden manually.

A *trip threshold* is the ground fault current which, when it is reached, will cause tripping of a GFCI.

Tripping is the automatic opening of a device.

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Section 2
CHARACTERISTICS OF GROUND FAULT CIRCUIT INTERRUPTERS

2.1 GENERAL

GFCI's are designed to interrupt the circuit when the ground fault current exceeds a predetermined level. This level is based on physiological reactions of a human body to alternating current and, as such, is independent of the branch circuit rating. The level of current at which a GFCI interrupts a circuit is extremely low when compared to that current required to operate the branch circuit overcurrent protective devices.

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2.2 PRINCIPLES OF OPERATION

The GFCI sensing system continuously monitors the current balance in the ungrounded "hot" conductor and the neutral conductor. If the current in the neutral wire becomes less than the current in the "hot" wire, a ground fault could exist. A portion of the current is finding a return by some path other than the neutral wire. With a current imbalance as low as 6 milliamperes, the GFCI will interrupt the circuit and this will be shown by a trip or "off" indicator on the device. See Figure 2-1.

The GFCI does not limit the magnitude of the ground fault current. It limits the time that a current of given magnitude can flow. The trip level-time combinations are based on physiological data established for avoiding injury to normal healthy persons. These trip level-time combinations may be too high for persons with heart problems, such as those wearing a pacemaker or under treatment in health care facilities.

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2.3 Double Grounded Neutral Protection

A Class A GFCI is designed so that it will automatically trip if the neutral conductor is grounded on the load side of the sensor.

If such a ground connection occurred, it would be possible for a person to contact a hot wire and ground, having the ground fault current flow through the inadvertent neutral ground and the neutral to the service entrance. Under this condition, there may not be enough imbalance in current through the sensor to cause the GFCI to trip.

The double grounded neutral protection feature prevents this condition from occurring.

This protective feature demands proper load-side building wiring. It continuously monitors the load-side wiring to detect a double-grounded neutral condition.

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2.4 TEST MEANS

Each GFCI is equipped with a means of testing the ground fault trip capability. A simulated ground fault through a test resistor is applied to the sensor through the activation of the test means. It is important that user testing procedures be followed.

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2.5 GFCI TRIPPING CHARACTERISTICS

Typical trip characteristics of GFCI's are shown in Figure 2-2.

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2.6 TYPES OF GFCI's

2.6.1 Basic GFCI

The basic GFCI consists of a ground fault detecting means coupled with a circuit interrupting means.

The detecting means measures the ground fault current as the difference between outgoing and incoming load current on the protected conductors. The current difference is suitably processed to activate the circuit interrupting means.

The circuitry module and associated interrupting means which make up the basic GFCI should be mounted in an enclosure or combined with some other device in order to be suitable for installation on a wiring system. The basic GFCI is combined into a complete device to make up the various types described below.

2.6.2 Switch Type GFCI

The switch type GFCI provides both personnel ground fault protection and switching capabilities. It may be rated for motor switching if so marked. It is not intended to be used as a substitute for a wall-mounted switch.

This type of device may have flexible insulated leads or binding screw terminals, and is to be mounted in an enclosure such as an outlet box.

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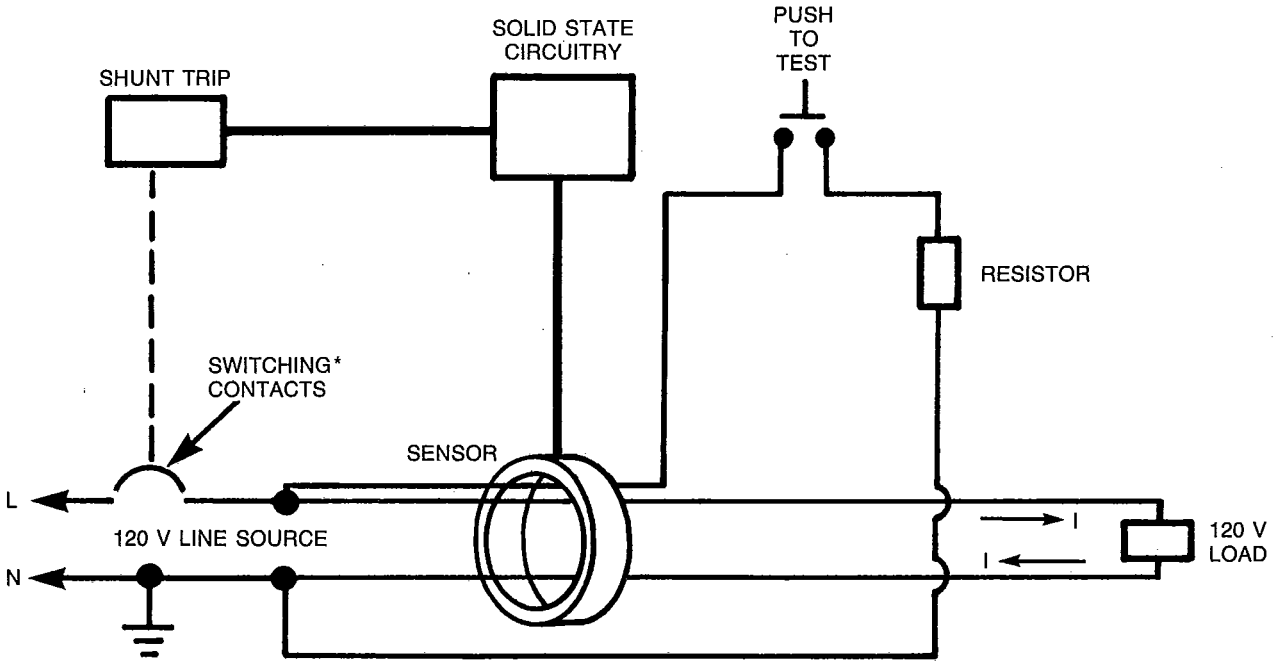
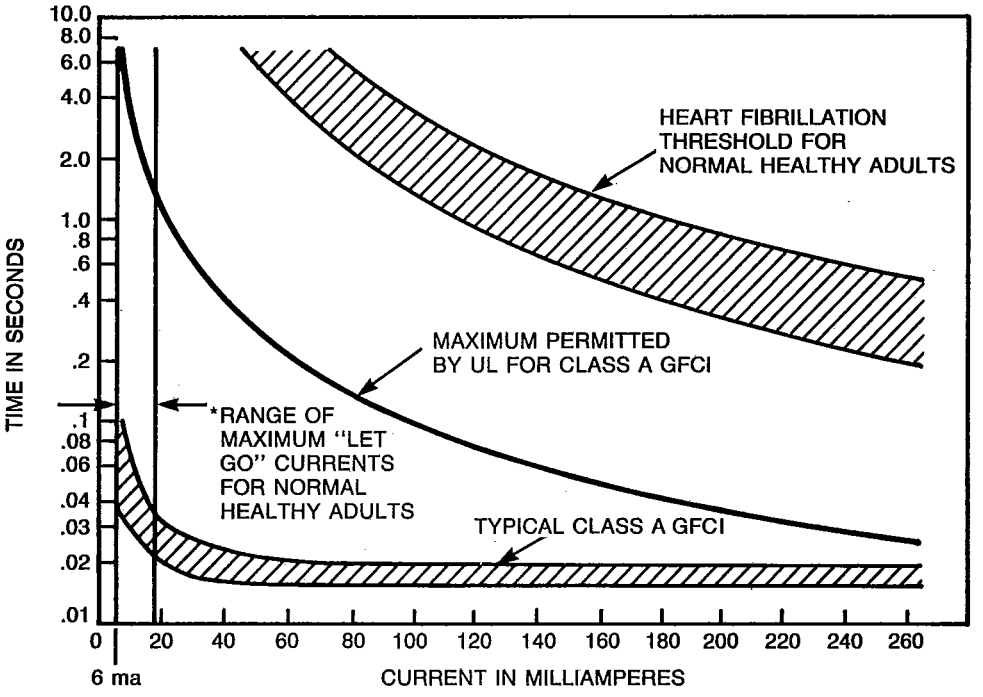


*Receptacle-type GFCIs switch both the phase and neutral

GROUND FAULT CIRCUIT INTERRUPTER (GFCI)
Figure 2-1



GFCI TRIPPING CHARACTERISTICS
Figure 2-2

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Means for five field connections are provided: line, line neutral, load, load neutral, and equipment grounding.

