C4 - Driver Lifetime

Issues effecting LED Driver lifetime.

Background

It is relatively easy to design a LED to operate for over 50,000 hours. It is *much* more difficult to design a LED *power supply* to last more than a few years.

Manufacturers claiming 50,000 hr LED lifetime are ignoring the reliability issues surrounding the operating of the LED driver. It is very likely that a standard Switched Mode LED Driver will need to be replaced multiple times over the life of a fitting.

LED Driver - Switched Mode Limitations

A switched mode LED driver is a power supply that converts AC mains voltage to a DC voltage for driving the LEDs. The high input voltage is rectified and filtered by components that store the energy between each mains cycle. The components that filter and store this energy are called Electrolytic Capacitors. The resulting high DC voltage is then able to be converted back to high frequency AC by chopping or switching it into a transformer. The transformer delivers a scaled AC output voltage which is again rectified and filtered (again usually with electrolytic capacitors) to provide the DC for driving the LEDs. So the low frequency AC has been converted to DC, back to high frequency AC where it is scaled and converted back to DC again.

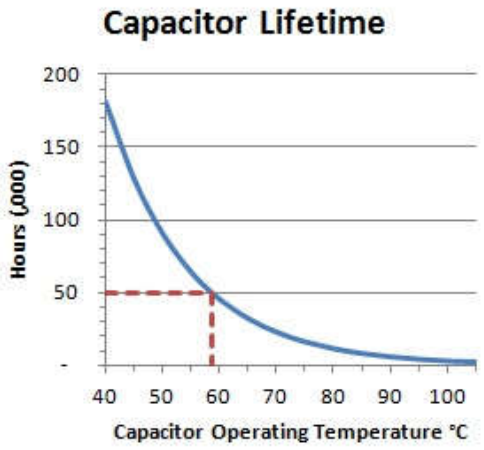
Although complex, the advantage of this system is that the transformer size is inversely proportional to frequency, so as the switching frequencies increase (500kHz - 1MHz) the transformer and output capacitors are miniaturised, and so the final solution can be much smaller and lighter than a traditional mains frequency transformer solution.

The disadvantage of this system is large amounts of electrical noise (from the high frequency switching) and lifetime limitations on the capacitors used to provide the filtering. Electrolytic Capacitors have typical lifetimes of 2,000 hours at rated temperature (usually 85°C or 105°C).

Capacitor lifetime will typically double for every 10°C reduction in operating temperature[1].

If a power supply used a 2,000hr 105°C rated capacitor that was run at 95°C, then you could expect this capacitor to last ~4,000hrs.

This means that in order to achieve a 50,000 hour lifetime, the 105°C rated capacitor must be run at less than 58°C throughout its life, regardless of the external ambient temperatures.



[1] $Lifetime_{Expected} = Lifetime_{Rated} \; 2^{\frac{Trated \; Ta}{10}}$ where T_a is the operating temperature of the capacitor

At 40°C ambient, this design would allow for an 18°C internal temperature rise before lifetime is compromised. Note that a 105°C rated capacitor is a relatively high quality item. Consumer grade parts may only be rated at 1,000 or 2,000 hours at 85°C meaning they must be run at 28°C or 38°C respectively, to offer the same 50,000 hour lifetime.

This temperature related lifetime limitation demands that the power supply must be run cool. Mounting the power supply directly on the LED heat sink, or under a hot roof, can severely compromised the power supply lifetime.

Figure 1. Typical Switched Mode LED Driver showing 8 major Electrolytic Capacitors in use.

Mean Time Between Failure (MTBF) Reliability Predictions

In an attempt to quantify likely failure rates, engineers derive a Mean Time Between Failure figure. MTBF figures are usually derived from MIL HDBK-217F which is a commonly used (military) standard that defines how failure rates may be predicted by summing the expected failure rate of each component, referring to each component's operating stress.

The MTBF figure ***does not*** directly relate to lifetime. Rather it indicates a likely failure rate according to the formula :

$$Failure\ Rate\ = \frac{Operating\ Hours}{MTBF}$$

From the datasheet, a typical LED driver can be expected to have a MTBF of 250,000 hrs ***at 25°C***. It is important to understand that this temperature relates to the *internal operating temperature* of the components. This MTBF figure typically decreases substantially when operated at normal running temperature. For example, on this same power supply, this figure will reduce to 85,000 hrs (55°C) or 15,000 hrs (85°C).

Regardless of the manufacture warranty, it can be seen that you could expect 72% failure rate on a 7yr warranty when run at 55°C[2] or a 409% failure rate when run at 85°C[3]! Even if you could run this power supply at an internal temperature of 25°C, you could still expect a 20% failure rate in 50,000 hours of operation.[4]

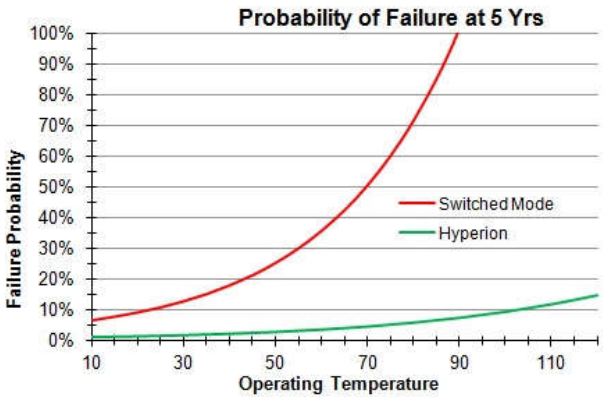


Figure 2. Probability of Failure with Increasing Temperature

Compuspec "Long Life" Driver technology

By eliminating the use of Electrolytic Capacitors, the Compuspec Hyperion driver technology has a MTBF of 1,100,000 hrs at 25°C reducing to 756,000 hrs at its normal running temperature of 55°C.

This results in an expected failure rate of just 6% over a 7 year warranty (at least a 12 fold reduction over competing technologies.)

[2] Failure Rate (7 yrs) = 61,320 hrs / 85,000 hrs = 72%
[3] Failure Rate (7 yrs) = 61,320 hrs / 15,000 hrs = 409%
[4] Failure Rate (50k hrs) = 50,000 hrs / 250,000 hrs = 20%