



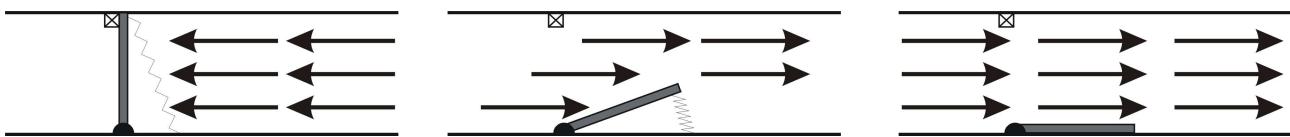
A Guide to LEDs

Simply put an LED is a diode that emits light. They are becoming the dominant light source but rapid changes in technology, terminology, wiring and control requirements causes confusion and misunderstanding. The aim of this document is to explain simply the general principles of LEDs and the associated terminology.

An LED is a diode that emits light and is an electronic device that will freely conduct electricity in one direction, its forward direction.

If we take a tungsten light bulb, the filament has an electrical resistance, and this restricts the amount of electricity that flow through it. So when connected to a supply with the correct voltage, the amount of electricity is regulated by the filament itself, which in turn gets hot and glows. Perhaps think of this as a hose connected to a tap, where the filament is the equivalent of pinching the hose to restrict how much water flows. The wattage of a lamp depends on the voltage and the resistance of the lamp (and therefore the current that flows).

An LED, being a diode is not like this, again in simplistic terms a diode acts like a spring loaded trap door, only allowing current to flow in one direction.



There is a certain amount of voltage, or electrical pressure required to open the door, and keep it open, but once open there's little or no restriction and any amount of electricity can flow through. This pressure required to open the door is the 'forward voltage' of the LED. Fed from a constant voltage a diode will turn on and then conduct huge electrical currents, and without anything to restrict this current will immediately overheat and destroy itself. A diode can therefore be thought of as a device that needs to be fed with an electrical source that provides an appropriate amount of current, or constant current.

The device which restricts this current for an LED can either be separate from the lamp, or incorporated within the lamp itself. Intrinsically all LEDs, the fundamental component, are always constant current devices. When a lamp, or fitting has a built in current limiter then that lamp or fitting can be fed from a constant voltage. Despite common usage often referring to these as being constant voltage LEDs, it is the lamp or fitting which is a constant voltage device, the core LED component is still, as always, a constant current device. Conversely we can then know that if a lamp is described as being 'constant voltage' it must therefore have some integral electronics, however simple, to perform the necessary current limiting.



Common types of LED lamps

Constant Voltage Tape

Constant voltage tape is commonly available in single or multi-colour varieties. Even though the rating of the tape is a low voltage, it is still a constant voltage rating i.e. 12 or 24V. This form of tape lighting will have an associated power supply, still outputting constant voltage, albeit at a lower voltage than mains, and therefore the tape must still have a current limiter fitted. This takes the form of resistors, which can invariably be seen on the tape as small dots, usually one for every 3 LEDs. This is using simple electrical resistance, as described when talking about tungsten lamps above, in line with the diodes to achieve the current limit. The downside to this method is that achieving a high brightness for each LED would involve the resistor getting hot, as a tungsten lamp would do, therefore higher brightness tape tends to simply use more LED/resistor groups.

Notes on dimming, LED tape is quite dimmable but requires either a dimmable power supply of some description or a dimming module connected between the power supply and the tape itself.

Mains Voltage GU10 Lamps

These lamps are rated to work from a constant voltage, in this case mains or 240V. And again there must therefore be some electronics to limit the current. In the case of a GU10 lamp the electronics are built into the base of the lamp, again these lamps are not simply LEDs but a combination of electronics and a single or multiple LEDs.

Notes on dimming, depending on the electronics fitted, this style of lamp may or may not be dimmable, the quality of dimming possible varies enormously.

