Guidance

Mythos MTBF

Getting correct interpretations of the helpful measure for switch-mode-power-supplies

Electro and Digital Industry Association

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Introduction

Motivation

Mean Time Between Failure (MTBF) calculations are often poorly understood and incorrectly used. Will a power supply with a million-hour MTBF last 114 years? (No). Is the power supply with the highest MTBF always the most reliable in service? (No). Are MTBF calculations then without any value? (Definitely not!)

To help shed some light on this often-misunderstood topic, ZVEI set up an ad hoc group of its members to collect and share their experience with MTBF calculations, norms, and mission profiles. The intention of this guide is to help explain how MTBF figures are derived and implemented by using real-life examples to show the differences and similarities between the various MTBF protocols.

When correctly used, MTBF calculations are a very useful tool, allowing manufacturers to design highly reliable power supplies and offer long warranties for brand-new products with confidence, while also allowing users to assess in advance the anticipated lifetime of their systems and implement the necessary maintenance or replacement schedules.

As an example, how to apply the MTBF value, it can be used as basis for further calculation or evaluation. Thus, this value can be used to specifically determine the number of failures per year for a known number of products in the field:

$$failures\ per\ time = \frac{1}{MTBF} \cdot number\ of\ products \cdot usagetime$$

$$failures\ per\ year = \frac{1}{500.000h} \cdot 10.000\ pcs \cdot 24h \cdot 365$$

However, it is also important to note that this calculation can only be applied effectively if the given MTBF value is suitable for the application and the ambient conditions. Which brings us back to the question what MTBF is, how it is calculated and what influences the calculated value.

1 Differences between: MTBF / MTTF / FIT / Lifetime / B10%

1.1 The Basics

To understand the difference between MTTF (Mean Time to Failure), MTBF (Mean Time Between Failures) and lifetime, it is helpful to consider the example of the reliability of a car:

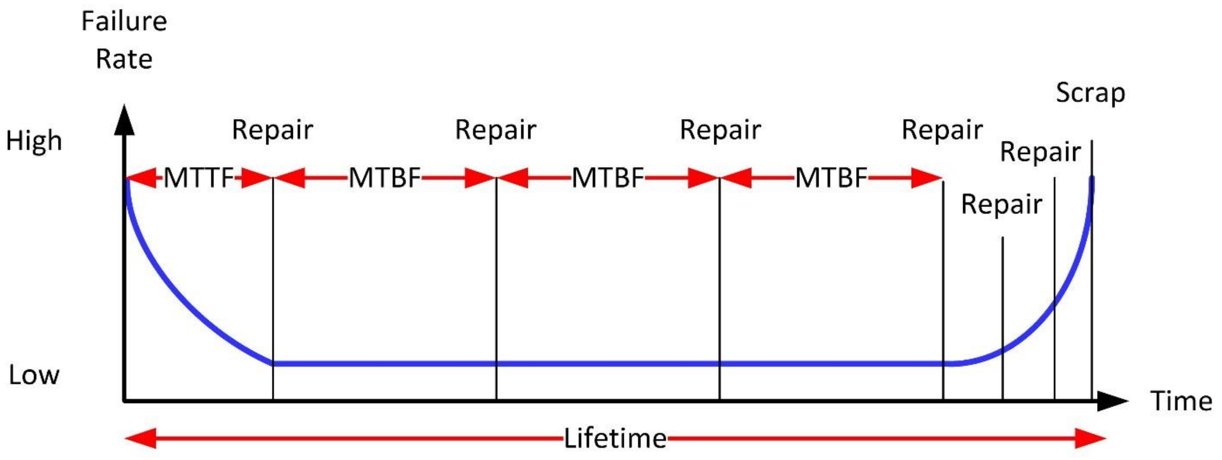

Figure 1: Failure rate of a large sample of components or systems as they age.

The MTTF is the time taken to the first failure of the vehicle, which can be short as it includes manufacturing and assembly faults, so could be a matter of months. After the car is in regular use, there may be the need for periodic repairs, typically every three to four years. As the car gets old, the need for repairs becomes more frequent and the car eventually becomes so unreliable it gets scrapped. The regularly reoccurring MTBF interval is a useful measure of the base failure rate of the vehicle because it ignores infant mortality and wear-out failures.

Electronic systems are rarely repaired, but MTBF is still a useful method to calculate the fundamental reliability of any circuit design, usually expressed in kilohours. Often, the inverse of the MTBF interval, Failure in Time (FIT), is used - the relationship is simple: FIT = 10^9/MTBF, expressed in failures per billion operating hours. Other reliability limits can also be used, such as B10% which is the time taken until 10% of the sample falls out-of-specification, rather than fails completely.