This device may be mounted in listed industrial control panels [UL Standard 508 (March 1982), *Electrical Industrial Control Equipment*[1]] and may be used as a motor controller if so marked. It may be mounted in other equipment and be listed by UL in combination with the equipment.

2.6.3 Permanently Mounted Type

The permanently mounted type of GFCI has an integral enclosure as a part of the total unit, and is designed to be permanently wired into the supply circuit.

2.6.4 Circuit Breaker Type

The circuit breaker type GFCI incorporates within one device the ability to provide all the functions of a circuit breaker as well as ground fault protection for personnel for the entire circuit.

It is intended to be mounted in an enclosure and frequently may be installed as a direct replacement for a circuit breaker in a load center or a panelboard.

Circuit breaker type GFCI's are available as single-pole and two-pole units with various plug-in and lug type electrical connections. Line neutral connections are usually made by means of a wire lead, and care should be taken to install the device according to the manufacturer's instructions.

2.6.5 Receptacle Type

The receptacle type GFCI incorporates within one device one or more receptacle outlets, protected by the GFCI. It is available as a "nonfeed-through" unit which provides GFCI protection only to the outlets in the unit, and as a "feed-through" unit which provides GFCI protection to downstream receptacles as well. The feed-through unit may also be used as a nonfeed-through unit. (See 5.9.)

Receptacle type GCFI's are available with various terminating means, including flexible insulated leads and "binding screws." The feed-through unit provides for five field connections: line, line neutral, load, load neutral, and equipment grounding. The nonfeed-through unit provides connections for line, line neutral, and equipment grounding.

Receptacle type GFCI's are intended to be mounted in an enclosure such as an outlet box.

2.6.6 Portable Type

The portable type GFCI is an easily transportable, self-contained, enclosed GFCI with one or more integral receptacle outlets protected by the GFCI module. In lieu of integral receptacle outlets, the load conductors may be attached by a cord and connector. Portable type GFCI's are normally connected to a supply receptacle by an integral attachment plug or a plug and cord. Receptacle cord connectors and plugs are available in various general purpose and locking configurations.

Enclosures for these units may be of the indoor type or the outdoor type. Indoor types usually have nonmetallic enclosures. The outdoor types may have metallic or nonmetallic enclosures suitable for the environment in which they are used. [See NEMA Standards Publication No. 250–1979, *Enclosures for Electrical Equipment (1000 Volts Maximum)*,[2] for enclosure information.]

The portable type GFCI has a no-voltage release feature which will automatically interrupt the circuit when any of the supply conductors is open.

2.6.7 Power Supply Cord Type

A power supply cord type GFCI consists of an attachment plug containing a GFCI; and a power supply cord. It provides GFCI protection for the cord and equipment to which the cord is attached. The attachment plug is generally unconventional in appearance.

This device is attached to other equipment and is listed by UL in conjunction with the equipment.

The power supply cord type GFCI also has a no-voltage release feature which will automatically interrupt the circuit when any of the supply conductors is open.

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Section 3
RATINGS

3.1 Rating Information

The rating of a GFCI includes the following: class, rated voltage, rated frequency, rated continuous current and, where applicable, rated interrupting current, and rated ambient temperature.

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3.2 Class

The GFCI designated "Class A" will trip when there is a fault current to ground of 6 milliamperes or more. The GFCI designated "Class B" will trip when there is a fault current to ground of 20 milliamperes or more. "Class B" GFCI's should be used only for underwater swimming pool lighting installed prior to May 1965 (prior to the adoption of the 1965 *National Electrical Code*).

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3.3 Rated Voltage

The common alternating-current voltage ratings of GFCI's are 120, 120/240, and 240 volts, single phase; and 208Y/120 and 240 volts, three phase.

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3.4 Rated Frequency

The rated frequency of GFCI's is 60 hertz.

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3.5 Rated Continuous Current

The common continuous current ratings of GFCI's are 15, 20, 25, 30, and 50 amperes.

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3.6 Rated Withstand Current

Receptacle and portable types typically have current-withstand ratings of 2000 amperes, rms symmetrical. Permanently mounted types normally have current-withstand ratings of 5000 amperes, rms symmetrical.

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3.7 Rated Interrupting Current

Circuit breaker types normally have current-interrupting ratings of 5000, 10,000, or 22,000 amperes, rms symmetrical.

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Section 4
MARKINGS

4.1 General

GFCI's are marked with the manufacturer's name or trademark, voltage rating, and load capacity in amperes. Additional information may also be marked on the GFCI or included with the manufacturer's literature.

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4.2 Types Which Are Permanently Connected Into Circuit

For types which are permanently connected into a circuit, which include the switch type, permanently mounted type, circuit breaker type, and receptacle type, the following additional information should be provided:

1. Installation instructions[1]
2. Test instructions to operate upon installation and at least monthly[1]
3. Test reminder with provisions for checking off monthly tests[1]
4. Warning against use in wet locations[1]
5. Warning that GFCI does not protect against shock hazard when both conductors are touched[1]
6. Statement—"For Use on Grounded Circuits Only"[1]
7. Class (A or B)
8. Proper conductor termination instructions

Marking on the device or literature packaged with the device should include the following or equivalent statement:

> "To avoid accidental bypassing of protection, the load-circuit wiring should be separated from other wiring by suitable insulation, barriers, or restraints."

4.2.1 Class A Devices

Marking on a Class A GFCI or literature packaged with the device should include the following or equivalent statement:

> "To minimize false tripping do not connect to swimming pool equipment installed before adoption of the 1965 *National Electrical Code.*"

4.2.2 Class B Devices

Marking on a Class B GFCI should include the following or equivalent statements:

> "Use only with underwater swimming pool lighting fixtures:
>
> CAUTION—To avoid possible shock, disconnect power before servicing fixture. To minimize false tripping, do not connect to more than __[2] feet of load conductor for the total one-way run."

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4.3 Types Which Are Cord Connected

For types which are cord connected, including the portable type and the power supply cord type, the following additional information should be provided:

1. Load capacity in watts.
2. The word **WARNING** and a statement to the effect that, to ensure protection against electric shock the test instructions should be followed before an appliance is plugged into any receptacle on the device. The marking describes the significance of the test and informs the user that, in the event of an indication of improper functioning, the cause of the malfunction should be corrected before further use of the device.
3. Unless a cord-connected GFCI has been found suitable for use in wet locations, it should be marked "Do not use where water is likely to enter case" or the equivalent.
4. A cord-connected device should be marked with a statement to the effect that the device does not guard against electric shock resulting from (1) some possible defects or faults in an extension cord or other wiring supplying the GFCI, or (2) contact with both circuit conductors.
5. A cord-connected GFCI not provided with a permanently attached cord 6 feet or longer in length should be marked "This product should be used only with a three-conductor, 120 volt, __[3] ampere supply cord set employing Type ST, SO, STO, SJT, SJO, or SJTO cord. In event of cord set damage, it should be replaced only with an equivalent cord set" or similar wording.

