How many fixtures on that breaker?

How to determine fixture counts in the age of LED

Tom Steer, ETC Inc, December 2019

Introduction

In the age of tungsten, determining the number of lights you could fit on a dimmer was pretty easy. You determined the power of your lamps, in watts; used the relationship P=IV (Power = Current x Voltage) to find the current, and compared that with the circuit breaker in the module.

For example, to determine how many 575W HPL lamps could be run from a 20A, 120V dimmer:

I = P/V = 575/120 = 4.8A – so each 575W lamp takes 4.8A at 120V.

Now divide the circuit rating by the current

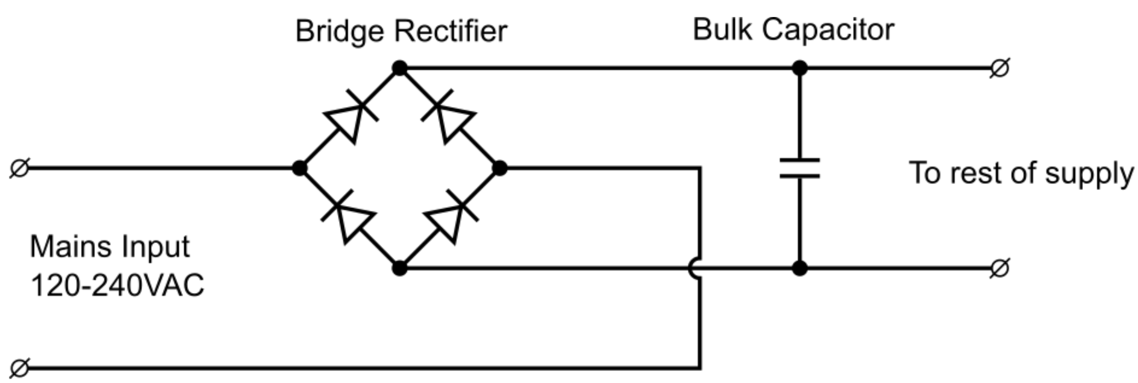
20 / 4.8 = 4.16 – rounding down, that means I can have a total of four 575W lamps on a 20A circuit

However, in the age of LED, an additional complication is introduced, which is ***power supply inrush***. This document will describe what power supply inrush is, how you can estimate the number of loads on a circuit, and the pitfalls in this process

Why is there inrush?

All modern LED fixtures (and indeed, many moving lights and other smart fixtures) have a switched-mode power supply in them. A switched-mode supply is an electronic device that converts the high-voltage, AC power from the mains supply to a lower, DC voltage to provide power to the internal electronics.

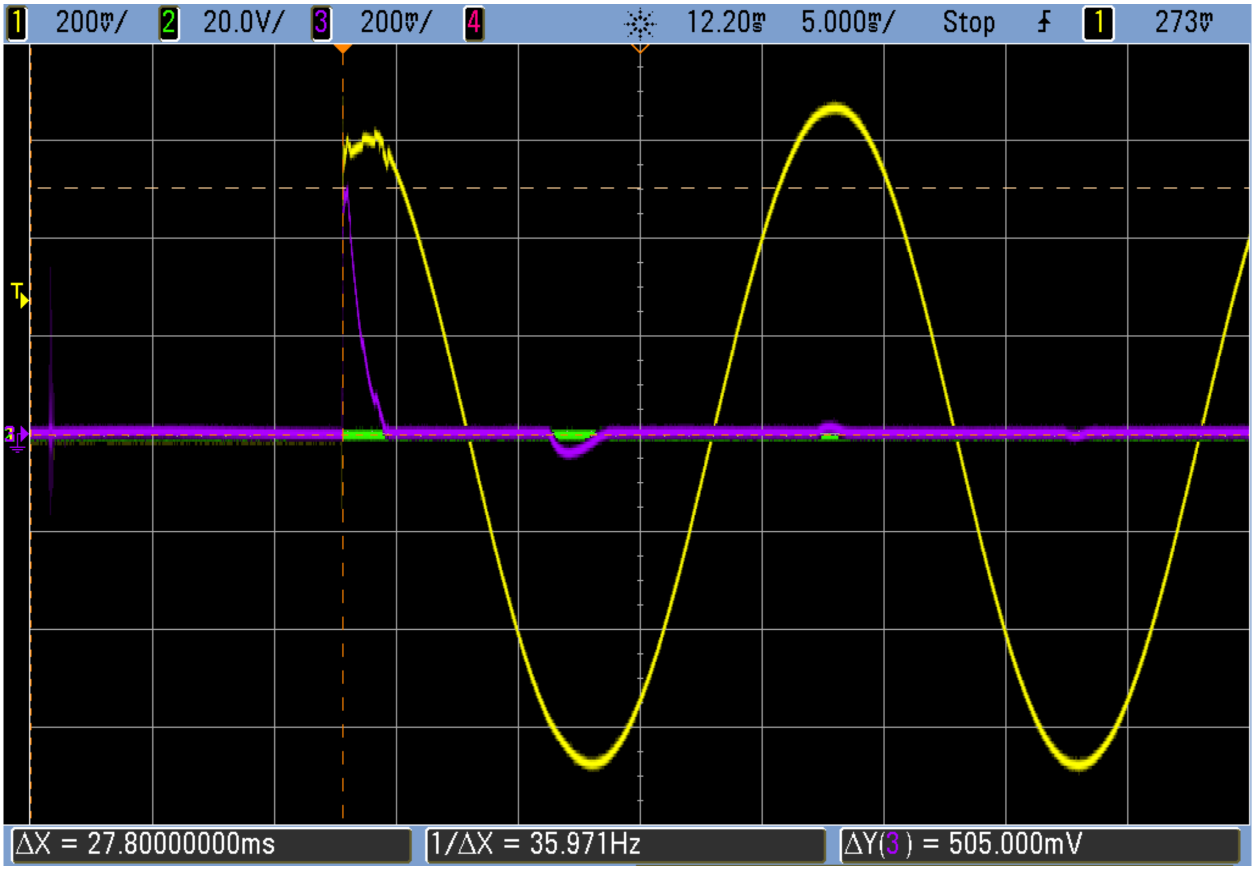
Understanding the precise way a switched-mode supply works isn't too important, but the input stage of these supplies usually look something like this:



If you think of electricity like water, the bulk capacitor you can think of like an empty tank. When the circuit first has power applied, water flows into the tank very quickly; once the tank fills up, there's no space for more water, so no water flows in. That initial fast flow is exactly what our inrush current is – current rushing in to fill up the bulk capacitor.

When you connect lots of power supplies onto one line, the amount of inrush adds together – so two switchmode supplies plugged in to a single line will have twice as much inrush as just one, and so on.

At ETC, when we release a new LED product we measure and publish the inrush data. Here's an example of an oscilloscope trace of the inrush for a fixture (in this case, the S4 LED Series 2)



The yellow trace is the mains waveform – power has just been turned on. The purple trace is current (20A per division). The current peak is 50.5A, but as you can see for a very short period – about 2.5 milliseconds (0.0025 seconds)

Why is inrush a problem?

The main problem with inrush is that it can trigger a device designed to protect us from too much current – a circuit breaker!

Circuit breakers are electrical-mechanical devices that are designed to protect us from too much current flowing which might start a fire. In a simplified way, they work by electromagnetism – the current flowing through the breaker is used to pull on a solenoid, which opens a set of contacts if too much current flows.

We are all used to the idea that circuit breakers have a "current rating" – like 16 amps or 20 amps – but that's not the full story.

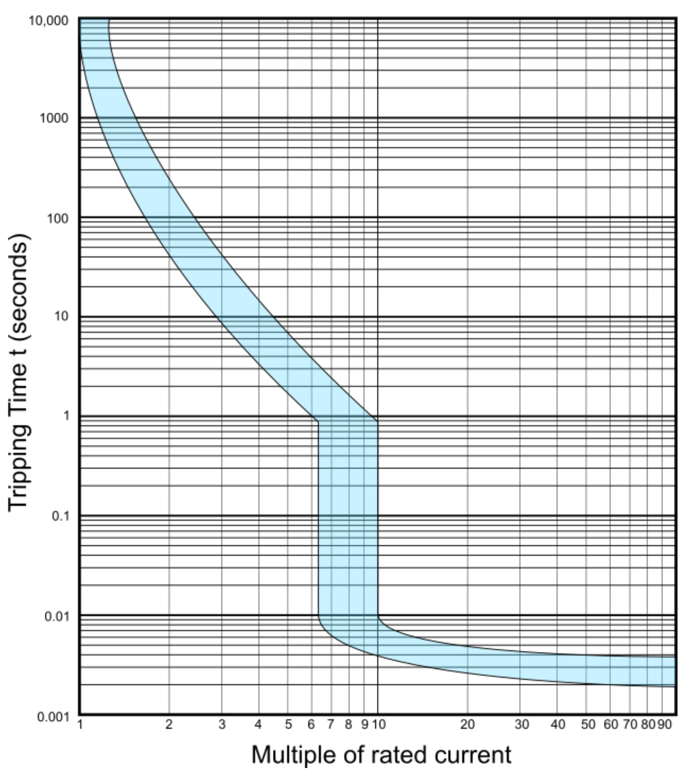
Many loads have some type of inrush as described above, so no common circuit breakers have an exact trip point. What the rating of a breaker means is that it will not trip when that much current is drawn through it – so for example, you can draw 20A through a 20A rated circuit breaker forever, and it won't trip.

