

Determining the Cause of AFCI Tripping Class 760

Retain for future use.

INTRODUCTION

⚠ DANGER

HAZARD OF ELECTRIC SHOCK, BURN, OR EXPLOSION

This document is written for qualified electricians. Other than connecting and disconnecting receptacle loads, the work described here should be done only by trained professionals.

Failure to follow this instruction will result in death or serious injury.

Arc-fault circuit interrupters (AFCIs) are required for installation in residences under the 2002 National Electrical Code (NEC). To meet this requirement, SQUARE D Company has developed the QO[®] and HOMELINE[®] ARC-D-TECT[®] arc-fault circuit interrupters.

When an AFCI trips, the cause of the trip must be determined before placing the circuit back into service. This data bulletin outlines possible reasons for an AFCI to trip, both in new and existing installations. It explores the most common causes of tripping, but not all that can occur.

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EXISTING INSTALLATIONS

A standard QO or HOMELINE circuit breaker will trip to protect a circuit from overloads or short circuits. A QO or HOMELINE AFCI will also trip to protect against ground faults on the circuit and arc faults. Thus, a trip of an AFCI can be caused by: overloads, short circuits, ground faults, parallel arc faults, or the AFCI itself, each of which will be discussed below.

Overload Trip

An overload trip is caused by a circuit carrying more current than the handle rating of the circuit breaker allows. For example, a 20 A circuit breaker can carry a load totaling 2,400 watts (at 120 V), but should not be loaded with more than 80% or 16 A (1,920 watts) continuous, per the NEC.

The overload feature of the circuit breaker works via a bi-metal component of the circuit breaker heating and bending to cause the circuit breaker to open. Its operation is a function of the time and current. Tripping occurs after a delay; the greater the overload, the faster the circuit breaker will trip.

Example 1: The bedroom AFCI trips about 30 seconds after a blow-dryer is turned on. The following devices shut off at the same time:

- Electric space heater (1,300 watts)
- Dresser lights (150 watts)
- Floor lamp (150 watts)
- Television (200 watts)
- Coffee maker (600 watts)
- Hair dryer (1,200 watts)

Total: 3,600 watts

NOTE: When calculating loads, always include everything on the circuit. Keep in mind that the circuit may serve loads outside the affected room (such as the coffee maker in the example).

In example one, the trip was not instantaneous. This indicates an overload trip.

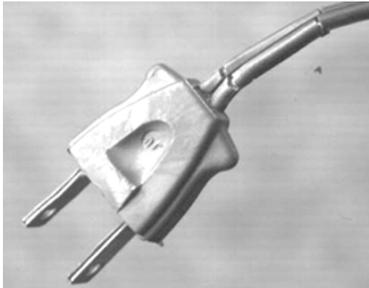
Calculating the total load of the circuit results in a total of 3,600 watts, far exceeding the 2,400 watts that a 20 A AFCI can serve without tripping. In fact, checking the trip curve for the AFCI shows that tripping should occur in 30 seconds when subjected to an overload of 1.5 times the rating (in this case, 3,600 watts).

One of the more obvious fixes for this example would be to leave the space heater off while using the hair dryer. Reset the AFCI and turn on each device except the space heater.

Short Circuit Trip

Figure 1: Damaged Electrical Cord

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Old, damaged cords are a common place for short circuits

A short circuit allows a very high amount of current to flow through the circuit. A short can appear between either line and neutral or line and ground.

As with most circuit breakers, an AFCI has an electromagnetic function that opens almost instantaneously when it detects a short circuit, typically in less than one-tenth of a second. It is important that the circuit breaker operates quickly to avoid damage to the conductors between the load center and the short circuit.

If a circuit breaker trips instantaneously when a device is turned on, remove the device from the circuit and turn the circuit breaker on. If the circuit breaker does not trip, there is possibly a short circuit in the device.

One phenomenon that appears as a short circuit to a circuit breaker (including AFCIs) is high inrush current. High inrush current can occur when several loads (or one large load) are connected to the switched half of the receptacles. If all the individual loads are turned ON, flipping a light switch ON can subject the circuit breaker to a momentary high inrush that far exceeds the normal operating current of these loads. This will appear as a short circuit to an AFCI and cause it to trip. The solution to this situation is to simply plug most of the load into the non-switched side for lighting. (This will prevent turning on several of the loads simultaneously.)