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[1] These instructions may appear in the literature packed with the GFCI.

[2] Specified by manufacturer.

[3] Fifteen-, 20-, or 30-ampere, to be specified by manufacturer.

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Section 5
GFCI APPLICATION CONSIDERATIONS

5.1 In most cases tripping of a GFCI is an indication of a dangerous condition that needs correction. GFCI tripping under such conditions is not "nuisance" tripping. The cause of the tripping should be identified and corrected.

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5.2 Unless the device is a circuit breaker type GFCI, it will not protect the circuit conductors against overcurrent. Separate overcurrent protection must be provided.

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5.3 Grounding and GFCI protection are used to complement one another, not to replace one another.

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5.4 Periodic tripping tests should be made in accordance with the manufacturers recommendations, using the test means on the unit. When the test button is pushed, a predetermined value of ground fault current is supplied to the GFCI, tripping the unit and thereby testing the GFCI and its associated circuit.

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5.5 To avoid damage to the GFCI, it must be disconnected before feeders or branch circuits are subjected to a megger, high voltage, or hi-pot test. Disconnect the electrical power supply and load conductors to isolate the GFCI.

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5.6 Carefully read the manufacturer's instructions before installation of the GFCI.

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5.7 A GFCI does not protect a person who comes in contact with two "hot" wires or any "hot" wire and the neutral wire.

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5.8 A GFCI does not protect a person from feeling and reacting to a shock.

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5.9 When using a feed-through receptacle-type GFCI, be certain that outlets to be protected are all on the downstream side of the GFCI.

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5.10 When a feed-through receptacle-type GFCI is used only to protect its own receptacle, the unused load wire connections, if any, should be properly insulated to prevent electrical hazard.

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5.11 When a feed-through receptacle-type GFCI is used to protect a complete load circuit or only a portion of a load circuit, the "load" wires should be connected to the remaining receptacles in the branch. The line and load connections should not be reversed; otherwise the GFCI's own receptacle will be unprotected and will remain energized after the unit has tripped.

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5.12 Depending upon where it is installed on a branch circuit, a feed-through receptacle-type GFCI can protect all of the receptacles on the circuit, a portion of the receptacles on the circuit, or only its integral receptacle.

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5.13 Suitable enclosures should be used for GFCI's or receptacles protected by GFCI's. This is especially important in the presence of moisture or a corrosive atmosphere.

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5.14 The GFCI contains an electronic circuit which is designed to be resistant to electrical interference. In the same way that a television set or radio suffers from momentary "static" in the presence of interference, so may the GFCI. However, in the television or radio, the interference is merely a temporary nuisance. The GFCI, as a safety device, may interpret this interference as a ground fault and trip. Therefore, the GFCI should not be used in an application where continuity of service takes precedence over the personnel protection feature, such as life-sustaining equipment in health care facilities.

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5.15 The trip characteristics established for the GFCI ground fault sensor are based on physiological data taken for normal healthy persons. These levels may be too high for persons with heart problems such as those wearing pacemakers or those under treatment in health care facilities. (See 2.2.).

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5.16 A portable GFCI will not protect the receptacle or any portion of the branch circuit into which it is plugged. It will protect only those conductors and devices connected to its load side.

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5.17 Equipment with high temperature sheathed heating elements such as dishwashers and electrical space heaters tend to have high electrical leakage which may cause tripping when used with GFCI's. This type of equipment should be effectively grounded.

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5.18 Permanently connected lights, without receptacles, need not be protected by GFCI's.

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5.19 Stationary appliances such as sump pumps and clothes washers should be effectively grounded. These types of appliances may have high electrical leakage caused by moisture. Refrigerators and freezers, particularly older units, may also have this type of leakage. When these appliances are on a GFCI-protected circuit, the leakage currents could exceed the GFCI trip threshold and cause the GFCI to trip.

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5.20 High moisture conditions may result in electrical leakage of portable tools. This will cause the GFCI to trip in some instances even if the tool is turned off, if the leakage exceeds the GFCI trip value.

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5.21 High moisture conditions may result in leakage of unprotected extension cord connectors and aged cord insulation. Replace or repair any aged wiring, extension cord, or portable tool which, under high moisture, causes the GFCI to trip.

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5.22 GFCI protection cannot be used for ranges, ovens, cooking units, and clothes dryers when the frame of the appliance is connected to the grounded circuit conductor. (See 2.3.).

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5.23 If a GFCI is used with a small portable generator, the GFCI circuit should be turned off when starting and until the generator has attained constant speed.

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5.24 A GFCI feeding an isolation transformer, which supplies circuits such as underwater swimming pool fixtures, will not detect a ground fault on the secondary side of the transformer.

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5.25 GFCI's should be used only on grounded systems; however the GFCI can be used on a two-wire circuit without a grounding wire as long as the system is grounded.

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5.26 The *National Electrical Code*[1] requires that the white (or grounded) conductor be grounded only at the service entrance. If this conductor is grounded again on the load side of the GFCI, tripping will occur. (See 2.3.).

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5.27 A 120/240V two-pole circuit-breaker-type GFCI need not have the load side neutral connected for 240V rated loads.

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5.28 Certain portable voltage testers or test lamps, when connected between line and ground on the load side of the GFCI, may cause the GFCI to trip.

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Section 6
INSTALLATION GUIDELINES FOR ELECTRICAL SYSTEMS WITH GFCI'S

6.1 LOCATION OF GFCI ON SYSTEM

6.1.1 At Load Center or Panelboard, Or a Permanently Mounted Type After Panelboard

6.1.1.1 Circuit breaker type of GFCI's have built-in overcurrent protection. Permanently mounted type GFCI's must be installed on the load side of an overcurrent protective device. The electrical power should be turned off before attempting installation of the GFCI.

6.1.1.2 The handle of the breaker type GFCI should be in the "OFF" position before installing.

6.1.1.3 The GFCI should be connected and installed in accordance with the manufacturer's instructions. Care should be taken to observe the markings on the device to maintain polarity of branch circuitry.

6.1.1.4 After the installation is complete, the electrical power can be restored and the handle of the breaker type GFCI can be moved to the "ON" position.

1. If the installation is correct and the load circuit is normal, the circuit breaker will remain on. The test button should be depressed; if the handle now moves to the "TRIP" position and the branch circuit becomes de-energized, the GFCI is operating properly. To reset the breaker, the handle should be moved to the "OFF" position and then to the "ON" position for normal operation. (Some circuit breaker type GFCI's have a common "TRIP and OFF" position.)

2. If the breaker handle moves to the "TRIP" position, the following steps should be taken:

   a. Move the handle to the "OFF" position.
   b. Turn off the electrical power to the panelboard.
   c. Disconnect the load power and load neutral wires from the GFCI. Recheck line connections.
   d. Restore electrical power to the panel.
   e. Move the handle of the GFCI to the "ON" position.
      (1) If the handle remains in the "ON" position and trips when the test button is depressed, the GFCI is operating properly and the fault is in the branch circuit system. The fault should be corrected and the GFCI device reconnected as above.
      (2) If the GFCI handle again moves to the "TRIP" position, replace the device.

6.1.2 At Outlet Box

To install a receptacle or switch type GFCI, the steps listed below should be taken:

6.1.2.1 Check to be sure that the device to be replaced is energized (will supply power to a connected load). If it is a duplex receptacle, be sure that both halves are checked.

6.1.2.2 Turn off power to the device by removing the fuse or switching the branch circuit breaker to its "OFF" position. If the specific fuse or circuit breaker is unknown, it can be located by removing fuses or switching circuit breakers one at a time while checking for power at the device to be replaced (both halves if duplex).

