flex Power Modules

DESIGN NOTE 002

Reliability aspects on power supplies

Abstract

As power supplies are the very heart of every electronic equipment, special attention must be paid to their reliability. For other electronics a certain failure mode, at least for a part of the total system, can often be tolerated without serious (critical) aftereffects. However, for the power supply no such condition can be accepted, since very high demands on the reliability must be achieved. The MTBF value (Mean Time Between Failures) is a quantitative measure of a product's reliability performance. This design note will explain how the MTBF and other definitions involved are found, and translates these definitions/values into practical examples as how the end-user can handle them.

Contents

General

Depending on the end-user area examined, present power supplies (DC/DC or AC/DC) can be described with MTBF from 100,000 hours at +35°C for typical office automation products up to 400,000 hours at +50°C for military and space use. Bearing in mind that the MTBF value decreases as the temperature increases, the importance of comprehending and handling these figures in a realistic way will be easily understood. Before going deeper in the different reliability definitions, it can be useful to make the following statements concerning a products failure rate behaviour during its lifetime (see fig. 1). It shows three distinct periods during the lifetime of a product.

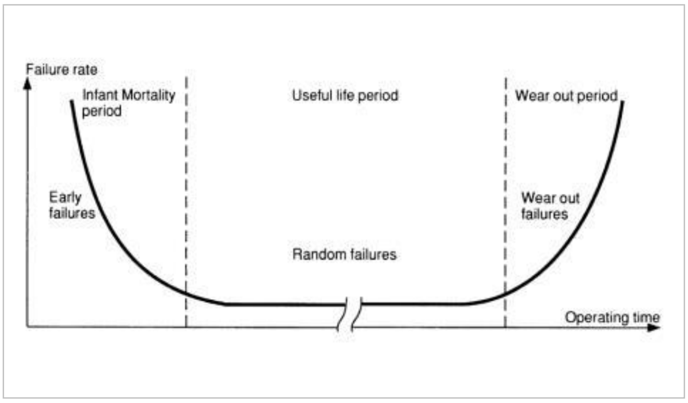

Figure 1: Typical failure rate curve known as the ''bath-tub-curve''

Infant mortality

During this period early failures occur at a decreasing rate as weak components fall out. The reasons for failure during this period are to be found in defects in technology, bonding, die-attach, mechanics, encapsulations, etc. To eliminate these failures, visual inspections and different kinds of electrical tests in combination with burn-in are carried out. In the burn-in, products are put into operations during a pre-determined period of time at room temperature or elevated temperature, to decrease the duration, followed by a 100% ATE-testing. This procedure makes it possible to provide a good quality level on the outgoing products.

Useful life time

After the initial relatively high but decreasing failure rate, a low and constant failure rate period follows. It is from this period that all statistic failure rates, which are used in the reliability calculations, are recorded. No testing method or burn-in process can avoid the failures occurring during this period. These occur at true random instances and are mainly related to temperature and voltage stress.

Wear out

In this period, the failure rate starts to increase due to the component's ageing, mechanical stress or other such reasons. The lifetime has ended.

Design rules

It is well known that the temperature has a great influence on reliability. Often ''rules-of-thumb'' are used for correlating one failure rate figure with another. One of these rules indicates that the figure doubles for every 7-10°C increase in temperature.

That rule takes for granted that all products are built following the same principles, and that components are equally utilized (i.e. chip temperatures are equal at given ambient temperature, etc.).

This is of course not true. One equipment/unit may use semiconductors at a temperature close to the ratings which the component supplier gives as maximum ratings, while another equipment/unit may have a built-in security in terms of utilization of lower temperature. Some of the later experiences shows that the failure rate will double for every 15-20°C increase during normal temperature conditions.

Since the temperature influence on the reliability can be described as an exponential function, it is obvious that these ‘‘rules-of-thumb” must be used carefully.

In fig. 2 an approximate curve of the relation between failure rate and temperature is shown.