Mains Rated Fittings

These are typically (but not always) supplied as fittings (lamp and luminaire combinations). They comprise of a constant current lamp and a driver, the term most commonly used for a separate current limiting device. The driver is the current limiting device and will often have the current rating marked on it e.g. 350mA, 700mA. The driver device may be attached, or even integral to the fitting or separate on a connecting lead. The manufacturer will supply the correct rated driver for the lamp.

These lamps may well be dimmable but the performance depends on the driver supplied.

Constant Current Fittings

These are LEDs mounted in a luminaire but without any current limiting electronics. To function these need to be paired with a driver, the current limiting device, with the correct rating. In some instances more than one fitting can be connected to a single driver or it can be a one to one pairing. Care needs to be taken to correctly match the ratings of the fitting and the driver. The two important characteristics are the current rating and the forward voltage rating. These terms are explained further later.

Notes on dimming – The performance when dimmed depends on the characteristics of the driver, as the LED fitting itself will be perfectly dimmable.



Low Voltage Lamps

These lamps typically have a 2-pin base and are designed to be direct replacements for low voltage halogen lamps, and work directly from the existing 12V transformer. Again, having a 12V rating these must have some built-in current limiting. These lamps have the challenge of compatibility between the lamp electronics and the existing transformer, which almost by definition is existing and therefore unlikely to have ever been tested with the lamp. Electronic transformers often have minimum load requirements when dimming, which typical LED lamps will not meet. They rarely dim satisfactorily except without significant wiring changes.

Tech Talk

To understand LEDs further we need to have a grasp of some basic electrical principles and the relationship between Power (measured in Watts), Voltage (measured in Volts) Current (measured in Amps) and Resistance measured in Ohms.

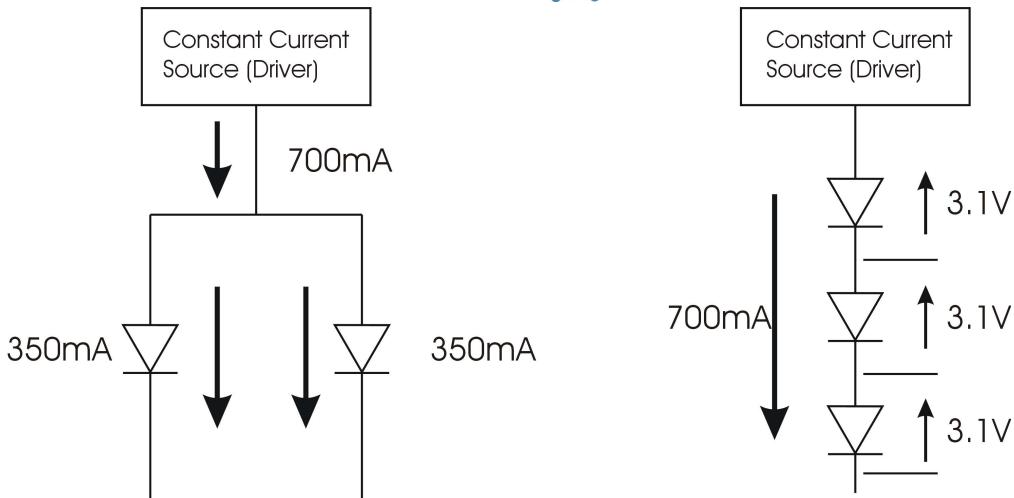
The power, or wattage of a device can be found by multiplying the electrical voltage and current, measured as volts and amps. Conversely we can find the current that flows through a lamp of a certain wattage by dividing the power by the voltage or find the voltage by dividing the power by the current. So if we take a 60w lightbulb that operates at 240v we know that the current flowing through that lamp is 60 divided by 240, giving the answer of a quarter of an amp. Equally we can calculate that if twice as much current were to flow, ie half an amp the power would be 240 (Volts) times 0.5 (amps) giving a power of 120W.

Knowing a few simple fundamentals we can then look at LEDs and the associated devices and make sense of the ratings that appear.