If both halves of a duplex receptacle are not on the same circuit, do not install a receptacle type GFCI since it will not function properly. A two-pole circuit breaker type GFCI may be used instead. (See 6.1.1.)

6.1.2.3 Install the GFCI device in accordance with the manufacturer's instructions, being sure to maintain polarity.

6.1.2.4 If the GFCI has the feed-through feature, it is important that input connections be made to the line terminals only.

6.1.2.5 Restore power by replacing the fuse or by switching the branch circuit breaker to its "ON" position.

6.1.2.6 Depress the reset button on the GFCI. This should energize any load connected to the GFCI device.

6.1.2.7 Depress the test button. An indicator should show that the device has tripped, and this tripping should de-energize the GFCI's own connected load. If the GFCI is used as a feed-through device, make sure the down line receptacles are deenergized when the GFCI is in the trip mode. If not, recheck the input line and output load connection.

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CAUTION: If, an indicator does not show that the device has tripped after the test button is depressed, immediately turn off the power at the circuit breaker or fuse panel, and recheck the electrical connections and repeat steps C through G.

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6.2 WIRING CONSIDERATIONS

6.2.1 At Load

6.2.1.1 The neutral should not be grounded at the load.

6.2.1.2 The load neutral should not be connected to any other circuit neutral.

6.2.1.3 Certain types of equipment tend to have high leakage current and cause tripping of GFCI's. These include units with high temperature sheathed heating elements and submersible water pumps. (See 5.17 and 5.19.)

6.2.1.4 Loads at excessive distances from the GFCI may cause tripping due to inherent leakages from the interconnecting wiring.

6.2.1.5 On 120/240V 2-pole circuit breaker type GFCI's the neutral *load* wire need not be connected if it does not carry current. However, the neutral *line* wire should be connected for proper operation.

6.2.2 On Construction Sites

6.2.2.1 High moisture conditions may result in high leakage in unprotected extension cord connectors and in aged cords and tools.

6.2.2.2 All wiring connections should be kept off the earth and protected from mud and water.

6.2.2.3 Receptacles protected by GFCI's on construction sites should not be installed on branch circuits which supply temporary lighting.

6.2.2.4 Proper grounding should be maintained even though GFCI protection is present.

6.2.3 Portable Units

The manufacturer's instructions packed with the GFCI should be read carefully in addition to the instructions which are marked on the GFCI.

6.2.4. Branch Circuits

6.2.4.1 120V 2W—With Equipment Grounding Conductor

Figures 6-1 and 6-2 show how some of the *National Electrical Code*[1] GFCI requirements of a typical dwelling unit can be met either by one single-pole circuit breaker type GFCI or by one feed-through receptacle type GFCI. (See the Appendix for a tabulation of NEC requirements.)

6.2.4.2 120V 2W—Older Branch Circuits Without Grounding Conductor

For many years, the *National Electrical Code* has required that equipment grounding conductors and grounding-type receptacles be used for 15 and 20A branch circuits. However, there are many wiring systems still in use which were installed before these requirements. Thus when it is desired to install GFCI protection on a branch circuit without an equipment-grounding conductor or grounding-type receptacles, special care must be exercised.

If a circuit-breaker-type GFCI is to be used, no special considerations are involved other than making sure that the neutral is not shared with other circuits. The GFCI installation is identical to that on a branch circuit with equipment ground, and personnel protection is provided to the two-wire receptacles.

If a receptacle-type GFCI is to be used, the requirements of Section 210-7 of the *National Electrical Code* regarding grounding of the equipment-grounding terminal of the receptacle-type GFCI must be met. When properly installed, a feed-through receptacle-type GFCI will provide personnel protection to down-stream, two-wire receptacles.

6.2.4.3 120/240V 3W—With Equipment Grounding Conductor

The two 20-amp small appliance branch circuits required by the *National Electrical Code* in dwelling units are frequently installed with a common neutral conductor.

A mistake often made with *single-pole* GFCI circuit breakers and GFCI receptacles is to try to install

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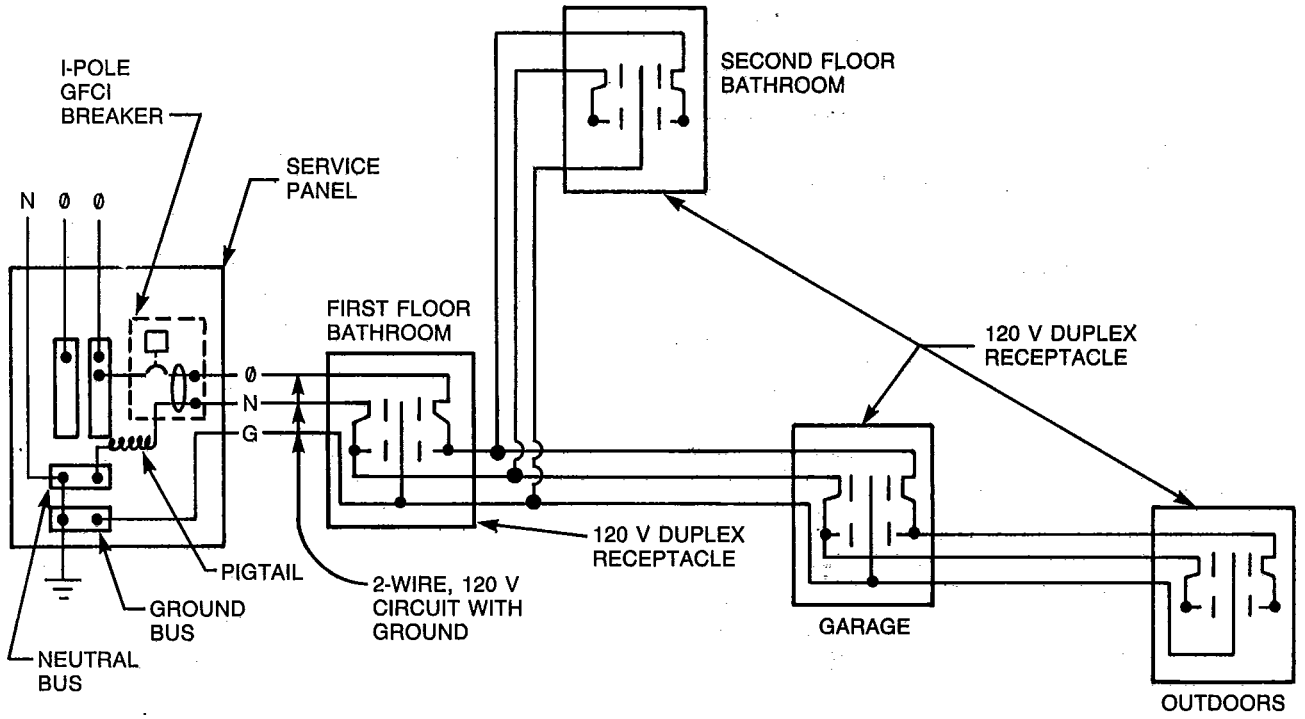
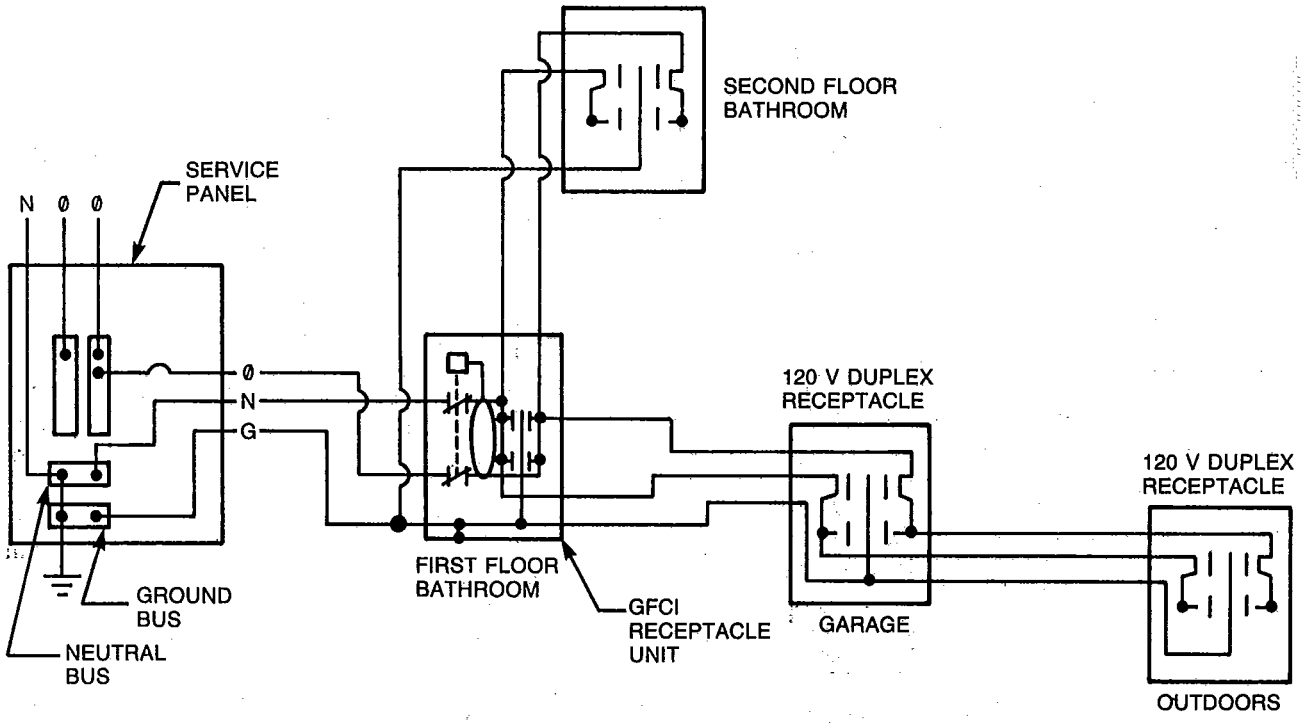