MTBF versus Lifetime

MTBF (Mean Time Between Failures) refers to the average time between consecutive failures of a system or component. It's a measure of reliability. On the other hand, lifetime typically refers to the total operational time of a system or component before it is retired or replaced. MTBF is a statistical measure, while lifetime is a real-world duration. They are not the same.

Lifetime is the time it takes for a product to fail its specification due to use/wear. The weakest link/component determines the lifetime.

MTBF, on the other hand, does not take into account wear and tear, but failure due to a fault, and therefore represents the statistical failure of a product.

Why can the MTBF be greater than the lifetime?

The lifetime of an SMPS typically describes the wear and tear of an electrolytic capacitor, whereas the MTBF describes the statistical failure of all components, where the “wear and tear” of the electrolytic capacitor is not counted as a failure.

Using the example of the car above, it is easy to explain this with a look at the tyres. After a certain mileage they are worn out and no longer fulfil their purpose. For safety reasons, the MTBF (e.g. the bursting of a tyre) is significantly greater.

1.2 Parts count principle

Calculated MTBF figures are based on the parts count principle. Each component in a system has its own reliability figure based on its individual environmental and operating stress, and the sum of all these reliabilities gives the overall reliability of the system. Thus, the more complex a system is, the more likely it is that it will suffer a failure.

1.3 Parts count stress principle

The are many environmental and operating stress factors involved in the MTBF calculation. Among temperature and electrical stress, there is also mechanical stress such as shock and vibration. All these factors have a different impact on the reliability. A detailed description of the stressors is attached in ‘6 Appendix’.

1.4 Reliability databases, overview

The MTBF calculations are based on a large database of components, each listed with its own fundamental reliability derived from statistical analysis of failures in the field. Different databases list different reliability rates, so the figures derived from the Military Standards Handbook 217, Edition F (MIL-HDBK-217F) will be different from the Siemens standard (SN 29500). It is important to realise that the figures are not directly comparable, because they use different ways of calculating the component stress factors and component base reliabilities, for example as shown in MIL Handbook (section 5.5):

$$\begin{gathered}
\mathit{Overall\ Reliability}, \lambda = \\
\sum \left(\mathit{Number\ ofparts}, N_C\ x\ \mathit{Part\ base\ reliabilty}, \lambda_C\right) \left(1 + 0.2\ \mathit{Environmental\ Factor}, \pi_E\right)\ x \\
\mathit{Interaction\ Factor}, \pi_F\ x\ \ \mathit{Quality\ Factor}, \pi_Q.\ x\ \mathit{Maturity\ Factor}, \pi_L
\end{gathered}$$

1.5 B10%

B10% is an operational lifetime figure after which 10% of the sample have failed and 90% are still operational. It is commonly used to determine the operational lifetime of devices that wear out relatively quickly and where the failure mode is total, such as lamps and bearings, for example. The B10 calculation uses a statistical method, but unlike MTBF calculations, it uses real-life failure data to derive the B10 hours. For long-lived products such as power supplies, it would take an inordinate amount of time to collect sufficient field data to create accurate B10 calculations. In addition, the definition of “failure” is not universally accepted – is it when the power supply stops working completely or when the output voltage drifts outside of the specification or takes too long to start up?

2 Advantages of reliability calculations

2.1 Predictive Reliability (MTBF)

As previously mentioned, the MTBF is a statistical calculation based on averaged component failure rates multiplied by certain stress factors. However, the MTBF calculation ignores the result of these individual failures – a power supply may still function even if a single component is defective, albeit maybe not with the full performance level.

Nevertheless, predictive reliability can be worked out from the MTBF figure. For example, if the failure rate of a unit should be less the 1% after 1 year of service, then the required MTBF is:

$$required\ MTBF = \frac{365\ x\ 24}{0.01} = 876\ khours$$

2.2 Demonstrated Reliability (dMTBF)

Demonstrated MTBF is based on actual failures in the field and is therefore a more reliable, if very resource intensive, way of determining proven failure rates. To be statistically meaningful, at least 50 units would need to be monitored over a long period of time.

2.3 Calculated Lifetime

As many electronic components cannot be repaired, calculated lifetimes can also be used to predict overall reliability rather than MTBF figures. As electrolytic capacitors are often considered to be the most unreliable component in an electronic circuit, calculating their lifetime is a useful way of predicting the lifetime of the whole unit:

$$Capacitor\ Lifetime, L = L_0 K_T K_R K_V$$

Where: L_0 is the datasheet lifetime at maximum ripple current, maximum operating temperature and maximum voltage, K_T is the operating temperature factor, K_R is the ripple current factor and K_V is the operating voltage factor.