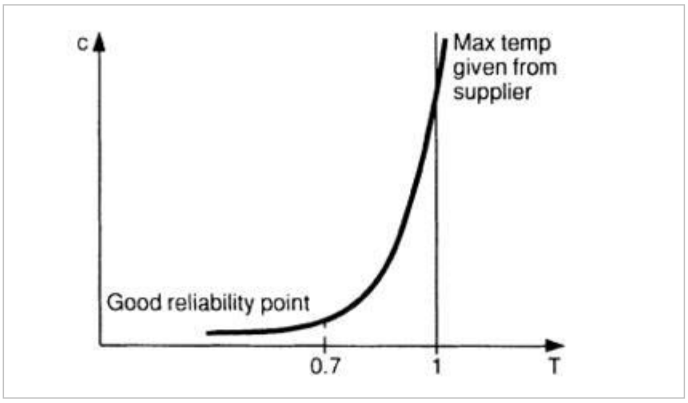

Figure 2: Behavior of acceleration factor (c) vs temperature (t)

Another ‘‘rule-of-thumb” which can be more valuable, signifies that at 0.7 T_{max} good reliability can be expected. Note that for semiconductors, +150 or +175°C is often guaranteed as T_{max}. In consideration of these figures, the chip temperature of semiconductors should be kept below +105 and +125°C respectively. Far too often this figure is exceeded, especially for power handling equipment. Keeping chip temperature low, in conformance with this design rule, will remarkably increase the reliability of an equipment.

Reliability definitions

Reliability calculations and designations are often misunderstood and confusing. Different MTBF values are often compared without clarifying the criteria for the calculations. It is therefore necessary to define the terms involved.

The reliability function

As previously stated, the reliability of a component can be described as an exponential function. The probability of finding a component operating after a time period, is defined as:

R (t) = $e^{-\lambda \cdot t}$

Where λ is the constant failure rate during the useful life period.

The mathematic mean value of R (t) occurs at t equal to 1/λ. 1/λ is the mean time elapsed until a failure occurs, or the ‘‘Mean Time To Failure”, MTTF.

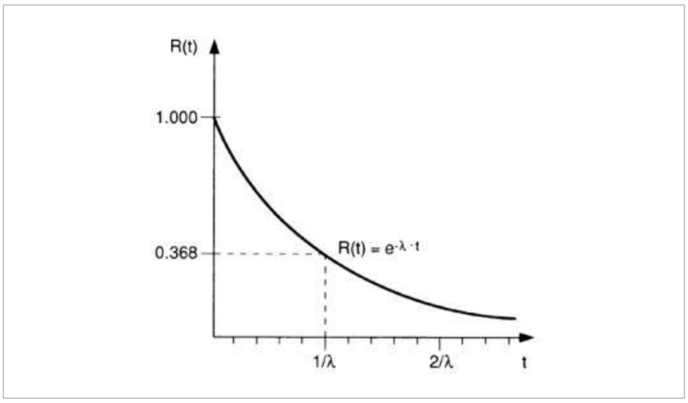

Figure 3: Reliability function

MTBF (Mean Time Between Failures)

As repair time (MTTR) normally can be neglected compared to MTTF for electronics, MTBF can be found as:

$$\mathbf{MTBF = MTTF + MTTR}$$

$$\mathbf{\approx MTTF = 1/\lambda.}$$

MTBF or the failure rate can be calculated using different kinds of input data. There are mainly 2 different categories:

Predicted value: Theoretically calculated value using ground failure rates and acceleration factors. MIL-HDBK 217 is an example of a procedure using predicted values.

Estimated value: Sometimes referred to as “proven reliability”. The ratio between accumulated component-hours and observed number of failures.

Predicted value and estimated value are often considered to be more or less the same. However, estimated values normally give a more realistic result when used in environments and applications which are similar to those from where the data is derived.

Failure rate and acceleration factors

The failure rate λ can be defined as the ratio between the number of failures and the accumulated operating time for a given number of units.

λ is normally given in 10^{-9} faults/hour (FIT) or 10^{-6} faults/hour (MIL-HDBK 217).

It is of greatest importance that the stress in terms of load, temperature, voltage etc. of a component is taken into account when calculating the failure rates.

The failure rates are normally given under normalized or typical conditions (load, voltage and temperature), and are referred to as basic failure rate λ_b . To find the actual failure rate for a given condition, λ_b should be multiplied by the acceleration factor (c).

$$\lambda = c \cdot \lambda_b$$

The acceleration factor depends mainly on the exposed temperature for both semiconductors and for passive components, electrolytic capacitors in particular (see fig 2.).