If there is neither a short circuit in one of the plugged-in devices nor high inrush current, then there may be a short circuit in the permanent wiring. Before checking the circuit, first open the AFCI (OFF position). Next, unplug all the devices from all receptacles on the circuit and turn off all lights or other loads. Finally, using an ohmmeter at the load center, check the resistance between line and neutral and line and ground. If either measurement shows low resistance (less than one kilohm), there is a short circuit between those conductors (or there are still connected loads). High resistance indicates the likely absence of a short circuit.

Example 2: The bedroom AFCI trips immediately whenever the electric space heater is turned on, causing everything in the room to turn off. Unlike the previous scenario, the hair dryer is not in use and there is no 30-second delay.

In example two, the trip was instantaneous. This indicates some kind of short circuit.

First, determine what load may have been added to the circuit when the circuit breaker tripped. In this case, it was the electric heater, so it should be unplugged and checked for shorts—if the circuit breaker can be reset when the electric heater is unconnected, this would indicate a short in the heater.

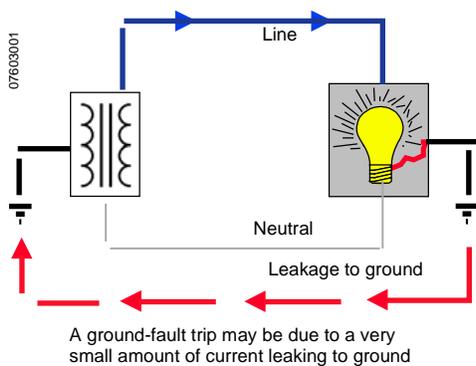
Ground-fault Trip

Ground faults are sometimes called “residual current faults” or “earth leakage” faults. They are due to unwanted paths from line to ground or neutral to ground. Unlike a short circuit, ground faults are typically much lower current. Most frequently, ground faults are caused by gradual deterioration of the wiring insulation or moisture in the circuit.

Usually ground fault interrupters (GFIs) can be found in a kitchen, bathroom, utility room, or outdoors. A GFI has the sensitivity (at 4–6 mA) needed to provide protection for people who might contact the circuit in some way. SQUARE D AFCIs do not provide people protection, but do detect residual current levels of 50 mA and greater.

In simple terms, the GFI or AFCI detects residual current by comparing the current flowing out on a line with current returning via the neutral. If these currents are not equal, then it is likely that there is an alternate return path, and thus a ground fault.

Figure 2: Diagram of a Ground Fault



A ground fault can be in either the permanent wiring, in an appliance, or in the appliance cord. Removing all the appliances from the circuit should be the first step to determine if there is a ground fault in an appliance or an appliance cord.

To confirm a suspected ground fault in the permanent wiring, remove all power from the circuit by opening the AFCI. Also, disconnect all appliances from the circuit. Then, look for low resistance between line and ground or between neutral and ground, indicating a ground fault.

Another test to check for a ground fault is to substitute a GFI circuit breaker for the AFCI. The GFI will trip at a lower level (4–6 mA) than the AFCI. If a ground fault is diagnosed, the faulty circuit (or the appliance) must not be used before it is replaced or repaired.

NOTE: Some electrical equipment such as motors, power converters, etc. may give the appearance of a ground fault, due to normal, non-linear behavior. But usually this leakage is much less than the 50 mA level, especially for devices found in a bedroom.

Example 3: Neither an overload nor a short circuit are found to be the cause of the bedroom AFCI tripping. Does this mean the trip was caused by an arc fault?

Not necessarily. An AFCI can also be tripped by the presence of a ground fault.

In example three, disconnect all appliances from the circuit. Substitute a GFI circuit breaker for the AFCI. If the GFI trips, then there is probably a ground fault in the circuit.

If the GFI does not trip, add the appliances to the circuit. If the GFI trips when one of the appliances is added, it must be replaced or repaired. If the GFI does not trip when all of the appliances are added, there is probably not a ground fault.

Arc-fault Trip

⚠ CAUTION
HAZARD OF INJURY OR EQUIPMENT DAMAGE
Do not continue to use any suspect loads until they are inspected and serviced. Replace them if necessary.
Failure to follow this instruction can result in injury or equipment damage.

After the other reasons for tripping have been examined and dismissed, an arc fault should be suspected. Tripping due to an arc fault appears to be instantaneous as do those from a short circuit trip and a ground-fault trip (typically in less than one-tenth of a second). Only overload trips respond relatively slowly (seconds or tens of seconds).

