Reliability: Specification of MTBF and service lifetime for PULS power supplies

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In practice, the terms 'MTBF' and 'service life' are often mixed up or used interchangeably.
However, these refer to different processes and both values are needed to describe reliability.
What they have in common is that higher temperatures make the values much worse.

MTBF

The MTBF (Mean Time Between Failure) specifies how often a unit fails as a statistical average. Even if all parties strive to keep the number of failures as low as possible, it is unavoidable that a technical product fails with a certain level of probability. The frequency of the failures is represented by the symbol for failure rate λ (Lambda). The MTBF is the reciprocal value of λ. λ specifies the number of failures per unit hour. In practice, specifications in MTBF are more common, presumably because the failure rate λ is given in 1/hour, and is a smaller value (as is the „failure in time" specification; 1 fit = 10^{-9} failures per hour), whereas the MTBF uses the unit of hours.

The failure rate expresses how many failures are to be expected when a certain number of units are operated for a specific period. This is the specification of interest in practice. An example: We take 1,000 units and operate them for 2,000 hours.

This results in 2 million unit hours. If we observe 4 failures in this period, the failure rate is 4 failures / 2 million unit hours = 2 x 10^{-6} per hour or 2 ppm per hour. The MTBF as the reciprocal value of 2 x 10^{-6} per hour gives 500,000h, which is clearer.

You can look at it like this: If you operate 1,000 units for 2,000 hours, corresponding to 2 million unit hours, and the MTBF is 500,000h, we can expect four failures (2 million / 500k = 4).
A simple working hypothesis could also be that 500,000 units are operated simultaneously, of which each has an MTBF of 500,000h: one unit would then fail every hour.

It is important to understand that the failure rate/MTBF relates to statistical failures that apply from the first operating hour. Early failures are not taken into account as the manufacturer should exclude these occurring at the customer's site. Wear effects do not play a role here either, as it starts from the phase in which no age-related failures should occur. Higher temperatures accelerate the processes, low temperatures are very important for a low failure rate or high MTBF.

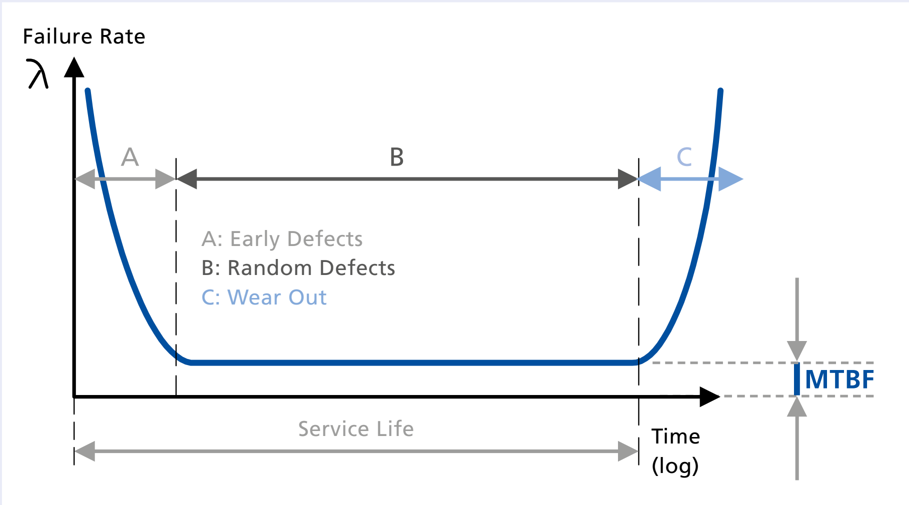

Figure 1: Bath graph
Error frequency across the service life of a unit

Service life

The service life does not relate to statistical failures during the normal operating time but instead refers to the time after which the components are no longer usable due to wear and tear. This specifies after how many years a power supply can no longer perform its specified service. The most relevant components affecting the service lifetime in a power supply are the electrolytic capacitors. They contain liquid electrolyte that during the course of time is diffused by the component seal. The end of the service life is defined by the manufacturer when parameters such as capacity and internal resistance have degenerated by a specific amount from the start value. The service lifetime is therefore dependent on the type of electrolytic capacitor and also on its operating temperature. Every increase of 10°C reduces the service life by a factor of 2.

