LUTRON

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Revision A
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Arc-Fault Circuit Interrupters (AFCI)

Overview

This document will cover the basics of an Arc-Fault Circuit Interrupter (AFCI) and will discuss the specific models of breakers that can control a full circuit of dimmed lighting. As of January 2010, the Square D® AFCI breakers used in Lutron HomeWorks QS AFCI dimming panels are able to control 2000 W (16 A) of connected dimming load without any false tripping. Eaton also offers AFCI breakers that are rated for use in Eaton® load centers and can control 2000 W (16 A) of connected dimming load without any false tripping.

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General AFCI Information

What is an AFCI and what purpose does it serve?

An AFCI is a special circuit breaker that is designed to help protect against fires resulting from electrical arcing, often caused by damaged or deteriorated wires and cords. Fires result from the heat generated by electrical arcs near combustible materials (e.g., paper, wood, carpet). Some causes of damaged and deteriorated wiring include: puncturing of wire insulation from picture hanging, cable staples, drywall screws, poorly installed outlets or switches, cords caught under furniture or in doors, furniture pushed against plugs in an outlet, natural aging, and cord exposure to heating vents and sunlight.

How have AFCI breakers evolved into the National Electric Code® (NEC®)?

Section 210.12 of the 2002 edition of the National Electric Code® (NEC®) requires all branch circuits that supply 120 V~, single phase, 15 A and 20 A outlets (includes lighting fixtures as defined by code) installed in dwelling unit bedrooms to be protected by an AFCI listed to provide protection of the entire branch circuit. This requirement became effective January 2002 for all new installations.

Section 210.12 (Arc-Fault Circuit Interrupter Protection) of the 2008 edition of the NEC® increased these requirements to include dwelling unit family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sun rooms, recreation rooms, closets, hallways, or similar rooms for all new installations.

Section 210.12 (Arc-Fault Circuit Interrupter Protection) of the 2017 edition of the NEC® increased these requirements to include dwelling unit kitchens, laundry areas, or similar rooms for all new installations. For reference, the table below shows dwelling unit requirements for AFCI protection.

2017 NEC® AFCI Protection Dwelling Unit Requirements

Location	AFCI protection
Accessory buildings	
Basements (finished and unfinished)	✓
Bathrooms	
Shower stalls, bathtubs, or sinks where receptacles are within 6 ft (1.8 m)	✓
Bedrooms	✓
Boathouses and boat hoists	
Breakfast rooms	✓
Closets	✓
Crawl spaces at or below grade level	
Dining rooms, family rooms, dens, living rooms	✓
Floors	
Foyers	✓
Garages	
Hallways	✓
Kitchens	✓
Counter top, work surfaces, pantries, and dishwasher branch circuit	
Laundry areas	✓
Outdoors	
Parlors, recreation rooms, libraries, and sun rooms	✓

General AFCI Information *(continued)*

How do AFCI breakers work?

The internal circuitry of an AFCI continuously monitors current flow in the branch circuit. AFCI breakers apply intelligent algorithms to the current flow information to distinguish between normal arcing (e.g., arcing that occurs when a mechanical switch is opened or closed) and unwanted arcing. This allows the AFCI to detect arcing conditions that conventional circuit breakers are unable to detect. Conventional circuit breakers only respond to sustained overloads and short circuits. Therefore, they do not protect against arcing that is characterized by erratic current flow. Once an unwanted arcing condition is detected, the AFCI control circuitry trips and de-energizes the circuit to avoid a potential fire.

How do AFCI breakers respond to solid-state dimmed loads?

Phase control dimmers reduce the amount of power delivered to lighting loads, therefore reducing light output, by electronically switching current flow on and off. This electronic switching results in current flow as seen in Figure 1. AFCI breakers will interpret this current waveform as arcing and may trip if the amplitude of the current exceeds the predetermined threshold. The higher the connected load wattage, the higher the current, and the closer the current will get to the trip threshold. Additionally, most lighting loads have a brief warm-up period where they will draw significantly more than their rated power (~10x). When the current flow is temporarily higher than normal and changing rapidly during the warm-up period, means that false tripping may occur when a load is turned on.