For example, if a capacitor with a L_0 lifetime of 7000 hours (0.8 years) is used at 70°C rather than the maximum of 105°C, with half of the maximum ripple current and 90% of the maximum operating voltage, then the predicted lifetime, L, will be 7000 x 32 x 1.3 x 0.6 = 174 khours or nearly 20 years.

3 Reliability Standards

3.1 MIL-HDBK-217F

The "US Military Handbook 217" was published in 1962 as the first procedural instruction based on a standard. It is one of the oldest procedural instructions for calculating the failure rate of electronic systems and quickly established itself as a global standard. Due to its high level of recognition worldwide, many manufacturers still follow it even though it has not been publicly maintained since 1995.

3.2 IEC 61709 (SN 29500)

In Germany, Siemens AG has addressed the issue of reliability. As a result of the company's experience as a component, device and system manufacturer the Siemens standard 29500 "Failure rates of components" was written. This standard is very general and can be applied to all electronic devices. Furthermore, it contains an extensive basic failure rate database of components.

With increasing globalization, a uniform procedure instruction was created within the framework of the International Electrotechnical Commission (IEC). The Siemens standard SN 29500 prevailed as the basis for an international standard which was published as standard IEC 61709 “Reference conditions for failure rates and stress models for conversion" in October 1996. It describes definitions, reference conditions and conversion models and is in full agreement with the already existing SN29500. The IEC standards include only the mathematical calculation model whereas the basic failure rates of the components must be determined by the manufacturer or by field experience.

IEC 61709 was adopted as European standard EN 61709 in March 1998 and published as DIN EN 61709 in January 1999.

3.3 Belcore/Telcordia SR-332

In parallel with the military industry, telecommunications industry developed their own codes of practice in the early 1980s. They were often based on the Military Handbook but dealt more specifically with industry-specific criteria. Well-known representatives are:

- ‘Reliability prediction procedure for electronic equipment’ (TR-NWT-332) of Bell Communications Research USA
- ‘Handbook of Reliability Data for Components used in Telecommunications Systems’ (HRD) of the British Telecom.
- ‘Recueil de Donnèes de Fiabilitè du CNET’ (RDF) of France Telecom.

The fact that these procedural regulations are only tailored to special electronic application areas can be seen in part from the length of the procedural manuals, which in some cases is only a few pages.

For a detailed timeline of Belcore/Telcordia standards see appendix.

3.4 Overview

	MIL-HDBK-217F	**Telcordia SR-332**	**Siemens SN 29500**	**IEC 61709** (a)
Last update	1995	2016	2014	2017
Stability date	–	–	–	2025
Environment	Ground Benign(b)	Ground Benign(c)	Ground Benign (d)	E1(e)
Temperature	25°C (f)	40°C	40°C	40°C
Load / stress	100% (g)	50%	100% (g)	100% (g)
Quality factor(s)	possible	possible (h)	for specific components e.g.: e-caps	–
Calculation principle	parts count or parts stress	parts count or parts stress	parts stress	parts stress
Use of real field-data	no	possible	no	possible (i)

Table 1: Different standards for calculating the MTBF

(a) the IEC version is based on Siemens SN 29500
(b) more possible: Ground Fixed, Ground Mobile, Airborne, …
(c) more possible: Ground Fixed, Controlled
(d) more possible: automotive, extreme pollution
(e) Stationary use at weather-protected locations
(f) according to the standard, all calculations are made with an ambient temperature of 25°C, but other situations can be considered.
(g) using the "parts stress" method every load situation can be considered.
(h) possible levels: 0, 1, 2, 3
(i) use of generic data is possible.

4 Calculation examples

4.1 Comparison of different Standards

Each standard assigns different weights to the influences of the stress factors d and thus a comparison between the standards is only possible to a limited extent. This is illustrated by an analysis of the buck converter schematic below.