In addition to the acceleration factors there is also a significant influence of the environmental conditions and also quality aspects considered. Usually it is convenient to include those in the λ_b value. This is normally the case for estimated values.

Calculation of MTBF for an equipment

When calculating the MTBF for an equipment its total failure rate λ_e must be found. Normally the assumption is that all components are needed for operation. Consider an equipment or apparatus containing n components. The probability to find n components in operation after the time t is:

$$R = R_1 \cdot R_2 \ldots\ldots \cdot R_n = e^{-\lambda 1 \cdot t} \cdot e^{-\lambda 2 \cdot t} \ldots \cdot e^{-\lambda n \cdot t} = e^{-(\lambda 1 + \lambda 2 + \ldots + \lambda n) \cdot t} = e^{-\lambda \cdot t}$$

and

$$\lambda = \lambda_1 + \lambda_2 + \ldots\ldots \lambda_n$$

The total failure rate for the equipment at specified conditions is accordingly achieved as:

$$\lambda e = \lambda_{b1} \cdot c_1 + \lambda_{b2} \cdot c_2 \ldots \lambda_{bn} \; c_n$$

By simply inverting this value, the MTBF figure for the equipment is found:

$$\mathrm{MTBF} = \frac{1}{\lambda_e}$$

Estimation of necessary repair/ service actions

Statistics can be used to get an idea of the service actions necessary for an equipment during its lifetime. The probability that the equipment will function without failures during a certain time is:

$$\mathbf{R(t) = e^{-t/MTBF}}$$

Where t = the time during which the product shall operate under stated conditions.

As an example we can use a 100,000 h (11 years) MTBF value at +35°C for a power supply intended for office automation. Suppose that the expected lifetime of the office equipment is 10 years. The probability that the equipment will function without failures caused by the power supply during 10 years is found as:

$$\mathbf{R\ (10\ years) = e^{-10/11} = 0.40}$$

In comparison, ignoring the difference in ambient temperature, the MTBF = 200 years given in the data sheet for the series will give the following probability for failure not to occur within 10 years:

$$\mathbf{R\ (10\ years) = e^{-10/200} = 0.95}$$

From this probability the end-user can estimate the number of service/repair actions that can be expected for a certain product during its lifetime.

Calculation of spare parts requirements

The MTBF value can also be used to calculate the number of spare parts required for a given unit/ component. The calculation is based on the faulty unit/component being replaced by a spare part and no repair is carried out on site:

$$\mathbf{Q = N} \cdot \frac{T}{MTBF}$$

Where:

Q = number of spare parts
N = number of operating products
T = expected equipment life time

Example: The spare parts needed for power supplies in 1,000 operating equipment within a service area shall be calculated. The expected life time of the product is 10 years.

MTBF for the power supply = 200 years.

$$\mathbf{Q = 1000} \cdot \frac{10}{200} \mathbf{= 50}$$

As can be seen, the need of spare parts corresponds to the MTBF value. The value is therefore important, even if the expected life time is relatively short. It is obvious that using highly reliable components, both repair actions and spare part inventory can be significantly reduced.

Conclusion

The MTBF figures given by the suppliers are useful for the end-user, but the comparison between one MTBF figure and another must be made very carefully. “Rules-of-thumb” must not be taken too seriously, but can give certain indications if other criteria are examined. Nowadays, the reliability dependence on temperature at normal operation conditions is not so extreme as when these rules were established. The reason might be that, thanks to the dynamics in research and development within the semiconductors and electronic industry, new improved technologies are continuously being invented, giving better and better reliability in electronics.

It is always important to have good MTBF figures in order to keep down the cost of service and spare parts. Low reliability figures for power supplies have a more drastic effect on the system behavior than other parts of the system.

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Flex Power Modules, a business line of Flex, is a leading manufacturer and solution provider of scalable DC/DC power converters primarily serving the data processing, communications, industrial and transportation markets. Offering a wide range of both isolated and non-isolated solutions, its digitally-enabled DC/DC converters include PMBus compatibility supported by the powerful [Flex Power Designer](flexpowerdesigner.com).

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