USING A I-POLE CIRCUIT BREAKER TYPE GFCI
Figure 6-1



USING ONE FEED-THROUGH GFCI
Figure 6-2

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them on only one leg of a three-wire common neutral branch circuit. This won't work. Since the neutral carries the load current of *both* hot legs, the current in the neutral will be different from the current in each individual hot leg, when both hot legs are carrying load currents. The GFCI will sense this difference as a ground fault and will trip, even though there is no ground fault.

Figures 6-3 and 6-4 illustrate two good ways to provide GFCI protection for three-wire 120/240V common neutral circuits:

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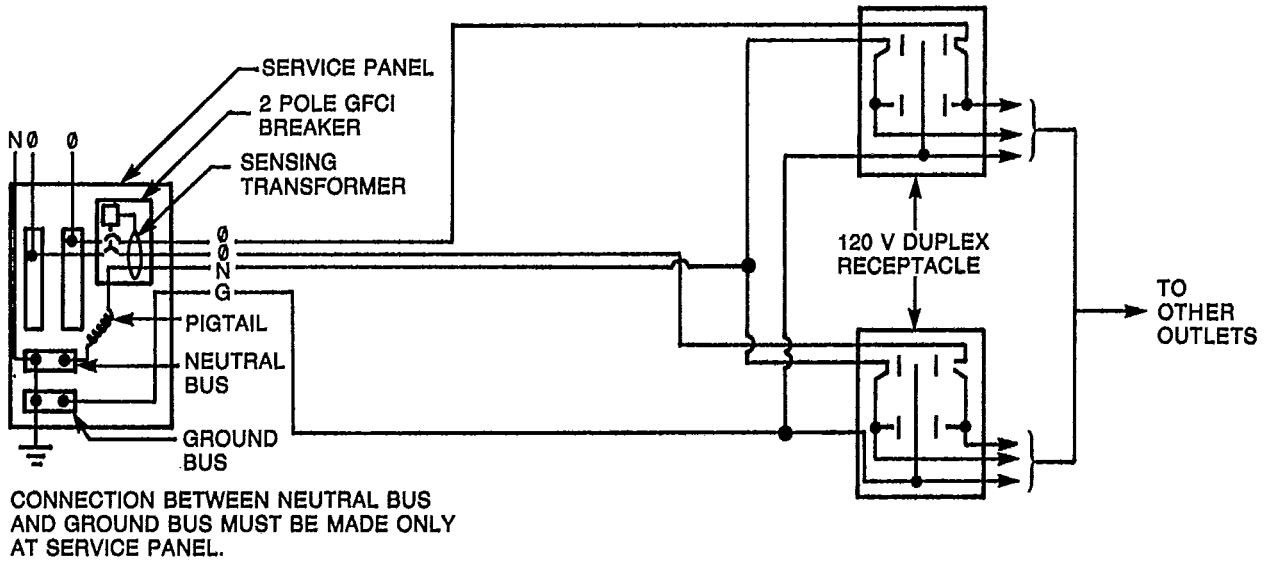
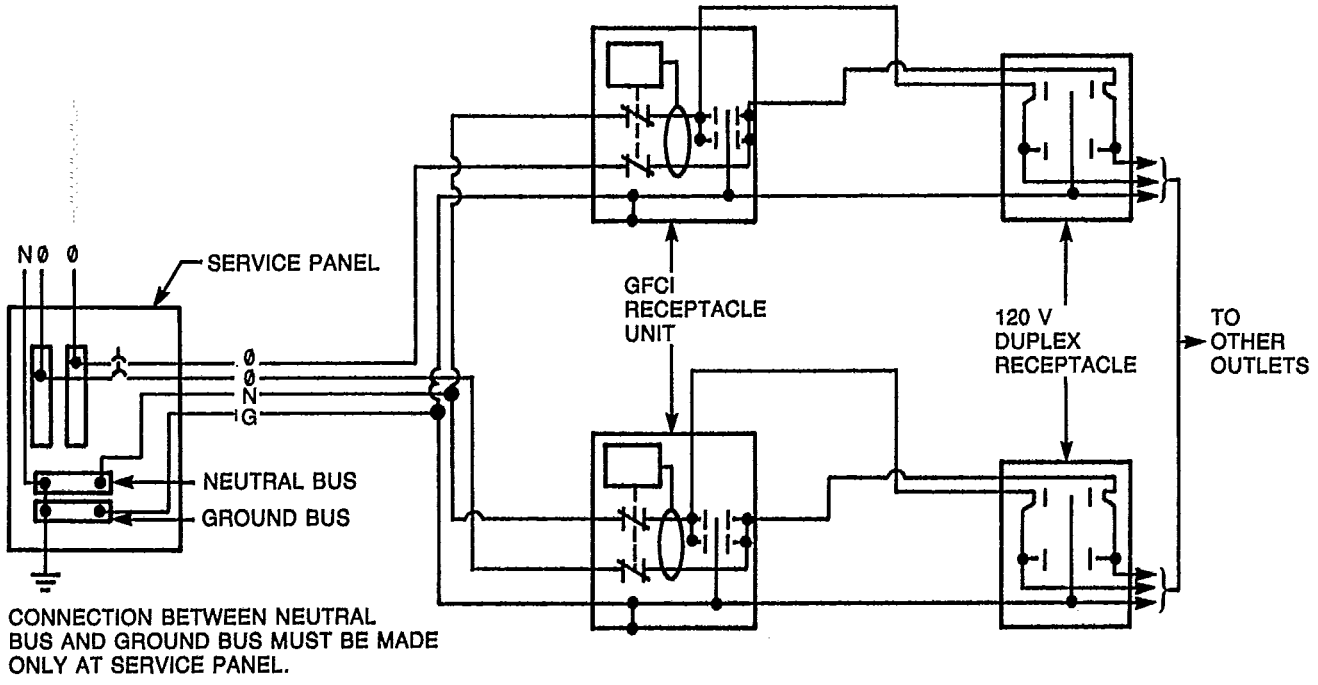