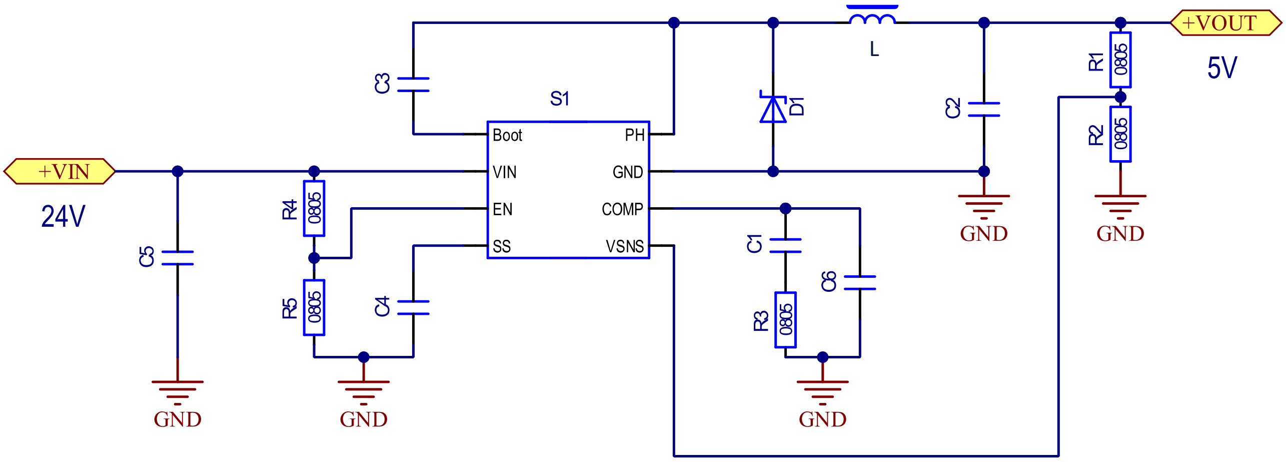

Figure 2: Simple DC/DC schematic used for the following calculation.

Results for different calculation methods (EN/IEC 61709 (SN-29500) and MIL-HDBK)

Preconditions:
SNA: Nonmobile operation ground benign
Ta: 25°C mean component ambient temperature
Zf: Continuous operation 8760 h per year

			SN 29500	**MIL-HDBK-217F**
Quantity	Component	Ident.	fit	fit
1	NON SYNCHR. BUCK I	IC-S1	16,4	70,9
1	DIODE	D1	2,2	4,8
1	CAP 220NF 25V	C1	0,6	0,3
1	CAP 4.7µF 25V	C2	0,4	1,3
1	CAP 220NF 25V	C3	0,3	0,2
1	CAP 220NF 25V	C4	0,2	0,2
1	CAPCE 2.2/50V/0603	C5	1,5	4,9
1	CAP 220NF 25V	C6	0,6	0,4
1	RES 0805 10K	R1	0,1	3,0
1	RES 0805 4K7	R2	0,1	3,0
1	RES 0805 33K	R3	0,1	3,0
1	RES 0805 56K	R4	0,1	3,0
1	RES 0805 10K	R5	0,1	3,0
1	Inductor 07HCP	L	1,4	0,8
34	Solder joints		1,0	2,3
FIT-Sum			**26**	101
MTBF	[khrs]		**38.462**	**9.901**

Table 2: MTBF calculation with Exar Software 11.0. ($T_{ambient}$ 25° with standard values for components and with specific, measured component temperatures)

Analysis/comments on the results

As can be seen with this simple DC/DC schematic with only 14 components, the MTBF values according to two different standards give very different results. Each standard is consistent within its own rationale, but comparisons between them is not useful. Therefore, when comparing datasheet MTBF values, it is essential to determine which standard is being used to generate the results.

4.2 Comparison of different Temperatures

The influence of different temperatures on MTBF is shown by following simplified AC/DC circuit:

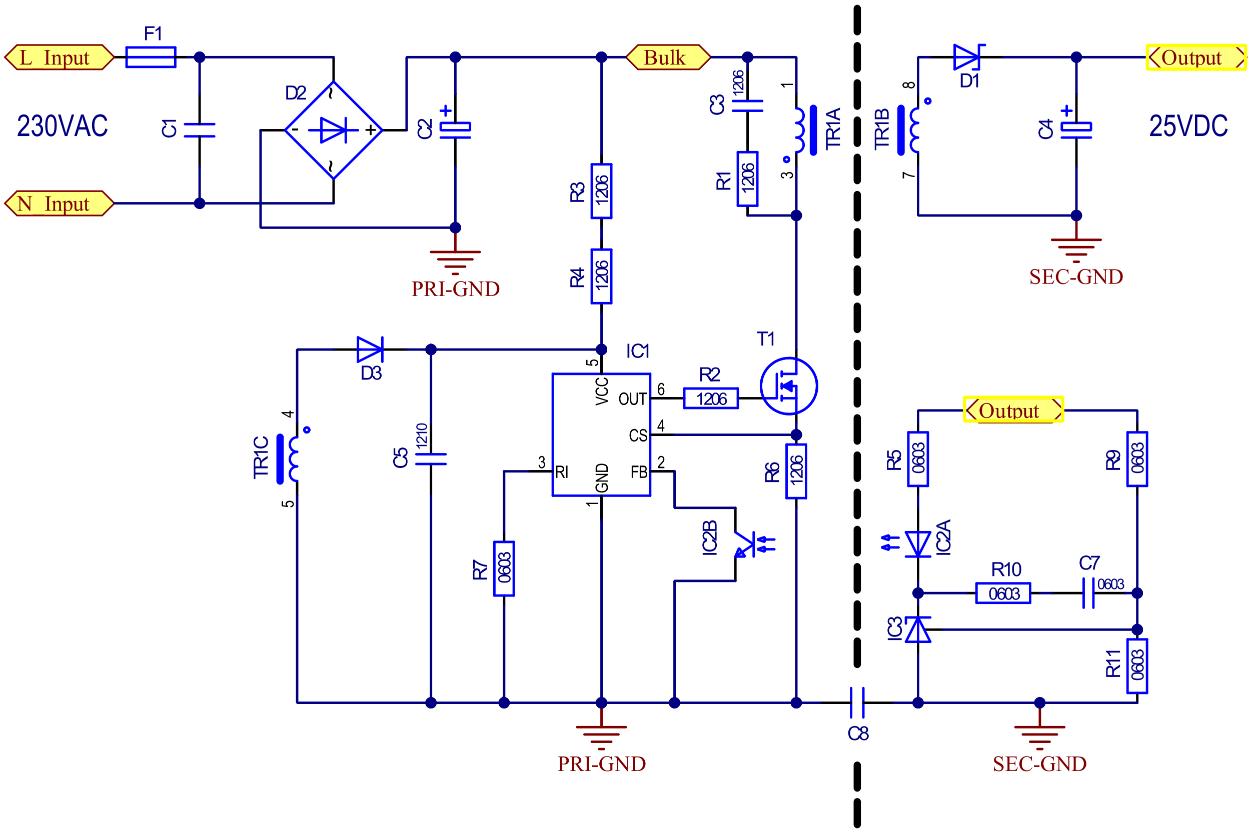

Figure 3: Simplified AC/DC Circuit used for the calculations.

The Calculation has been done according EN/IEC 61709 (SN29500) and MIL-HDBK-217 with different stress factors / ambient temperatures (25°C, 40°C, 60°C), whereas the temperature model is based on EN/IEC 61709 (modified Arrhenius).

Preconditions:
SNA: Nonmobile operation ground benign
Ta: 25-60°C mean component ambient temperature
Zf: Continuous operation 8760 h per year

			SN-29500			**MIL-HDBK-217**		
			25 °C	**40°C**	**60°C**	**25 °C**	**40°C**	**60°C**
Quantity	**Component**	**Ident.**	**fit**	**fit**	**fit**	**fit**	**fit**	**fit**
1	SG6859	IC1	5,5	10,0	22,6	42,1	109,8	388,2
1	Fuse TR5 1A 300V	F1	25,0	25,0	25,0	10,0	10,0	10,0
1	TR1	TR1	4,4	5,0	6,7	4,9	5,8	8,1
1	STU5N65M6	T1	31,6	60,0	143,1	1169,2	1451,4	1887,3
1	MKP X2 0.1µF/275V	C1	0,3	0,7	2,2	10,9	12,4	19,6
1	B250D	D2	5,7	10,0	19,9	472,0	688,6	1087,3
1	ELCAP 10UF 400V	C2	1,8	5,0	18,6	37,1	57,1	117,2
1	CAP 1206 X7R 10NF	C3	1,0	2,0	4,4	5,4	5,6	6,0
1	RES 0204 47R	R1	0,5	0,7	1,1	3,0	3,5	4,4
1	BAS20	D3	0,5	1,0	2,3	5,5	8,7	14,9
1	CHIP 10UF 25V	C5	1,0	2,0	4,4	5,4	5,6	6,0
2	RES 0204 1M	R3 R4	1,0	1,4	2,2	6,0	7,1	8,8
1	RES 100K /0603	R7	0,1	0,2	0,3	3,0	3,5	4,4
1	RES 0204 100R	R2	0,5	0,7	1,1	3,0	3,5	4,4
1	RES 0204 4R7	R6	0,5	0,7	1,1	3,0	3,5	4,4
1	30BQ100	D1	5,7	10,0	19,9	22,1	32,3	51,0
1	ELCAP 470UF/35V	C4	1,8	5,0	18,6	37,1	57,1	117,2
1	TLP785	IC2	6,4	15,0	41,5	91,6	137,7	224,6
1	RES 3K3/0603	R5	0,1	0,2	0,3	3,0	3,5	4,4
2	RES 10K/0603	R9 R10	0,3	0,4	0,6	6,0	7,1	8,8
1	CAPCE 10N/50V/0603	C7	1,0	2,0	4,4	5,4	5,6	6,0
1	RES 1.1K /0603	R11	0,1	0,2	0,3	3,0	3,5	4,4
1	CAP Y1 1NF	C8	1,0	2,0	4,4	5,4	5,6	6,0
1	TL431CLP	IC3	1,6	3,0	6,7	10,5	27,5	102,9
69	Solder joints		2,1	2,1	2,1	4,8	4,8	4,8

fit$_{sum}$			**100**	**164**	**354**	**1970**	**2661**	**4101**
MTBF	[khrs]		**10.029**	**6.088**	**2.828**	**508**	**376**	**244**

Table 3: Calculated values by EXAR Software 11.0

Analysis/comments on the results

As can be seen with this simple AC/DC schematic, the MTBF values according to the different standards all decrease (become more unreliable) with increasing temperature stress, but the rate of change is not proportional between them, again due to different weighting factors used by each standard.