Comparison of the reliability values for the CP10 with 24V/10A under various conditions

Service life:

5A	25°C	230V	499,000h *)
10A	25°C	230V	338,000h *)
10A	25°C	120V	211,000h *)
5A	40°C	230V	176,000h *)
10A	40°C	230V	120,000h
10A	40°C	120V	75,000h

**) Values exceeding 130,000h, in other words 15 years, are calculated values only and are no longer guaranteed by the manufacturers.*

MTBF:

			SN 29500	MIL HDBK 217F
10A	25°C	230V	1,185,000h	381,000h

Figure 2: Reliability values for the CP10

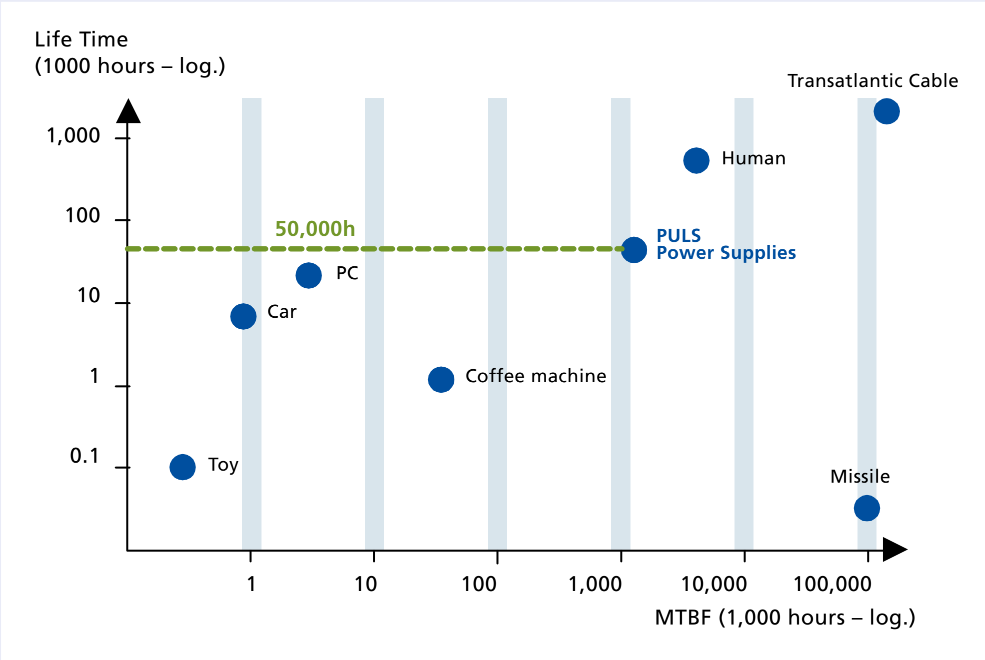

Figure 3:
Difference between service life and MTBF using the example of several units

A clear comparison of the statistical failure rate MTBF and the expiry of the service life in a range of applications is given in figure 3. For example, in a rocket application, a short service life of 5 to 10 minutes is sufficient as in that time it has done its job and then crashes. With the variety of components it comprises, and in the light of the damage arising due to non-functionality, the failure time during these 10 minutes should be very low, however, meaning the MTBF is very high. A contrasting example is an amplifier in a submarine cable. It must last for 40 years as it cannot be easily replaced; on the other hand it is not so complex and a poorer MTBF is acceptable to compensate for the long service lifetime.

For high quality industrial power supplies, both the MTBF and the service lifetime are important. During the normal duration of use, as few failures as possible should interrupt operation and the usability of the machine should be achieved over many years without changing components.