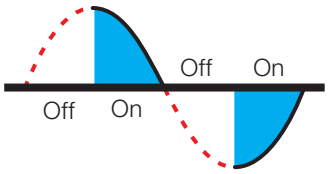


Figure 1 – Typical dimmer current flow

How do AFCI breakers respond to switched loads?

A switched output does not remove power from the load while in the on state and the current flow looks like Figure 2. The AFCI interprets this as “normal” current flow and will not trip.

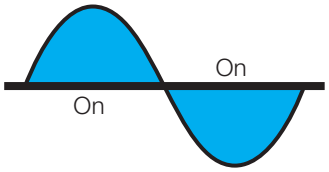


Figure 2 – Switched output current flow

If I set a dimmer to high-end with a zero second fade time, is that the same as a switch?

No. Most dimming products require a portion of the sine wave for charging the internal power supply and performing three-way signaling. This is shown as the small pieces removed from the sine wave in Figure 3. Dimmers will not power the load during this reserved period and thus do not meet the requirements of a switch. Therefore, setting a dimmer to high-end with a zero second fade time may cause an AFCI to trip if the maximum rated amount of connected dimmable load is exceeded.

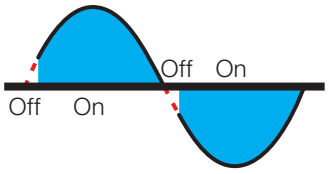


Figure 3 – Dimmer current flow at high-end

Does increasing the distance between the power module and load increase the chance of nuisance tripping?

Increased distance greater than 100 ft (30.5 m) between the power module and the load can increase the chance of nuisance tripping when certain AFCI breakers are used. This is a by-product of the ground fault protection on AFCI breakers. The load wiring will have some leakage to ground and dimmers will have increased leakage to ground. The leakage current can vary with the type of wiring used and may or may not be an issue depending on the breaker used. This applies to all phase control dimming devices on the circuit.

Using AFCI Breakers Rated For 2000 W of Dimming

Why is it a big deal to have the ability to control 2000 W of connected dimming load per AFCI breaker?

Breakers of all types are UL® Listed before being sold. To become UL® Listed, the testing criteria states that an AFCI will not trip when less than 1000 W of dimmed tungsten lighting is connected (UL® File 1699, Section 41.3.1, Subsection C). According to these testing requirements, it is permissible for an AFCI to trip with greater than 1000 W of dimmed tungsten lighting load. Remember that the goal of an AFCI is to try to detect arcs and disconnect the circuit.

Because of this, the number of AFCI circuits required on a project often needs to be doubled for dimmed loads that exceed 1000 W to prevent false tripping. This greatly impacts the design, installation, and overall cost of a project.

Does Lutron offer HomeWorks QS panels with AFCI breakers installed?

Yes. Lutron offers panels with AFCI breakers installed (PD8-65A-120Lx-xx and HWAP-8D).

Can I load each AFCI circuit with a full 2000 W of dimmable load?

Yes. As of January 2010 (Square D date code of 1001 or later), the AFCI breakers installed in Lutron AFCI breaker panels are rated for the full 2000 W of arc-fault dimming per circuit.

Who is the manufacturer and what are the model numbers of the AFCI breakers used in Lutron AFCI breaker panels in HomeWorks QS systems?