4.3 Results for different Input Voltages

The influence of different input voltages can be shown by calculation according EN/IEC 61709 (SN-29500).

In respect to the different current, the components show different the self-heating T_{self}.

Preconditions:
SNA: Nonmobile operation ground benign
Ta: 25°C mean component ambient temperature
Zf: Continuous operation 8760 h per year

			110Vac		**230Vac**	
Quantitiy	**Component**	**Iden.**	**fit**	**Δ Temp stress [°C]**	**fit**	**Δ Temp Stress [°C]**
1	SG6859	IC1	11,7	$T_{self} = 34$	10,4	$T_{self}=31$
1	Fuse TR5 1A 300V	F1	25,0		25,0	
1	TR1	TR1	7,5	$T_{self}=54$	7,3	$T_{self}=53$
1	STU5N65M6	T1	20,8	$T_{self}=50$	24,5	$T_{self}=54$
1	MKP X2 0.1µF/275V	C1	0,8	$T_{self}=17$	0,6	$T_{self}=11$
1	B250D	D2	4,1	$T_{self}=37$	2,3	$T_{self}=24$
1	ELCAP 10UF 400V	C2	7,9	$T_{self}=22$	5,0	$T_{self}=15$
1	CAP 1206 X7R 10NF	C3	4,4	$T_{self}=35$	5,4	$T_{self}=41$
1	RES 0204 47R	R1	0,8	$T_{self}=35$	0,9	$T_{self}=41$
1	BAS20	D3	1,1	$T_{self}=32$	0,9	$T_{self}=28$
1	CHIP 10UF 25V	C5	4,2	$T_{self}=34$	3,8	$T_{self}=31$
2	RES 0204 1M	R3 R4	1,5	$T_{self}=33$	1,3	$T_{self}=26$
1	RES 100K /0603	R7	0,2	$T_{self}=34$	0,2	$T_{self}=31$
1	RES 0204 100R	R2	0,9	$T_{self}=39$	0,8	$T_{self}=37$
1	RES 0204 4R7	R6	0,9	$T_{self}=41$	0,8	$T_{self}=36$
1	30BQ100	D1	5,5	$T_{self}=44$	4,6	$T_{self}=40$
1	ELCAP 470UF/35V	C4	7,9	$T_{self}=22$	5,7	$T_{self}=17$
1	TLP785	IC2	14,2	$T_{self}=29$	11,4	$T_{self}=25$
1	RES 3K3/0603	R5	0,2	$T_{self}=31$	0,2	$T_{self}=25$
2	RES 10K/0603	R9 R10	0,4	$T_{self}=31$	0,4	$T_{self}=25$
1	CAPCE 10N/50V/0603	C7	3,8	$T_{self}=31$	3,0	$T_{self}=25$
1	RES 1.1K /0603	R11	0,2	$T_{self}=31$	0,2	$T_{self}=25$
1	CAP Y1 1NF	C8	3,0	$T_{self}=25$	2,5	$T_{self}=20$
1	TL431CLP	IC3	4,7	$T_{self}=31$	3,7	$T_{self}=25$
69	Solder joint by machine		2,1		2,1	

FIT-Sum			**134**		**123**	
MTBF	[khrs]		**7.484**		**8.141**	

Table 4: Different input voltages calculated for SN 29500 based on EXAR Software 11.0

Analysis/comments on the results

A universal input AC/DC converter will have different component stresses under different operating conditions which are not always considered in the MTBF calculations.

For example, an input voltage of 110 Vac/60Hz will have double the input current compared to 230 Vac/50Hz for the same load. This higher current and mains-frequency will disproportionately stress the input fuse and bridge rectifier, but the lower mains voltage will reduce the stress on the input capacitor. On the other hand, operation with 230 or 277 Vac will lower the input current stresses but increase the voltage stress on the input capacitor and switching transistor.