Since the introduction of the DIMENSION product range, PULS has been a pioneer in specifying the values for MTBF and service life in its data sheets. Considerable value is set on ensuring that the definitions are clearly specified.
With the MTBF in particular, there are many ways to calculate the figure and depending on the calculation method and the definition of the operating conditions, the results are very different. The simplest method is the „parts count". Here only the number of components is counted and multiplied by a mean failure rate to calculate to the failure rate of the overall equipment. This is an over-simplification. It is more precise, more complicated and therefore unpopular with developers to consider each individual component in the power supply (which can be hundreds) to determine the electrical stress via calculation and the thermal stress via measurement. These values then produce a program on the failure rate for the component under this stress condition and the total of the individual failure rates of the components gives the total failure rate/ MTBF of the device.

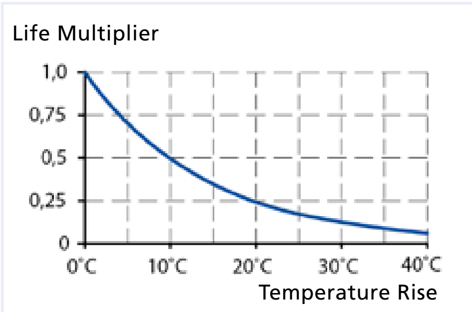

Figure 4:
For every 10°C temperature rise, service life is halved

There are existing various standards for the failure rate of the components. The MIL Handbook 217F has widespread international acceptance, but according to PULS' experience, the values it uses for failure rates are too conservative. The values in Siemens standard SN 29500 that are based on a broad range of industrial experience are more realistic. The calculation method is defined in the IEC 61709. When assessing an MTBF value it is therefore always important to know both the underlying data used as well as the operating conditions (stress factors) of the equipment. MTBF figures without this information are worthless.

As temperature has a significant influence, a precise definition is important here. The key issues are the temperature of the individual components and these are dependent on the ambient temperature and self-heating. The self-heating results from the losses in the power supply and varies with the load and the input voltage. The ambient temperature alone has a considerable influence and as a result PULS specifies the MTBF at +25°C to facilitate a comparison

$$\text{MTBF} = \frac{1}{\lambda}$$

$$\lambda = \frac{\text{number of failures}}{\text{number of power supplies x operating hours}}$$

λ (lambda) = number of failures (fit)   1fit = 10^{-9} failures/hour

Figure 5: Definition of the MTBF

with other manufacturers, and at +40°C because this is a more realistic operating condition as full load is assumed at all times. Even at a standardized full load, the bandwidth – e. g. for a CP10 – ranges from 250,000h (MIL, 100Vac, +40°C) to 1 185 000h (SN 29500, 230Vac, +25°C), in other words a difference of a factor of 4.7.

The data specified by the manufacturers of the electrolytic capacitors is used to calculate the lifetime. These are minimum values as the manufacturers guarantee that at the specified load, the capacity has decreased by no more than 20% from the baseline and the internal resistance is still below double the specified value. PULS determines the temperature stress of all electrolytic capacitors under different operating conditions and then calculates the service lifetime based on the manufacturer specifications. In practice this provides a reserve because a power supply can still function with these impairments but as there are no further reliable specifications available, this gives the user a good basis for comparison.

PULS makes the reliability of its products a very high priority. As a consequence, the data for MTBF and service lifetime is described in great detail in the data sheets for every product and is specified precisely for many operating conditions. In addition, there is an in-house guideline at PULS defining that for every product in the DIMENSION range a minimum service life of 50,000h has to be accomplished at full load, nominal mains voltage 120V/230V and an ambient temperature of +40°C in accordance with the method described above. This requires an additional loop in the development process, but the user has the advantage that he can take any product from the range and rely on specified and uniform minimum values. When looking at the values for reliability in particular, significant differences in comparison to other power supplies can be seen clearly.