Again, the first diagnostic step should be determining if the arc fault is in the permanent wiring or in an appliance or its cord. Isolate all appliances by disconnecting them. If the AFCI does NOT trip when it is reclosed, then the problem is likely in an appliance or its power cord. The faulty appliance can be identified by connecting one load at a time until the AFCI trips again. Check the last load connected for arcing, insulation problems, shorted or pinched wires, etc.

If the AFCI continues to trip after all of the appliances are unplugged, then the problem has been narrowed down to the permanent circuit or AFCI. First, check for arcing, insulation problems, and shorted or pinched wires at outlets, switches, and junction boxes. If these simple tests do not show an obvious defect in the permanent wiring, it may be best to consider the AFCI next.

Example 4: The AFCI trips only when someone is sitting in a rocker in the corner.

The old lamp cord passing under the rocker has been there long enough so that the insulation on both conductors has been damaged, causing a parallel arc fault (line to neutral).

The cord should be replaced.

In example four, disconnect all appliances from the circuit. The AFCI does not trip when reclosed, so the problem would appear to be one of the appliances.

Connecting them one load at a time shows that the AFCI trips when the lamp in the corner is plugged in. An inspection of the lamp shows that the lamp cord, which is old and worn, has damage to the insulation on both conductors, causing a parallel arc fault (line to neutral).

The cord should be replaced.

The AFCI

NOTE: The AFCI includes a test button on the front. Its purpose is to verify the AFCI will trip. However, it cannot indicate whether it is tripping for no obvious reason. This push-to-trip button only functions if the AFCI is installed.

There can be two causes for an AFCI to trip when all other possible causes have been dismissed: either the AFCI is damaged or was installed improperly. See "New Installations" on pg. 5 before replacing the AFCI.

Disconnect the load power and the load neutral wires from the AFCI. If it continues to trip, the AFCI may be damaged and should be replaced.

If it is not obvious whether the problem is in the AFCI or the circuit, replace the AFCI with a new one. If the new AFCI does not trip, it is likely that the old one was damaged.

Check the Permanent Wiring

It is possible to confirm that there is either an arc fault or short circuit in the permanent wiring, and to even determine which conductor is the one affected. Follow this process:

CAUTION

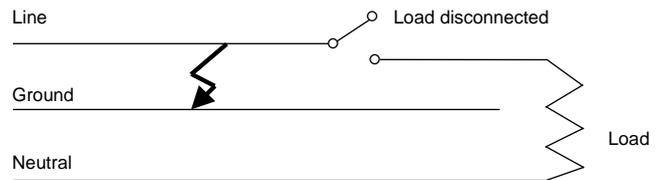
HAZARD OF INJURY OR EQUIPMENT DAMAGE

It is important to recognize that the AFCI has provided an indication of a condition that could be a fire hazard. Do not continue to use a circuit in this condition without correction.

Failure to follow this instruction can result in injury or equipment damage.

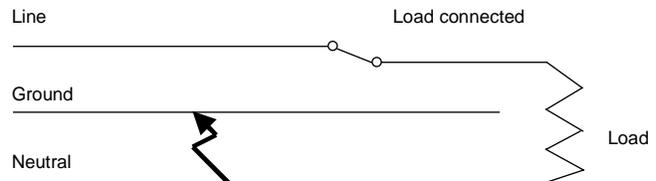
- Line (hot) conductor: If the AFCI trips even when there is no load connected to a receptacle, this indicates that the line conductor has a fault. The fault may be to the neutral or to the ground conductor.

Figure 3: Line Conductor Fault



- Neutral conductor: If the AFCI trips only when there is a load connected to a receptacle, that indicates it is the neutral that has a fault to ground.

Figure 4: Neutral Conductor Fault



NEW INSTALLATIONS

If an AFCI trips soon after it has been installed, some of the reasons may be different from those for an AFCI that has been in service for some time. The problem is much more likely to be incorrect installation, and much less likely to be an appliance problem. On a new installation, a trip of an AFCI can be caused by: overloads, incorrect installation, shared neutrals, short circuits, ground faults, parallel arc faults, or the AFCI is damaged, each of which will be discussed below.

Overload

First check whether any construction tools (air compressors, circular saws, etc.) are plugged into the circuits and overloading the AFCI. Be sure to check not only the receptacles in the affected room, but also any external outlets like those in an adjacent hallway.

Installation Procedure—Correct or Not?