4.4 Influence of operating conditions and environment

Influence of ambient temperature

The following graph shows the calculated MTBF value (MIL-HDBK-217F, GB) shown in blue compared with a simple logarithmic relationship against ambient temperature (dotted red line) for a simple DC switching regulator design. The close correlation indicates that for low component count circuits, the main stress factor is temperature and the other stress factors can largely be ignored.

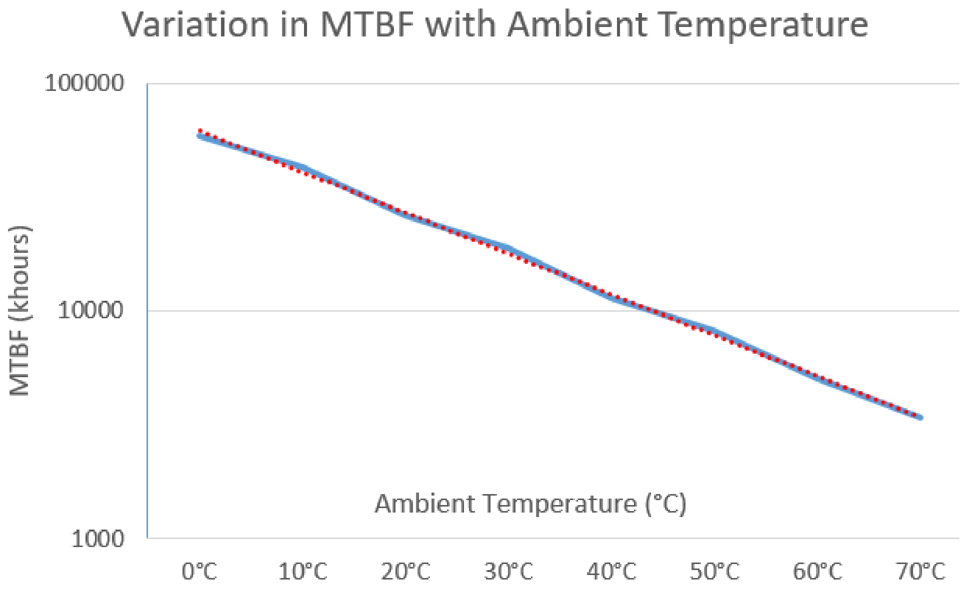

Figure 4: Correlation of MTBF and Temperature, calculated values.

Analysis/comments on the results

As a rule-of-thumb, for every 10°C increase in ambient temperature, the MTBF value halves (vertical axis is logarithmic, horizontal axis is linear)

While this relationship only applies over a limited temperature range and for simple converters, it is a useful approximation that can be used to estimate the MTBF values for ambient temperatures not given in the manufacturer’s datasheet.

Influence of other operating conditions

Be aware: For a DC/DC converter, the component stresses are highest at the extremes of the input voltage range. If a converter with 18-36 VDC is operated with the nominal 24 VDC input, then the PWM controller will usually have a 50% duty cycle, but at 18 VDC the off times will be very short while at 36 VDC the on times will be very short. These high duty cycle ratios with high dv/dt and di/dt slew rates stress the switching transistor, inductor, and output capacitor disproportionately.

The MTBF calculations allow additional stress factors to be included if it is known that the input voltage will vary widely in normal operation by adjusting the environmental stress factor π_E, but datasheet MTBF calculations always assume nominal input voltage.

5 Learnings & Conclusions

5.1 Learnings / Differences between Schemas

All MTBF schemas and standards have the same goal: to describe the reliability and failure rate of electronic devices. Due to the fact that they originate from different industries such as military or telecommunications they use different source databases for their calculations. Additionally, the FIT values which are used to calculate the MTBF results are derived from different publication dates. This is important because electronic components and their reliability have changed significantly over the years, becoming more reliable as production processes and quality control are improved. Another difference between the standards is the definition of fixed load and environment conditions which may differ from a real application. The use of measured field data could solve the inaccuracy that comes with “old” reliability data, but it is not always applicable, nor can an expected reliability be calculated where no long-term operating data has been collected.

The source databases from which the FIT values originate, and the weighting factors assigned to the stress conditions are key to calculating an accurate result and are the main differences between the standards.

5.2 Conclusions:

- *All schemas are valid within their stated application and rationale.*
- *According to load and other stress factors, different components may be flagged as the weakest link, so the calculations should be repeated with different expected operating conditions in order to identify the most stressed component.*
- *MTBF values from different standards are not equivalent and cannot be compared or transferred from one standard to another.*
- *Calculated reliability is a statistical result that does not represent the single unit lifetime, but can accurately predict the reliability of a large number of units*
- *MTBF values given without indicating which standard and operating environment were used for the calculation are useless.*

- ***correctly used, MTBF is a useful tool to make reliability predictions, even for a new product that has no operational reliability history***

6 Appendix

The following is a description of stress factors to be considered.