As we have described earlier, an LED, the actual core device is always a constant current device. It must be fed with an appropriate amount of electrical current and this, multiplied by the voltage required to switch it on (think of the trapdoor analogy) gives us the power. The voltage of an LED used for lighting purposes is usually in the region of 3-3.3V. For any calculations here we will take the operating voltage, known as the forward voltage as being 3.1V. An LED can take lots of electrical current but its life will be shortened by getting too hot, sometimes catastrophically. Therefore the current rating of an LED will therefore be governed largely by how efficiently the heat can be removed, in other words how good the heat sinking is. A high power fitting with a big heatsink may be rated as high as one amp, with a single LED giving a power of $3.1V \times 1A = 3.1W$. Equally an LED on flexible tape with no heatsinking may take as little as 0.02A giving a power per LED of 0.062W ($0.02A \times 3.1V$).

Using the above and looking at constant current LED fittings we can tell that with a single LED a fitting rated at 350mA (0.35A) will have a power of $3.1V \times 0.35A = 1W$. A single LED with a rating of 700mA (0.7A) will have a power of $3.1V \times 0.7A = 2W$. If we see a fitting rated as, for example, 700mA and 6W we know that there is more than one LED in that fitting. In fact we can presume that there are 3 actual LEDs fitted, even though the fitting may be described as 'an LED'.

If we now look at how multiple LEDs must be connected when fed from a single constant current source. If we take a driver that gives us say, 700mA. We know that each LED wants to be fed 700mA. If the LEDs were to be connected in parallel, DIAGRAM, the 700mA would have to be split between the LEDs, and each would only be fed with half, or 350mA. To receive the full 700mA constant current LEDs need to be connected in series.



In this way all the LEDs will receive the same current. This brings us to the next commonly misunderstood issue with constant current LEDs. We have described earlier how a certain voltage is required to make an LED operate. As we connect LEDs in series each LED requires another 3.1V to switch on and operate so as LEDs are added in series the total voltage required to switch on and operate adds up.

It is common to see markings on a driver for constant current LEDs to have a voltage range, e.g. 15-30V or a maximum voltage. This is the forward voltage that the driver can deliver, or the range in which it is designed to perform. We can also see that if 10 LEDs were to be connected in series the total forward voltage would be $10 \times 3.1V = 31V$ and therefore a driver with a 30V maximum voltage can only operate a maximum of 9 LEDs.

Once again we are discussing individual LED components, it may be that a fitting has a marked forward voltage of, say 10V, in which case we can assume that there are actually 3 physical LEDs within the fitting.

Unfortunately the method of marking and describing LED characteristics is not standard but some knowledge of their workings allows us to better understand what information is available.

Rating of LEDs When Used With Dimmers

LEDs are far more efficient light sources than tungsten lamps, hence their popularity, but the way in which they take their power means that a significant de-rating factor needs to be applied when calculating how many can be connected to a dimmer of a given rating.

With a tungsten lamp the power is taken smoothly across the whole mains cycle and as a result a dimmer could be loaded to its maximum rating (with maybe a small de-rating if transformers are used). An LED tends to take its power as a spike of power in the middle of the mains cycle **DIAGRAM**. Whilst the actual power taken may well be a lot less than a tungsten lamp of equivalent brightness the peak currents can be significantly higher. As a dimmer has electronic components with maximum current ratings, and may well have current limiting circuitry, these limits may well be reached with total load wattages well below the rating for a tungsten lamp.

One major LED manufacturer states a de-rating factor of 10 times when using lamps with dimmers. This would mean that when calculating the maximum load a dimmer can handle LED lamps should be considered as having the same wattage as a tungsten lamp of the equivalent brightness.



The severity of this 'spiking' effect is a function of the driving electronics and varies from lamp to lamp and fitting to fitting. De-rating by 10X is a safe but possibly conservative calculation but the only certain way to be confident of higher loadings is to test the lamp/fittings in question.