USING A 2-POLE GFCI CIRCUIT BREAKER
Figure 6-3



USING TWO FEED-THROUGH RECEPTACLE GFCI's
Figure 6-4

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Section 7
FIELD TEST DEVICES

7.1 INTEGRAL TEST DEVICES (GFCI Testers)

The test button on a GFCI simulates a differential current between the ungrounded (or "hot") and the grounded (or neutral) circuit conductors. The built-in test circuit verifies that the GFCI is functional, when installed properly, and is the preferred method of testing GFCI operation.

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7.2 SUPPLEMENTAL TEST DEVICES

There are a number of devices and test instruments whose function is to give an indication of whether or not a GFCI is operating properly. These "GFCI testers" vary in the amount of information that they provide the user. Before any GFCI tester is used, polarity should be correct or problems will result. There are single plug-in devices which will give an indication under certain conditions as to whether or not a given receptacle is protected by a GFCI. These devices have commercial tolerances and are not precise test instruments.

There are also test instruments with greater sophistication which will give more precise information. These instruments can create either discrete step or continuously varying values of ground fault current by means of internal circuitry, which connects the ungrounded ("hot") conductor to the grounding conductor.

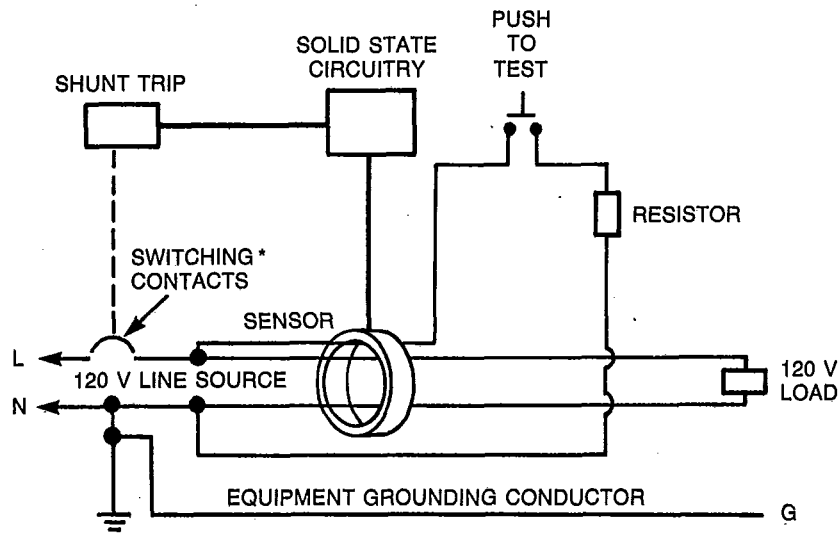
7.2.1 Possible Improper Indications when Using Supplemental Test Devices

7.2.1.1 Supplemental Test Device On Circuits Containing Leakage

If there is no leakage current on the circuit prior to using the supplemental test device (Figure 7-1), then the *total circuit leakage current* (I_t) will be provided by the tester. Figure 7-2 illustrates a circuit with no leakage current other than the current caused by the supplemental test device. The total circuit leakage I_t as seen by the GFCI is I_{td} ; $I_t = I_{td}$.

If, as in Figure 7-3, the circuit contains *leakage current* (I_e) while the supplemental test device is in use, the tester could give a misleading indication, since the total circuit leakage current (I_t) as seen by GFCI is the sum of I_{td} and I_e ($I_t = I_{td}+I_e$), e.g., if I_{td}=3ma and I_e=3ma and the GFCI tripped, one might assume that the GFCI was defective and it tripped below its rated range of 4–6ma. Actually, at 6ma the GFCI would be functioning properly, as $I_t = I_{td}+I_e$=3ma + 3ma = 6ma.

To ensure that the tester is providing an indication of the proper trip-level current, the branch circuit should be checked for leakage beyond the GFCI, on the ungrounded conductor, grounded conductor, or load to ground. If leakage is suspected, disconnect all loads on the GFCI.



*Receptacle-type GFCIs switch both the phase and neutral

CIRCUIT WITHOUT LEAKAGE
(No Ground Fault Current and Prior to Using the Supplemental Test Device)
Figure 7-1

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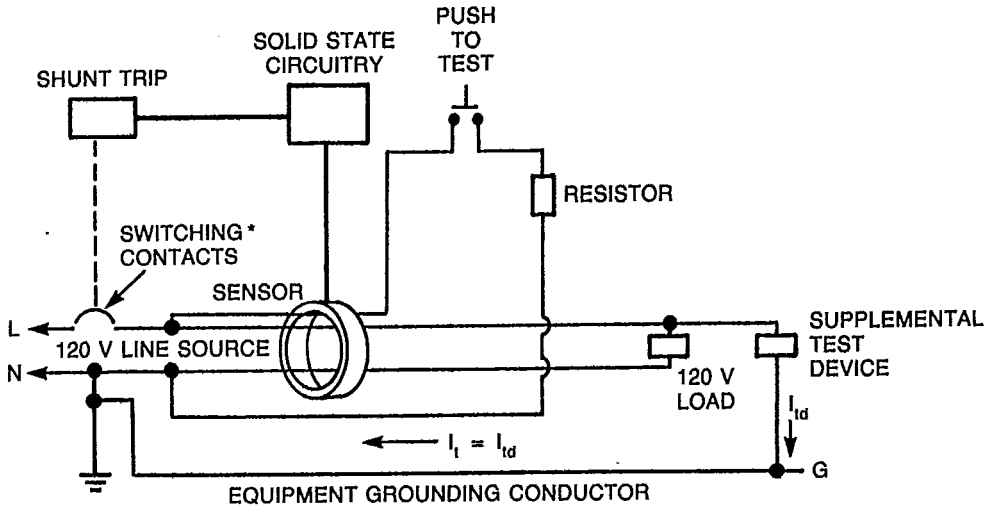
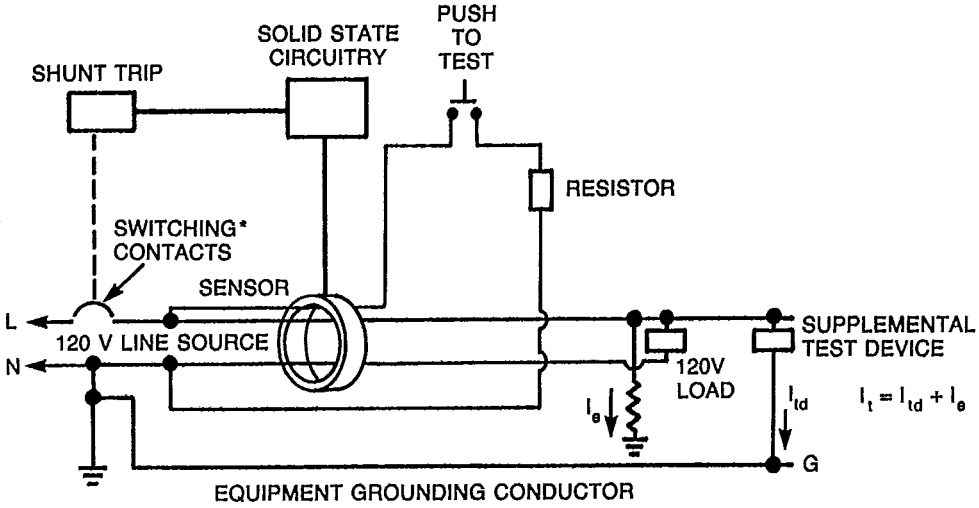


