LED Drivers And Capacitor Reliability

There is some question as to whether the use of aluminum electrolytic capacitors is appropriate for LED driver circuitry. The question is raised in response to a high failure rate of these units in the late 1990s and early 2000s. It should be remembered that the current controversy regarding the reliability of these capacitors grew out of a case of industrial espionage. Company A stole from the formula for the electrolytic fluid used in the capacitors from Company B. It was later found that the stolen formula was either incorrect, incomplete, or both. Company A sold its fluid for a very attractive price and, as a result, a large quantity found its way into the supply stream, with the major victims being Taiwanese capacitor companies. Most of the offending units were used in the manufacture of computer mother boards and power supplies which started experiencing high failure rates after approximately a year of service. At the present time, these defective capacitors have been purged from the supply stream.

The question remains, are aluminum electrolytic capacitors inherently unreliable? The short answer is no. The slightly longer answer is that capacitors have always had higher failure rates than other electronic components. Thus, relatively speaking, they have high failure rates, but in absolute terms, they are extremely reliable when correctly used. Aluminum electrolytic capacitors are ubiquitous, and are included in applications with the most stringent reliability requirements, e.g., Minuteman missiles. Also, the expected life numbers found on catalog pages assume the capacitor is being run at its maximum rated voltage and maximum rated temperature. Once these stress factors are reduced, the expected life increases dramatically.

For an objective estimate of reliability, the failure rates and methods of calculation contained within MIL-HDBK-217F are up-to-date, complete, and conservative. The failure rate for a given component is calculated by taking its base failure rate and multiplying that figure by various usage related factors. For aluminum electrolytic capacitors, the overall failure rate is given by:

$$\lambda_\tau = \lambda_\rho(\alpha T \cdot \alpha C \cdot \alpha V \cdot \alpha SR \cdot \alpha Q \cdot \alpha E)$$

where λ_τ = total failure rate

λ_ρ = base failure rate

αT = temperature stress factor

αC = capacitance factor

αV = voltage stress factor

αSR = ESR factor

αQ = quality factor

αE = environmental stress factor

In MIL-HDBK217F, failure rates are given in failures per 10^6 hours. For the capacitors in question the failure rate is:

$$\lambda_\rho = .00012/10^6 \text{ hours}$$

The other factors are:

αT = temperature stress factor

αC = capacitance factor

αV = voltage stress factor

αSR = ESR factor

αQ = quality factor

αE = environmental stress factor

Some of the critical factors are calculated as follows:

$$\alpha V = (S/.6)^5 + 1 \quad \text{where } S = (\text{applied dcV} + \text{acV})/\text{rated V}$$

$$\alpha T = \exp\left\{(-.35/(8.167 \times 10^{-5}))\ (1/T+273 \cdot 1/298)\right\}$$

$$\alpha C = C^{.23}$$

For purposes of this calculation, it was assumed that commercial parts with no reliability screening would be used, along with a worst case ground-based environment That led to the factors used here being:

$\alpha T = 2.9$ (assumes 50 deg C ambient)

$\alpha C = 3.4$ (assumes 200 mfd)

$\alpha V = 5.7$ (assumes S = 0.7)

$\alpha SR = 1$ (recommended value from MIL-HDBK-217F)

$\alpha Q = 10$ (value for non-reliability rated commercial parts)

$\alpha E = 10$ (based on non-protected ground environment)

Using these values, the total failure rate per capacitor is:

$$\lambda\tau=(.00012/10^6 \text{ hours})(2.9 \cdot 3.4 \cdot 5.7 \cdot 1 \cdot 10 \cdot 10) = 0.674424/10^6 \text{ hours}$$

Thus, if you are designing a circuit which uses ten aluminum electrolytic capacitors and you remain within the stress factors given, you would expect an average failure rate of 6.7 failures per million hours (or one failure approximately every 150,000 hours) based solely on capacitor failure rates. The overall failure rate will, of course, be higher once the rates for the other components are included. The failure rate of the capacitors is quite low and would certainly result in a driver with an expected life which exceeds the published L50 or L70 lumen maintainence figures given by the LED manufacturers.

It is also important to realize that not all of the capacitor failures noted during the so-called ñcapacitor plagueò were catastrophic failures. Rather, some were characterized only by a reduction in capacitance. Whereas diminished capacitance would result increased ripple on the VCC supply in a computer could cause degraded operation, it would have much less impact on an LED driver.

This is encouraging in view of the fact that aluminum electrolytics have the highest available volumetric efficiency for energy storage in voltages over fifty volts. At lower voltages tantalum capacitors have an advantage in volumetric efficiency. The failure rate of tantalum is attractive at low stress factors, but increases drastically if the voltage stress exceeds 50%.

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