Lutron AFCI breaker panels use Square D QO series AFCI breakers, which are commercial-grade, high-magnetic inrush, combination AFCI breakers. The model numbers of the Square D QO series AFCI breakers that allow for 2000 W of connected dimming load are listed below. For Square D technical data sheets, see www.squareD.com

QO Series (plug-on)

- QO115CAFIC (1 pole, 15 A)
- QO120CAFIC (1 pole, 20 A)

Using AFCI Breakers Rated For 2000 W of Dimming *(continued)*

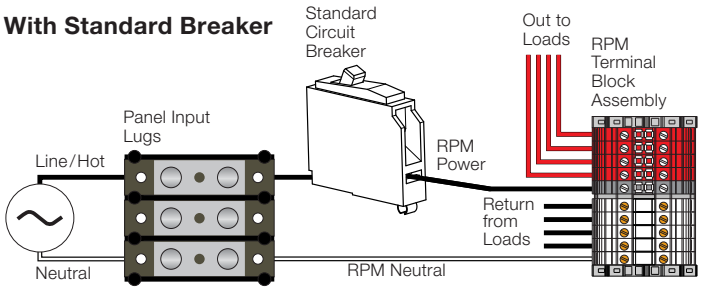
Can I retrofit a standard RPM breaker panel (HWBP) with AFCI breakers?

Yes, you can as long as Square D QO series AFCI breakers (called out previously) are used. See below for instructions. This procedure will require re-wiring a portion of the panel due to neutral wire requirements of the AFCI breakers. Modifying the breaker panel may affect the UL® Listing of the panel. A qualified UL® inspector should inspect the panel after the modifications have been made. Contact Lutron for details.

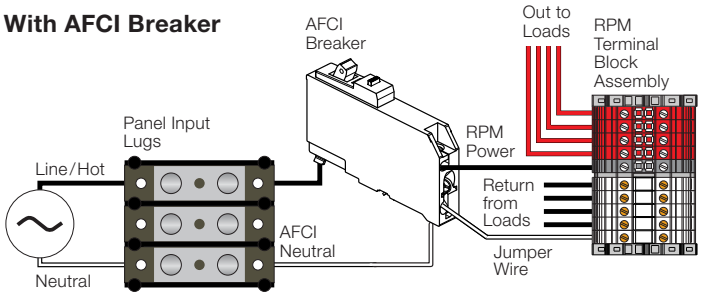
WARNING: Electric Shock hazard. To avoid the risk of electric shock, this installation must be done by a qualified person and must meet all local and NEC® codes. Failure to comply could result in serious injury or death.

1. Turn off input power to the panel.
2. Locate the circuit breaker to be replaced.
3. Remove the black RPM power wire from the breaker.
4. Remove the breaker.
5. Install the AFCI breaker.
6. Install the black RPM power wire to the load terminal on the AFCI breaker as specified in the instructions included with the AFCI breaker.
7. Remove the white RPM neutral wire from the RPM terminal block assembly on the same circuit as the breaker being replaced.
8. Connect the white RPM neutral wire to the AFCI neutral wire (pigtail wire permanently connect to AFCI). In most cases, an additional wire length will be necessary to reach the RPM neutral wire.
9. Install a jumper wire between the neutral terminal on the RPM terminal block assembly and the neutral load terminal on the AFCI breaker.
10. Verify wiring and turn on power to the panel.

With Standard Breaker



With AFCI Breaker



Using AFCI Breakers Rated For 2000 W of Dimming *(continued)*

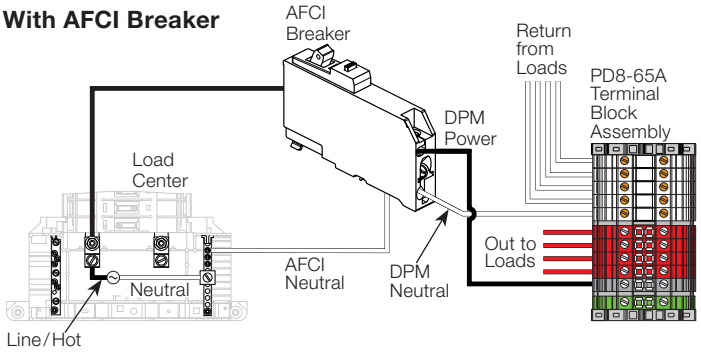
Can I replace AFCI breakers in PD8-65A panels with standard breakers?