Does that mean if you draw 20.1A it will trip instantly? No, it doesn't – generally, drawing more current will make it trip faster – but if you want to know the full story, you need what is called the ***curve*** of the circuit breaker. I'll now describe what a breaker curve is, and how to read it. If you have a breaker, the manufacturer of the breaker should generally be able to provide you with information on the curve.

For customers in Europe, and much of the world outside the USA, breaker curves are standardized. You will typically be able to find a marking on your breaker which indicates with a letter (Typically A-D, with a few additional options) the curve, with A being a "faster" curve and D being "slower". You can easily find curve drawings for the breakers online.

For customers in the US, breaker curves are less standardized, and it is best to obtain the breaker curve diagram from the manufacturer of the breaker you are using.

Here is an example of what a breaker curve drawing looks like:



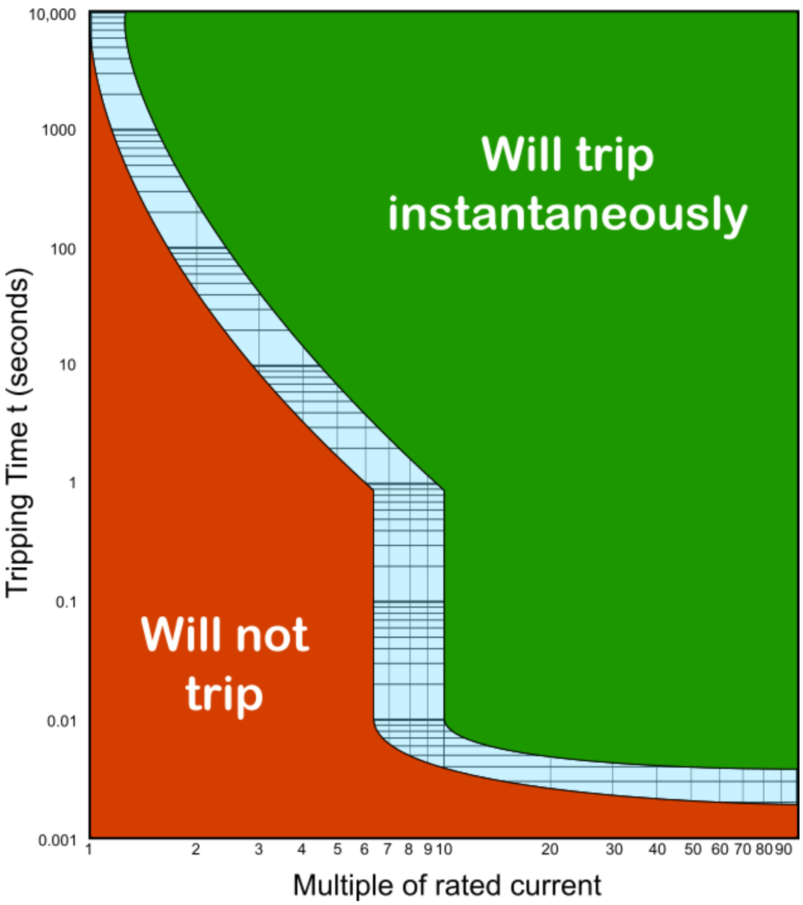
There's a couple of things to note about this:

This is a special type of graph called a ***logarithmic graph***. As you can see the numbers on the axes don't simply go up by the same amount every time; they go up, for example looking at the X axis, by 1 for the first 10 steps, but then it goes up by 10. This is a technique for squashing extra information into a graph that works quite well for this situation.

The second is to look at the axes. The horizontal/x axis is the multiple of the rated current, with 1, the actual rated current of the breaker, at the left.

The vertical/y axis is the tripping time, that is, how quickly the breaker will trip at any value of current.

Now on to how we determine what the breaker will do, which is the blue strip in the middle. It's sometimes easiest to think about this imagining the inverse of the strip, like this:



This makes it easier to understand. If a particular point is in the red, left-hand region, the breaker will not trip when subjected to those conditions. If a point is in the green, right-hand region, it is guaranteed the breaker will trip.

The middle area is a grey zone where the breaker may or may not trip based on manufacturing tolerances. If you are after working out the guaranteed maximum current you can deal with, you should probably use the left-hand edge of the central section.