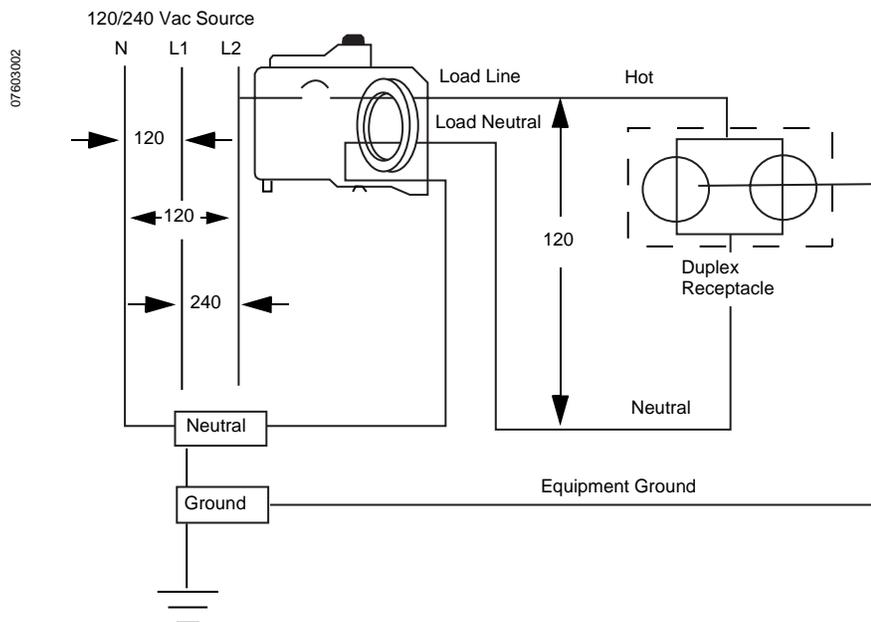
The next thing to check is the installation of the AFCI in the load center. Were the connections to the AFCI made properly? It is mandatory that these three connections are correct: load power wire (black), load neutral wire (white), panel neutral wire (coiled, white pigtail).

Usually, the color-coded wires make it easy to confirm that they were installed in the load center correctly. Refer to the Instruction Bulletin that came with the AFCI (instruction bulletins 48840-122-02, 48840-123-03). If you see a red wire connected to the load power terminal of the AFCI, see "Shared Neutrals," on page 6.

Make sure the load power and load neutral wires are not intermixed between two or more branch circuits. If they are, the AFCI will immediately trip when any load is applied.

If the wiring to the AFCI is correct, check for other wiring problems in the circuit.

Figure 5: Wiring of an AFCI

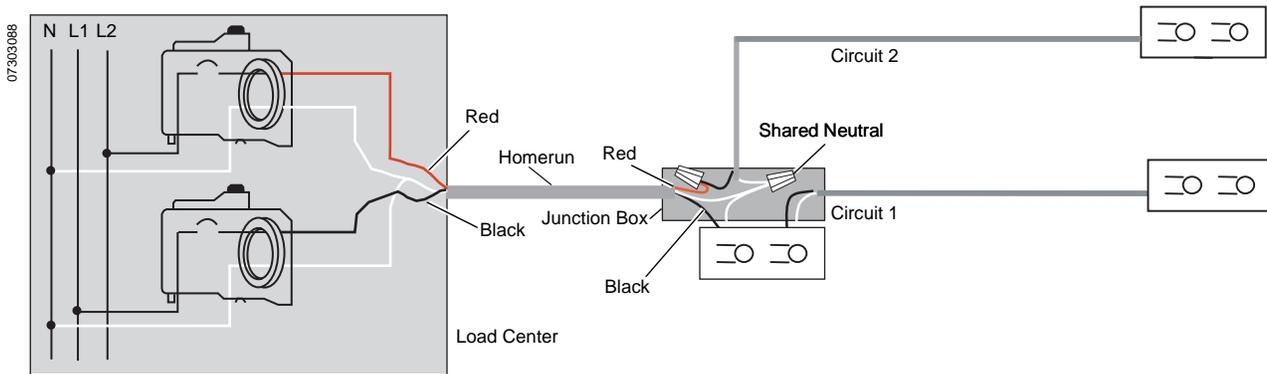


Shared Neutrals

Installing single-pole AFCIs to protect a “shared neutral” circuit will cause misoperation. Some localities allow the use of a shared neutral when running a home run cable to two adjacent bedrooms at the far end of a house. Other situations where shared neutrals may be found include:

- separate circuits for lighting and receptacle outlets
- kitchen circuits where under-cabinet outlets are separate from above-counter receptacles