Yes. Replacement of AFCI with standard breakers is easy to accomplish. See below for instructions.

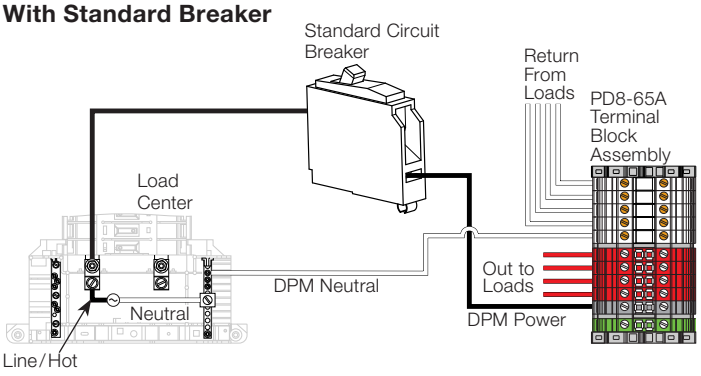
WARNING: Electric Shock hazard. To avoid the risk of electric shock, this installation must be done by a qualified person and must meet all local and NEC® codes. Failure to comply could result in serious injury or death.

1. Turn off input power to the panel.
2. Locate the circuit breaker to be replaced.
3. Remove the black DPM power wire and the white DPM neutral wire from the AFCI breaker.
4. Remove the white neutral wire permanently attached to the AFCI breaker from the neutral bar of the load center.
5. Remove the AFCI breaker.
6. Install a standard breaker.
7. Connect the black DPM power wire to the load terminal on the standard breaker. The DPM power wire can be black, red, or blue depending on the phase.
8. Connect the white DPM neutral wire to the neutral bar of the load center.
9. Verify wiring and turn on power to the panel.

With AFCI Breaker



With Standard Breaker



Using AFCI Breakers Rated For 2000 W of Dimming *(continued)*

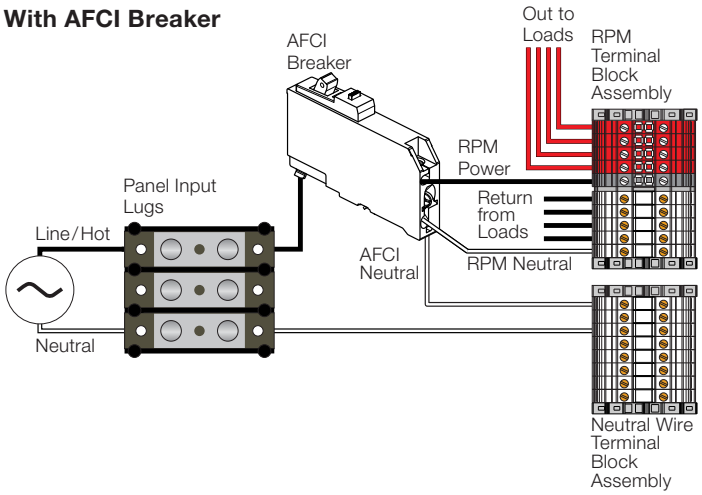
Can I replace AFCI breakers in HWAP panels with standard breakers?

Yes. HWAP panels were designed with additional terminal block connection points to make installation, removal, and replacement of AFCI and standard breakers easy to accomplish. See below for instructions.