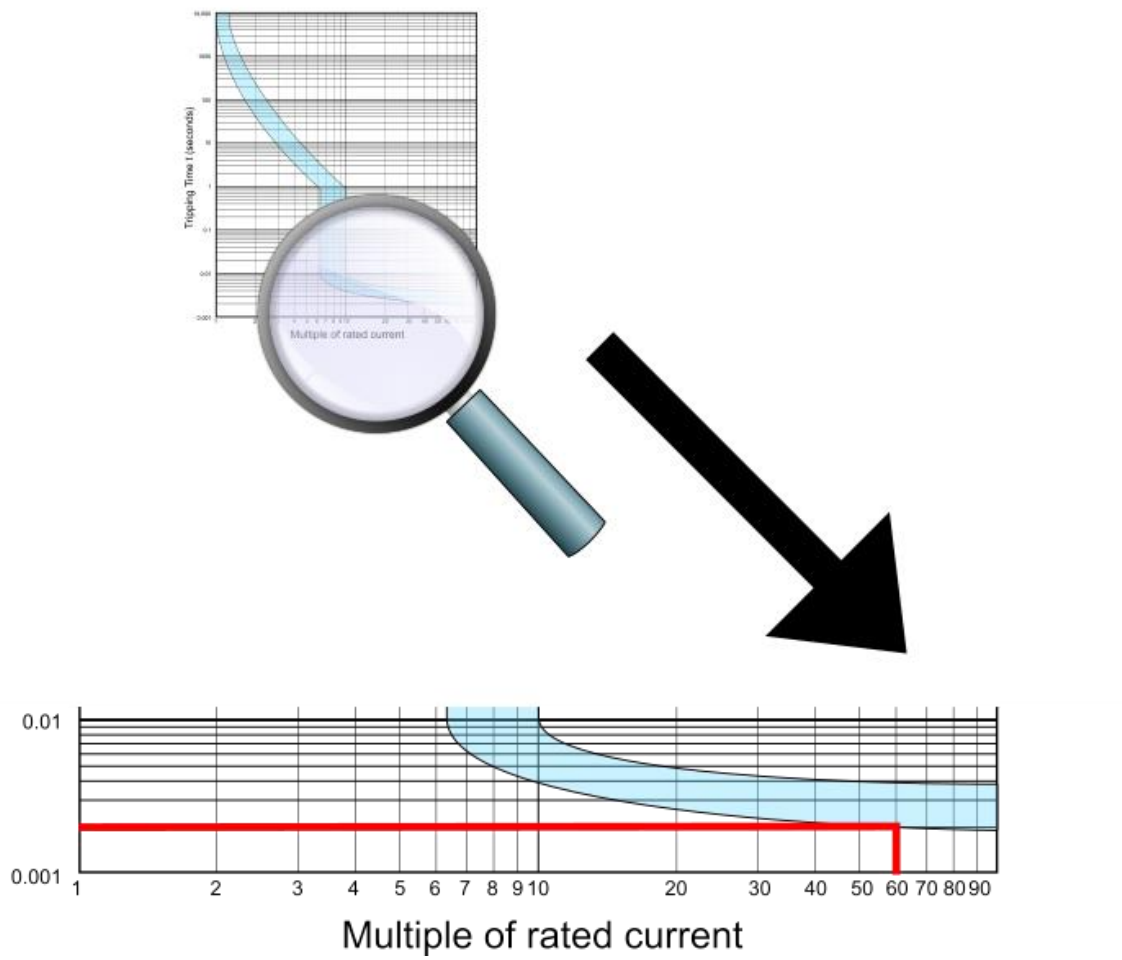
How to calculate fixture count

Now that we know what inrush is and how it is measured, and how to read a trip curve, we can put the two together to work out how many fixtures can be put on a particular circuit breaker.

Let's use our example circuit breaker, and Source 4 LED series two as an example.

We know that the S4LED draws 55A for 0.002 seconds

Looking at the bottom part of the graph, we can follow the 0.002 second line across:



By following across the 0.002 second line, we see this breaker can hold 60 times its rated current at this timespan.

If we say that in this example it’s a 20A breaker, that would equate to (60 x 20) = 1200A of inrush that it can tolerate for this time.

Since each fixture draws 55A of inrush our total would be (1200 / 55) = 21 fixtures.

Now, of course, you still need to check that against the normal running power of the fixtures, but most times the inrush is the limiting factor.

Is that it?

Unfortunately, not quite. Fixture numbers calculated this way are a very worst case estimate. In the real world, the impedance of the cable and the mains supply to the fixture tends to limit the inrush to the fixtures, meaning that in actuality you can probably have more fixtures and still be OK. However, unfortunately that is not really possible to calculate in advance. For now sticking with this design limit is probably for the best; as power supply designs continue to improve it is likely that the inrush will continue to decrease in newly designed products.

ETC lists the number of fixtures that can be reliably used on our own products with breakers on our datasheets. For third party breakers, you will need to perform the assessment as described above to calculate the number of fixtures a breaker can take.