help desk

Demystifying LEDs | By Wayne Howell

"LEDs are different - their effective resistance changes with voltage. The value depends on the chemical construction of the LED . . ."

Scanning back through my *Help Desk* columns I notice that I've often commented on how one particular subject seems to dominate questions that month. This month was no different, and the subject everyone's been asking about is what you can and can't do with LEDs . . .

It isn't surprising that there is a lot of confusion. We see LED products advertised as Tape, Constant Voltage, Constant Current, Bulb Replacement, LED Neon and many more terms.

There are essentially three types of LED on the market: constant voltage (CV) which includes LED tape and LED neon; constant current (CC), and LED replacement bulbs. This month, I run through the electronics that underlie CV and CC LEDs and will come back to mains LED and LED replacement bulbs in the future. Spoiler alert - there is some maths! OK, cast your mind back to May 1827 . . .

OHM'S LAW

Georg Simon Ohm published what is now known as Ohm's Law in 1827. The law tells us that the current through a conductor is directly proportional to the voltage across the conductor. The law can be written in numerous forms, but these are the most common:

$V=IR$

$I = V/R$

The second is most useful and seems fairly simple: the current (I) through a conductor is defined by the ratio of the voltage across the conductor (V) and the resistance of the conductor (R). Let's apply that to a simple circuit diagram (*see Fig 1*) . . .

The rectangle in the middle is a resistance of value R (in Ohms). This could be an electrical component called a resistor, or just the inherent resistance that exists in a copper cable.

The voltage across the resistance is Vr. Ohm's Law tells us that the current through the resistance (Ir) is: Ir = Vr /R

TURNING ON AN LED

The classic LED circuit is shown in *Fig 2*. The arrow symbol in red is the symbol used to designate an LED. An LED has a positive (anode) and a negative (cathode) terminal. The arrow points to the cathode - so, in this drawing, the anode is at the top and cathode at the bottom.

The intensity of an LED is defined by the current that flows through it; the bigger current, the brighter the light. All LEDs will have a maximum current rating and so need something to limit the current that passes through them. Without that they will burn out, pretty much instantaneously. The classic circuit above shows a resistor in series with the LED. The resistor is there to limit current.

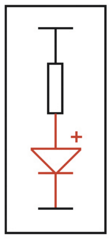
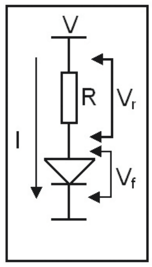


Fig 2

Fig 3



Let's add some parameters so we can describe the operation (*see Fig 3*).

This is very similar to the previous example; except we now have the voltage across the LED which I'll call Vf. The current flow though a resistance is linear against voltage - we get a nice straight-line graph. LEDs are different: their effective resistance changes with voltage. Vf is a parameter that is quoted by the manufacturer of the LED. The value depends on the chemical construction of the LED, ranging from 2V for green and yellow and up to 4V for blue (and so white) LEDs.

When the voltage across the LED is below Vf, it will not illuminate. When the voltage is above Vf, the LED will illuminate and the current flow will be controlled by the resistance.

For the purposes of this description, we can call Vf a constant for a particular circuit. The important fact is that I is the current though the entire circuit - it is the same current though the resistor and the LED.

Can we use Ohm's Law to calculate the resistance that will allow the LED to operate at the correct current?

$I = Vr / R$

$Vr + Vf = V$

So, we can calculate the correct value of the resistance as follows: R = Vr / I. Which is the same as: R = (V-Vf) / I.

REAL-WORLD EXAMPLE

We can use the above equation to choose the correct resistance for LEDs, where V is the voltage of the DC power supply you have chosen; let's say that's 24V. So, the equation becomes: R = (24-Vf) / I.

Let's assume you are driving a single 350mA blue LED. That means I = 350mA or 0.35A. So, the equation becomes R = (24-Vf) / 0.35. A blue LED will have a Vf of, say, 4V (check the data sheet). So, the equation becomes R = (24-4) / 0.35 = 20 / 0.35 = 57Ω.

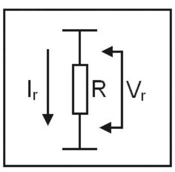


Fig 1

Wayne Howell is the CEO of Artistic Licence, the lighting controls company that he founded in 1988. Wayne invented Art-Net and is actively involved in the ESTA technical standards programme.

In fact, choosing a 24V power supply to drive a single LED would be a bad idea. As we can see below, it will waste a lot of power, generate heat and compromise the dimming.

An equation intimately linked to Ohm's Law is: P = I V. P is the power in watts. In the example above, the power dissipated in the resistance is: P = I Vr = 0.35 * 20 = 7W

To put that in context, 7W for a resistor is a huge amount of heat. This is why we have a divergence between the two key types of LED illuminator, constant voltage (CV) and constant current (CC).

CC LED light sources tend to use a small number of high current LEDs. As the calculations above describe, using a resistance to limit current in a high power LED is not viable. For this reason, electronic current limiting drivers (called constant current drivers) are used. This allows the CC LEDs to be driven efficiently.

CV LED light sources tend to use a large amount of low current LEDs. This allows very power efficient use of LEDs and current limiting resistors. The drawing below shows how the LED circuit in a white LED tape may look (*see Fig 4*).

Let's say we are using 24V white LED tape. In a tape, the LEDs are connected in series, which means the Vf of each LED is summed. So, the equation becomes R = (24-5*Vf) / I. The LEDs used in tape are relatively low power. We'll use 50mA for this example, turning the equation into this: R = (24-(5*4)) / 0.05 = 80Ω.

Equally important is the power calculation. The cumulative Vf of the series LEDs means that the voltage over the resistor is now only 4V. The power dissipated in the resistance is only 200mW.

P = I Vr

P = 0.05 * 4 = 0.2W = 200mW

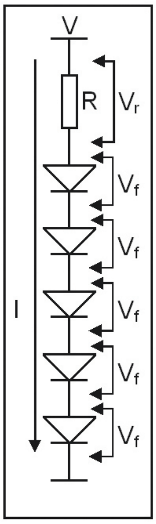


Fig 4

CONCLUSION

All LEDs need a way to control the current that flows through them. Ohm's Law allows us to calculate the resistance that will set the maximum current and the most efficient power supply voltage to use with a particular LED configuration. The two types of DC driven LED (CV & CC) on the market have benefits and drawbacks. Next edition I'll look at that in more detail . . .