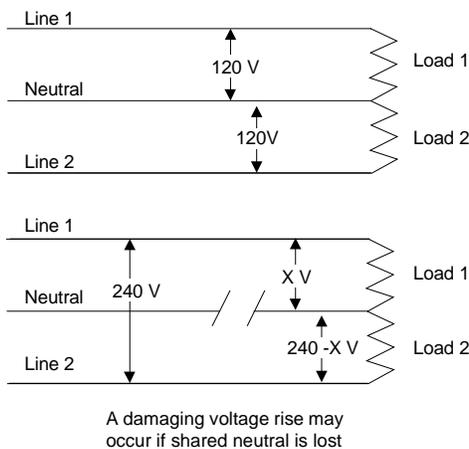
In the load center, the most obvious clue that there is shared neutral wiring is the presence of a black, a red, and a white wire from one cable going to two single-pole AFCIs.



A single-pole AFCI will not operate properly on shared neutral wiring. This may not become apparent until a load is applied to at least one of the circuits. The best solution to this is to avoid the use of shared neutrals and their inherent problems.

The practice of shared neutrals may seem attractive due to possible savings associated with the reduction of a neutral conductor. However, there are serious disadvantages to sharing neutrals:

Figure 6: Damaging Voltage Rise



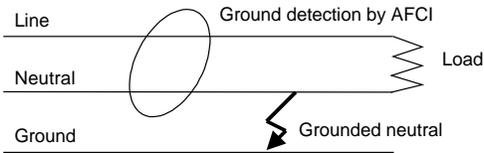
- If the shared neutral is lost, the connected loads are subject to voltages varying from 0 V to 240 V (line-to-line). This is especially true if one load has much larger impedance than the other. The likely result from this is severe damage to some connected devices due to extreme under- and over-voltage conditions. See Fig. 6.
- On two-pole common-trip circuit breakers, both circuits are interrupted during any type of fault. If a shared neutral circuit feeds two rooms, then both rooms lose power if a fault occurs in either. If a shared neutral circuit feeds receptacles and lights, both will lose power with a fault on either one.
- On two-pole independent-trip circuit breakers, one may find hot wires in a junction box that was presumed dead. One cannot overemphasize how dangerous this would be. If one of the shared neutral circuits were to trip due to a short-circuit or overload, the other circuit would remain hot. Anyone servicing any device in that junction box may be exposed to live conductors.

Short Circuits

Short circuits can occur in new installations. They are more likely to be in the permanent wiring since there are unlikely to be many loads plugged into the receptacles of a new house. A potential short circuit can be diagnosed using the process outlined in “Check the Permanent Wiring” on page 5.

Inadvertent Grounded Neutral

Figure 7: Detection of Grounded Neutral



A grounded neutral appears as a ground fault

Example 5: The wiring in a new split-level is complete and the electric utility has hooked up the meter. Inspection shows that all the circuits are fine—except for one bedroom AFCI. It trips whenever a ceiling light is turned on.

A special type of ground fault (but a frequent one) is an inadvertent grounded neutral. This occurs when the neutral conductor contacts a grounded conductor (ground wire, grounded outlet box, etc.). This can happen in a receptacle box, switch box, or a fixture. When this condition occurs, the balance between the line and neutral currents no longer exists and the AFCI trips.

To determine if the problem in example five is a grounded neutral, visually inspect the wiring at the ceiling light fixture. Discovery of the bare ground wire touching the neutral wiring connector of the lamp shows an inadvertent grounded neutral. The symptom—the AFCI tripping immediately when the lamp is turned on—is explained by the ground wire touching the neutral.

Arc Faults

Just as in existing installations, parallel arc faults in new installations are generally an infrequent cause of an AFCI tripping. However, if other causes of tripping have been ruled out, look at two potential arc fault causes:

Series arcing: A series arc is caused by a break in a conductor, and low current flow created by the high-resistance break attempts to cross the break and thus arcs. Loose connections can also be the cause of a series arc. Branch/feeder circuit breakers typically do not detect and clear the lower-energy, series arcs, unless the condition involves a fault to ground.

Parallel arcing: A parallel arc is caused by a partial short circuit between the line conductor and either neutral or ground. While these may be easy to detect in appliances and their electric cords, they can be difficult to locate in the permanent wiring. The most common cause of arcing in permanent circuits is a nail or screw driven through the wall into the conductor, damaging the insulation, and creating a low impedance path for the arc.

CONCLUSION

Understanding the different trip functions of an AFCI can help to determine why it has tripped. The preceding examples are not comprehensive but they should serve as a beginning guide to help you determine what has happened to cause a trip and what the proper correction should be.

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