*Receptacle-type GFCIs switch both the phase and neutral

SUPPLEMENTAL TEST DEVICE ON CIRCUIT WITHOUT LEAKAGE
(Ground Fault Current Created by Tester)
Figure 7-2



*Receptacle-type GFCIs switch both the phase and neutral

SUPPLEMENTAL TEST DEVICE ON CIRCUIT WITH LEAKAGE
(Ground Fault Current From Circuit and Tester)
Figure 7-3

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7.2.1.2 Supplemental Test Device on Circuit With Open Grounding Conductor

Supplemental GFCI testers operate by using the equipment grounding conductor in the test circuit. If the equipment grounding conductor is open as illustrated in Figure 7-4, the tester will not be able to cause the GFCI to trip, and this will give the impression that the GFCI is defective. The correct functioning of the GFCI can be verified if the GFCI's integral test is successful since the integral test circuit does not use the equipment grounding conductor.

7.2.1.3 Supplemental Test Device On Circuit With Reversed Polarity

If the ungrounded and grounded conductors are reversed, as shown in Figure 7-5, there will not be a voltage across the GFCI tester, and test current will not be able to flow. As no test current will flow, the GFCI will not trip and thus the GFCI might erroneously be considered defective.

7.2.1.4 Supplemental Test Device On Circuit With Grounded and Equipment Grounding Conductors Interchanged

If the grounded (neutral) and equipment grounding conductors are reversed at the supplemental test point as illustrated in Figure 7-6, the current through the GFCI tester will not pass around the sensor but will return through the sensor and will be sensed as a normal load. The GFCI will not trip and thus might erroneously be considered defective.

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7.3 OTHER TEST DEVICES AND TEST INSTRUMENTS

When voltmeters, voltage testers, or other testing devices are used on GFCI protected circuits, the possibility of tripping a GFCI exists. As long as both instrument connections are made hot-to-neutral on the line side, or hot-to-neutral on the load side, no problem should be encountered.

However, if a hot connection on the line side and a neutral connection on the load side is made, or vice versa, the current through the instrument can cause the GFCI to trip if it exceeds the minimum trip value of the GFCI.

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7.4 PERIODIC VERIFICATION CHECKS

GFCI's should be tested regularly, as specified by the manufacturer, by using the built-in test button. Date of test should be recorded on record sheets provided for convenience by the manufacturer of the GFCI. Portable units should be tested before each use.

UNDER NO CONDITIONS SHOULD THE LOAD CONDUCTORS OF A GFCI BE JUMPERED TO TEST THE OPERATION OF THE GFCI. High fault currents can cause a shock or burn hazard to individuals and can damage the branch circuit or its components.

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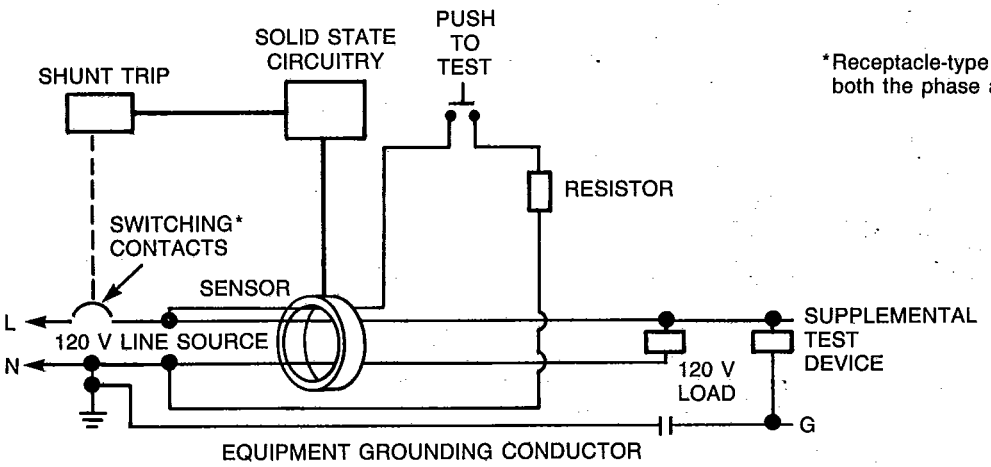

SUPPLEMENTAL TEST DEVICE ON CIRCUIT WITH OPEN GROUNDING CONDUCTOR
(No Ground Fault Current Because of Open Circuit)
Figure 7-4

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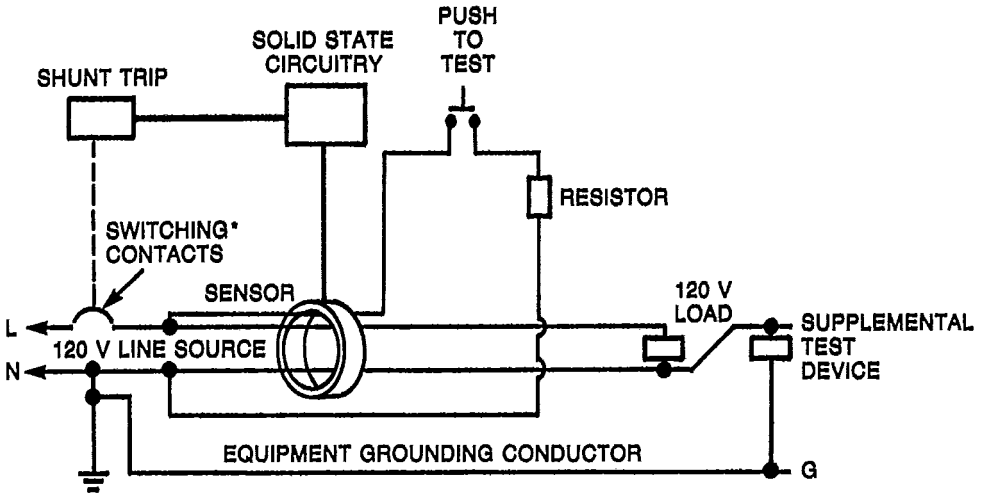
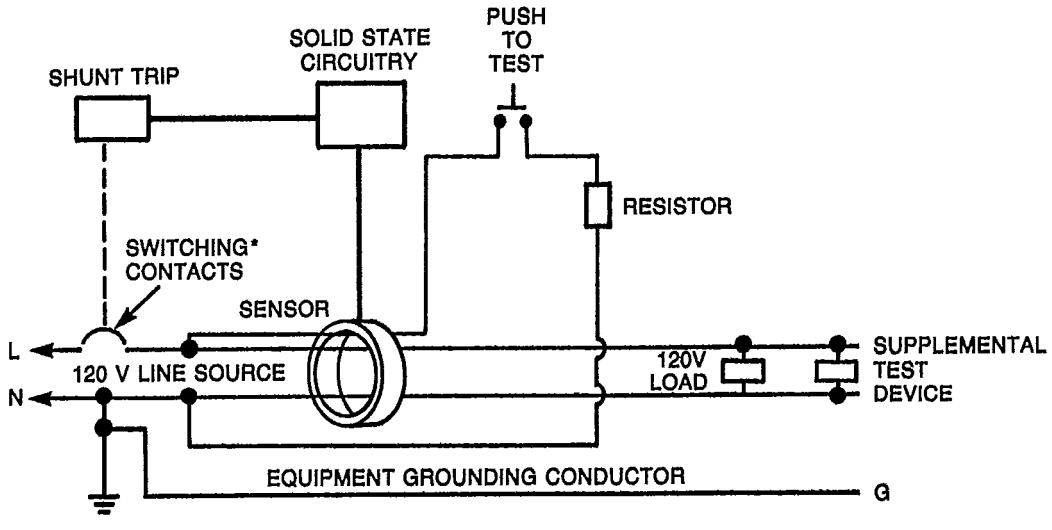