Temperature

Arrhenius

The Swedish chemist, Svante Arrhenius, developed an equation relating the rate of chemical reactions and temperature, which basically stated that chemical reaction rates double for each 10°C increase in temperature. As many component failures are chemical in origin (corrosion, leakage currents, diffusion and migration effects, etc.), temperature is usually the most aggressive stress factor.

Eyring model

Henry Eyring further developed Arrhenius's work to develop a model that includes more stress factors besides temperature, so, for example, the reliability of a capacitor or semiconductor device is dependent on both temperature and the voltage stress across it. The Eyring model is the justification for accumulating multiple acceleration factors in the MTBF calculation.

Electrical Stress

Often components fail due to “Electrical Over-Stress” (EOS), even when used within their datasheet parameters, the failure mechanisms include:

Hot carrier injection model

In semiconductor devices, charge can break free and transfer across isolation barriers if the electrons or “holes” in the material gain sufficient energy to overcome the potential barrier. Trapped charge eventually causes permanent damage to the semiconductor. The higher the voltage stress, the more mobile or “hot” these charge carriers become.

Electromigration/Corrosion model

Electromigration is a similar mechanism as hot carrier injection, except with atoms rather than electrons. Under thermal and voltage stress, atoms can break free from structures and be deposited elsewhere, creating open or short circuits. Corrosion can also be accelerated as atoms leave exposed surfaces and allow liquid or gas ingress.

Environmental Stress

Mil Std.

MIL HDBK 217F defines standard military environmental stress conditions depending on where the part is used - Ground Benign (GB), Ground Fixed (GF), Ground Mobile (GM), Naval Sheltered (NS), Naval Unsheltered (NU), Airborne Inhabited Cargo (AIC), Airborne Uninhabited Cargo (AUC), Space Flight (SF) and Missile Launch (ML). GB is the least stressful while, unsurprisingly, missile launch is the most aggressive For electronic circuits, GB is the most used factor as it represents the environment in which the majority of electrinic equipment is used.

Mechanical fatigue (shock/vibration)

Repeated mechanical shock and vibration causes metal fatigue leading to structural damage such broken component legs, dry solder joints or loose bond wires as well as systematic failures such as loose connectors, fasteners or mechanical wear.

Humidity

High humidity can cause oxidisation and corrosion in metals, degradation of plastics and swelling and delamination of PCBs. The effect is accelerated if salt is also present.

High temperature and humidity

High humidity and high temperature are strong acceleration factors for the Arrhenius equation (the combination is called the Arrhenius-Peck equation). In Highly Accelerated Stress Screening (HASS), testing for 96 hours at elevated temperature and humidity can be used to simulate years of operation in standard environments.

Low temperatures

At extremely low temperatures, components and solder joints become brittle and more susceptible to mechanical shock and vibration, also any differences in coefficients of thermal contraction between materials can cause mechanical strain within components at low temperatures leading to fractures, delamination, and separation of the parts.

Temperature cycling

Temperature cycling severely stresses electronic components and solder joints, so it is often required to pass automotive and railway quality standards which demand reliable operation over decades of use. The number of cycles, the dwell time, and the rate of change in temperature are all important stress factors. Most MTBF calculations, however, assume stable unvarying operating temperatures.

Quality Factor

The quality factor relates to the screening of the components used before they are used to ensure that production and quality tolerances are minimised. Mil Spec uses the tightest screening protocol, followed by automotive and then commercial quality levels.

Mission Profile

The mission profile recognises that how often a product is switched on and off in a 24-hour timeframe will affect the reliability. While MIL HDBK 217F assumes continuous 24/7 operation, IEC 62380 allows for a mission profile adjustment to the overall reliability by factoring in additional stress factors such as inrush current surges and component temperature cycling caused by repetitive on/off switching.

For an in-depth presentation of the importance of a mission profile for any reliability statements, please refer to the ZVEI Handbook for Robustness Validation.

Telcordia History: (Bell Communications Research, Inc or Bellcore)

Bellcore TR-TSY-000332 Issue 2 (1988)
Bellcore TR-NWT-000332 Issue 3 (1990)
Bellcore TR-NWT-332 Issue 4 (1992)
Bellcore TR-332 Issue 5 (1995)
Bellcore TR-332 Issue 6 (1997)
Telcordia SR-332 Issue 1 (2001) (1)
Telcordia SR-332 Issue 2 (2006)
Telcordia SR-332 Issue 3 (2011)
Telcordia SR-332 (Issue 4) (2016)

(1) In 1997, the company Bellcore was acquired by Science Applications International Corporation (SAIC) and the company's name was changed to Telcordia.

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