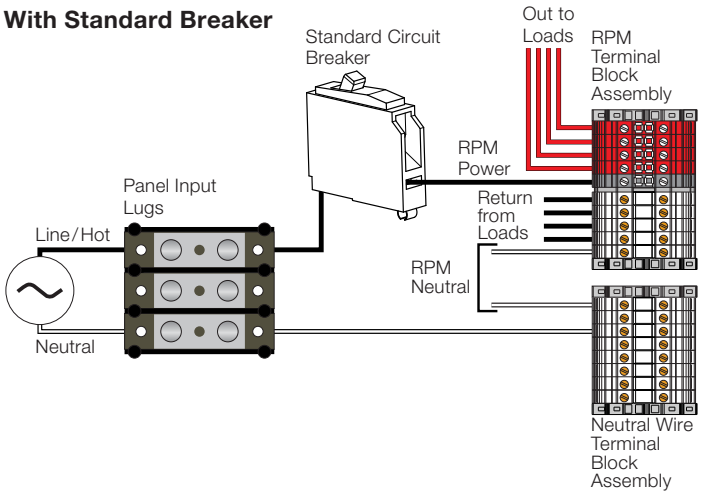
WARNING: Electric Shock hazard. To avoid the risk of electric shock, this installation must be done by a qualified person and must meet all local and NEC® codes. Failure to comply could result in serious injury or death.

1. Turn off input power to the panel.
2. Locate the circuit breaker to be replaced.
3. Remove the black RPM power wire and the white RPM neutral wire from the AFCI breaker.
4. Remove the white neutral wire permanently attached to the AFCI breaker from the neutral wire terminal block.
5. Remove the AFCI breaker.
6. Install a standard breaker.
7. Connect the black RPM power wire to the load terminal on the standard breaker.
8. Connect the white RPM neutral wire from the RPM terminal block assembly to the neutral wire terminal block.
9. Verify wiring and turn on power to the panel.

With AFCI Breaker



With Standard Breaker



Using AFCI Breakers Rated For 2000 W of Dimming *(continued)*

If I am not using Lutron AFCI breaker panels, but using other Lutron products (e.g., feed-through panels, local controls), am I still able to achieve the full 2000 W of arc-fault dimming?

Yes. There are 2 options available to achieve the full 2000 W of connected dimming load per AFCI circuit:

OPTION 1:

You can use Square D QO series or Homeline series AFCI breakers, with a date code of 1001 or later, mounted in Square D breaker panels (load centers). Square D breakers must be mounted in Square D breaker panels due to their proprietary mounting system. The model numbers of the Square D AFCI breakers are listed below and are available through Square D distributors and local home improvement centers. For Square D technical data sheets, see www.squareD.com

QO Series (plug-on)

- QO115CAFIC (1 pole, 15 A)
- QO120CAFIC (1 pole, 20 A)

QO Series (bolt-on)

- QOB115CAFIC (1 pole, 15 A)
- QOB120CAFIC (1 pole, 20 A)

Homeline Series (plug-on)

- HOM115CAFIC (1 pole, 15 A)
- HOM120CAFIC (1 pole, 20 A)

OPTION 2:

You can use Eaton BR, CH, or QB series AFCI breakers mounted in Eaton breaker panels (load centers). Eaton BR, CH, and QB series AFCI breakers are currently only UL® listed and rated for use in Eaton breaker panels. The model numbers of the Eaton AFCI breakers are listed below and are available through Eaton distributors and local home improvement centers. For Eaton technical data sheets, see www.eaton.com

CH Series (3/4 in (19 mm) plug-on)

- CHFCAF115 (1 pole, 15 A)
- CHFCAF120 (1 pole, 20 A)

BR Series (1 in (25.4 mm) plug-on)

- BRCAF115 (1 pole, 15 A)
- BRCAF120 (1 pole, 20 A)

QB Series (1 in (25.4 mm) bolt-on)

- QB1015CAF (1 pole, 15 A)
- QB1020CAF (1 pole, 20 A)

Using AFCI Breakers NOT Rated For 2000 W of Dimming

Am I able to fully load an AFCI circuit with 2000 W of dimmable load with "other" AFCI breakers?

No. Currently, Square D QO and Homeline series and Eaton BR, CH, and QB series AFCI breakers are the only breakers that have been verified with ALL Lutron products that allow for the full 2000 W of dimming capability. The maximum allowable dimming load with any AFCI breaker other than Square D QO or Homeline series or Eaton BR, CH, or QB series AFCI breakers is 1000 W.