*Receptacle-type GFCIs switch both the phase and neutral

SUPPLEMENTAL TEST DEVICE ON CIRCUIT WITH REVERSED POLARITY (Ground Fault Current Too Small to Operate GFCI)
Figure 7-5



*Receptacle-type GFCIs switch both the phase and neutral

TEST DEVICE ON CIRCUIT WITH GROUNDED AND EQUIPMENT GROUNDING CONDUCTORS INTERCHANGED (Test Device Current Cannot be Recognized)
Figure 7-6

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Section 8
FIELD TROUBLESHOOTING

8.1 LINE SIDE OF GFCI

The system neutral and equipment grounding conductor should be grounded at the service entrance in accordance with the *National Electrical Code.*[1] Connections to the GFCI should be in accordance with the manufacturer's instructions. If the test button does not trip the GFCI, the line connections should be checked for proper voltage. If proper voltage exists, the GFCI should be replaced.

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8.2 AT THE GFCI

For receptacle type, reversal of line and load conductors at a GFCI receptacle will not provide GFCI protection for the unit's own receptacle(s). Therefore, check circuit connections for correctness (line and load, hot, neutral, and grounding).

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8.3 LOAD SIDE OF GFCI

8.3.1 Load Side of Neutral Ground

The GFCI is designed to trip if the neutral is grounded on the load side of the GFCI. If the GFCI trips as soon as energized, but with no load on the circuit, a grounded neutral on the load side is a possible cause. This should be removed for proper operation of the GFCI.

8.3.2 Equipment Ground and Neutral Connected Together on Load Side

This condition will cause the device to trip. (See 8.3.1.)

8.3.3 Excessive Leakage to Ground

Leakage current in excess of the trip level rating of the GFCI will cause the GFCI to trip as designed. (See 2.2)

8.3.4 Multi-Wired Branch Circuits (Shared Neutral)

When GFCI's are used on circuits with shared neutrals, special considerations are required or tripping will occur. This is a problem that may not be detected until a load is connected to the circuit. (See 6.2.4.3.)

8.3.5 High Moisture Conditions

When a GFCI trips in the presence of moisture, it is doing its intended job of preventing a hazard. The solution is to eliminate the leakage current caused by the presence of moisture.

8.3.6 Inability to Reset Tripped GFCI

All connected equipment and appliances should be removed from the load side of the GFCI. If the GFCI will not reset, circuit conductors should be disconnected from the load side of the GFCI and an attempt made to reset. If the GFCI still will not reset, it should be replaced. If after disconnecting all circuit loads the GFCI resets, each load should be connected individually. If a GFCI trips when a load is connected, that load should be checked as the possible cause of the problem. If a summation of faults appears to be the cause, the connected loads on the GFCI circuit should be limited and an additional GFCI-protected circuit used.

8.3.7 Circuit Breaker Type

A circuit breaker type GFCI provides protection in the event of an overload, short circuit or high level ground fault, as well as providing low level ground fault protection and ground fault protection for personnel. Any of these conditions could cause breaker tripping, and there may be no indication of which condition caused the trip. Unless the cause is obvious, the breaker should be reset. If the breaker trips again, circuit wiring should be disconnected from the load side of the GFCI and an attempt made to turn it on. If the breaker does not turn on, it should be replaced. If the breaker does not trip, the problem is in the branch circuit and should be located.

The problem could be with either the circuit conductors or with connected loads. The ampere load should be checked to ensure the breaker rating is not exceeded. Motor starting currents should also be considered. If the circuit rating is exceeded, the load on the circuit should be limited and additional circuits used. If overloading is not the cause, each load should be connected individually. If one load causes a trip, the equipment should be checked for faults. If individual loads do not cause tripping, multiple loads should be connected. If multiple loading causes tripping, the leakage of each load should be checked as a summation of leakage currents could be the cause. If this is the case, the load on this circuit should be limited and additional GFCI-protected circuits used.

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Appendix
GFCI CROSS REFERENCES TO *NATIONAL ELECTRICAL CODE*[1]—1984 EDITION

NEC Page	Article	Subject
10	100	Definition of GFCI
33	210–7b exception No. 2	Effective Grounding of Grounding Contacts
33	210–7d exception	Replacement of Two Wire Receptacles
34	210–8	Branch Circuit Ground Fault Protection for Personnel
34	210–8 (a)	Dwelling Units
34	210–8 (a) (1)	Receptacles in Bathroom
34	210–8 (a) (2)	Receptacles in Garages
34	210–8 (a) (3)	Receptacles Outdoors
34	210–8	Uses permitted—other circuits, locations, & occupancies
34	210–8 (b)	Receptacles in Bathrooms of Hotels & Motels
42	215–9	Feeder Ground-Fault Protection for Personnel
130	305–4	Receptacles on Construction sites
333	426–31	Outdoor De-Icing-Impedance Heating Voltage Limitation—Exception
336	427–26	Fixed Heating of Pipelines—Impedance Heating Voltage Limitation—Exception
481	517–90 (c)	Receptacles in Wet Locations of Patient Care Areas of Health Care Facilities
513	550–6 (b)	Mobile Home Receptacles Outdoors & in Bathrooms
521	550–23 (c)	Mobile Home Service Equipment Additional Receptacles
527	551–7 (c)	Recreation Vehicle Receptacles
540	551–42	Recreation Vehicle Park Receptacles
543	555–3	Marina & Boat Yard Receptacles
549	600–11	Outdoor Portable Signs—Internal Wiring
598	680–5 (b)	Swimming Pools—GFCI Types Permitted
598	680–5 (c)	Swimming Pools—Wiring GFCI's
599	680–6 (a) (1) & (3)	Swimming Pool Receptacles
599	680–6 (b) (2)	Swimming Pool Lighting
601	680–20	Swimming Pool Underwater Lighting Fixtures
602	680–21	Swimming Pool Enclosures for GFCI's
605	680–24	Swimming Pool Grounding of GFCI's
605	680–25 (b) (2)	Swimming Pool—Methods of Grounding Exception No. 2
607	680–26 (b)	Electrically Operated Pool Covers
607	680–31	Storable Pools—GFCI's Required
607	680–40	Outdoor Spas and Hot Tubs—Listed Cord Connected Exception No. 2
608	680–41 (a)	Indoor Spa & Hot Tub Receptacles
608	680–41 (b)	Indoor Spa & Hot Tub Lighting Fixtures & Outlets
609	680–51 (a)	Fountains—GFCI's Required
610	680–56 (a)	Fountains—Cord & Plug Connected Equipment
611	680–62 (a)	Therapeutic Tubs—GFCI's Required
612	680–62 (f)	Therapeutic Tub Receptacles

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General Electric Company
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Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

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2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

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(Bylaw—Art. V, Sec. 6, 1st Sentence)

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(Bylaw—Art. V, Sec. 4, Subsection A)

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