If I am not using Square D QO or Homeline series or Eaton BR, CH, or QB series AFCI breakers, how does this impact my project design?

Lutron recommends using Square D QO or Homeline series or Eaton BR, CH, or QB series AFCI breaker whenever possible; however, we realize that this may not always be feasible.

To maximize dimming equipment utilization while still meeting the 1000 W maximum dimmed lighting load requirement on AFCI breakers that are not Square D QO or Homeline series or Eaton BR, CH, or QB series, it is recommended that lighting zones which typically do not require dimming be controlled by a switching device and that the load type be designated in the software as non-dimmed (when it is selectable). Mix these switched loads with dimmed loads to maximize equipment utilization. Closets, garages, and some outdoor lighting are often applications where dimming is not required, so switch those zones. By thoughtfully combining dimmed and switched lighting zones and being mindful of the 1000 W dimmed lighting maximum using AFCI breakers that are not Square D QO or Homeline series or Eaton BR, CH, or QB series, you can minimize the need for additional AFCI breakers and lighting control equipment.

See below and the next 2 pages for project design recommendations when using RPM panels, DPM panels, Maestro local controls, GRAFIK Eye units, or Wallbox Power Modules (WPM) that are controlling AFCI loads. If you exceed 1000 W of dimming in any of the examples, you will need to use one or more power boosters. Each power booster must be on a separate AFCI.

RPM Panels

Dimming modules (HW-RPM-4A, HW-RPM-4J, or HW-RPM-4U) accept one dedicated feed from the distribution panel. To minimize the required number of AFCI breakers, place all AFCI controlled loads together. Do not place more than 1000 W of dimming load on each AFCI breaker.

A single HW-RPM-4A, HW-RPM-4J, or HW-RPM-4U can support 4 zones at 1920 W total. Up to 1000 W on any or all of those 4 zones can be dimmed. Any load beyond the dimmed 1000 W must be switched* or moved to a different module or breaker.

Note: HW-RPM-4J has a lower zone capacity than HW-RPM-4A. Each zone on HW-RPM-4J has a maximum capacity of 720 W (6 A at 120 W).

Example:

	Dimmed Load		Switched Load		
Zone 1	300 W				
Zone 2			400 W		
Zone 3	500 W				
Zone 4	200 W				
	1000 W	**+**	**400 W**	**= 1400 W**	RPM total must not exceed 1920 W

Dimmed total must not exceed 1000 W

* This only applies to the HW-RPM-4U. HW-RPM-4A and HW-RPM-4J modules do not support switching.

Using AFCI Breakers NOT Rated For 2000 W of Dimming *(continued)*

DPM Panels

Phase control dimming modules (LQSE-4A-120-D) accept one dedicated feed from the distribution panel. To minimize the required number of AFCI breakers, place all AFCI controlled loads together. Do not place more than 1000 W of dimming load on each AFCI breaker.

A single LQSE-4A-120-D can support 4 zones at 1200 W total. Up to 1000 W on any or all of those 4 zones can be dimmed. The LQSE-4A-120-D does not support switching. Any load beyond the dimmed 1000 W must be moved to a different module (LQSE-4S8-120-D) or breaker.

Example:

	Dimmed Load (LQSE-4A-120-D)		Switched Load (LQSE-4S8-120-D)		
Zone 1	400 W		250 W		
Zone 2	100 W		250 W		
Zone 3	250 W		250 W		
Zone 4	250 W		50 W		
	1000 W	**+**	**800 W**	**= 1800 W**	DPM total must not exceed 1200 W

Dimmed total must not exceed 1000 W

Maestro Local Controls

Do not place more than 1000 W of dimming load on Maestro dimmers (models shown below) fed by AFCI breakers.

- HQRx-6CL*
- HQRx-6ND*
- HQRx-6NA*
- HQRx-10D
- HQRx-10ND
- HQRx-G25LW*
- HWx-6CL*
- HWx-6ND*
- HWx-6NA*
- HWx-10D
- HWx-10ND
- HWx-G25LW*
- RRx-6CL*
- RRx-6ND*
- RRx-6NA*
- RRx-10D
- RRx-10ND
- RRx-G25LW*

* A power booster is needed if exceeding product wattage rating. Refer to install guide or specification guide for individual dimmer power ratings.

1920 W can be attached to a single 20 A AFCI breaker. Up to 1000 W may be dimmed lighting load on a single dimmer or several dimmers combined. The remaining 920 W available for that AFCI must be switched.

Example:

	Dimmed Load		Switched Load		
Dimmer 1	100 W				
Dimmer 2	300 W				
Switch 1			200 W		
Switch 2			150 W		
Dimmer 3	400 W				
Dimmer 4	200 W				
	1000 W	**+**	**350 W**	**= 1350 W**	Circuit total must not exceed 1920 W

Dimmed total must not exceed 1000 W

Using AFCI Breakers NOT Rated For 2000 W of Dimming *(continued)*

GRAFIK Eye or Wallbox Power Module (WPM)

Do not place more than 1000 W of dimming load on GRAFIK Eye or WPM units (models shown below) fed by an AFCI breaker.

- QSGRJ-3P
- QSGRJ-4P
- QSGRJ-6P
- HQRJ-WPM-6D-120
- LQRJ-WPM-6P

Note: Zone count can vary on QSGRJ models.

Note: You must not exceed 800 W on any single zone of a GRAFIK Eye or WPM unit unless you are using a power booster.

Example: A QSGRJ-4P can support 4 zones at 1920 W total. Up to 1000 W total can be dimmed across any of those 4 zones. The remaining 920 W available for that AFCI must be switched.

	Dimmed Load		Switched Load		
Zone 1	600 W				
Zone 2			200 W		
Zone 3	400 W				
Zone 4			500 W		
	1000 W	**+**	**700 W**	**= 1700 W**	Total must not exceed 1920 W

Dimmed total must not exceed 1000 W

Lutron Recommendations for AFCI Nuisance Tripping

I have existing AFCI breakers with dimmable loads over 1000 W that are nuisance tripping, what options do I have?

1. Install or replace the existing load center with **either** a Square D load center with Square D QO or Homeline series AFCI breakers **or** an Eaton load center with Eaton BR, CH, or QB series AFCI breaker. This will allow for the full 2000 W of dimming per AFCI circuit.
2. If option 1 is not feasible, you will need to re-lamp the circuits to reduce the total wattage of the connected dimmable loads.
3. If options 1 and 2 are not possible, convert some of the dimmed loads to switched loads.
4. If options 1, 2, and 3 are not possible, while not guaranteed to resolve nuisance tripping, the following four suggestions are known to affect what the AFCI detection circuitry is measuring and therefore what the internal algorithm decides is happening (arc vs. no arc). Whether these suggestions resolve the AFCI nuisance tripping will depend on the specific conditions at the installation.

a. Change bulb wattages. 40 W bulbs at a higher dim percentage may cause less tripping than 60 W bulbs with a lower dim percentage and can provide the same light output.

b. Stagger when the loads turn on (both switched and dimmed). Due to the 10x inrush current when starting up a load, a delay of 1–2 seconds between the start up of large loads may avoid tripping.

c. Stagger the fade on/off rates of the dimmed loads. Fading on/off several loads at the same rate aligns the dimmers firing edges. Staggering these fading rates 0.5–3 seconds (or longer if possible) may avoid tripping.

d. Stagger or change the programmed dim percentages. 1000 W of dimming on multiple zones all set to exactly 50% may trip an AFCI but those same loads with the dim percentages staggered 45–55% may avoid tripping.

5. If all other options above are not possible, rewiring the installation to rebalance the loads is a last resort.

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