Reliability Report

Mean-Time-Between-Failure (MTBF) Prediction
MIL-HDBK-217F Method
for

Switch Type Power Supply

Prepared by:

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December 7, 2017
Revision C

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Summary of Results

Description of Equipment

This Mean-Time-Between-Failure Prediction has been performed for the Switch Type Power Supply. The following describes the equipment.

Outputs	V1	V2	V3
Rated Outputs	+3.3V/16A	+2.5V/20A	12V/3A

Output Power Rating: Continuous output power is not to exceed 122 watts with 300 LFM of forced air.

Assumptions and Conditions

This calculation relates to operational hours, as opposed to elapsed hours, so this should be reflected in the overall reliability if required.

Models provided by the MIL-HDBK-217F, FN2, Specification for Reliability Prediction were used, except where manufacturer's failure rate data was available.

Ambient temperature = 25 ^{o}C with 300 LFM of forced air.

Environment = Ground Benign, Controlled (G_B,G_C)

Model = Serial, no redundant paths exist.

Component Quality Level = Commercial

Calculation Method = Limited Stress, Method I, Case 3

Electrical Stress - See Appendix B.

Vin = 230 VAC

Outputs	V1	V2	V3
Vout	+3.3V/16A	+2.5V/20A	12V/3A

Pd for SMT Resistors = 30% of rated power

These stress levels represent worst case conditions. All the information in this document was obtained in specific environments, and is presented as an illustration. The results obtained in other operating environments may vary.

Omitted Items

Device	Reason for omission
Assembly hardware	Stationary mechanical devices are not included in the calculation

Summary of Results

1.0 MTBF Predictions

Reliability predictions are presented in Table 1.0 for the Switching Power Supply per MIL-HDBK-217F.

Table 1.0

Switching Power Supply MTBF & Failure Rate

*MIL-HDBK-217F, **Ground Benign, Controlled,** G_B,G_C*

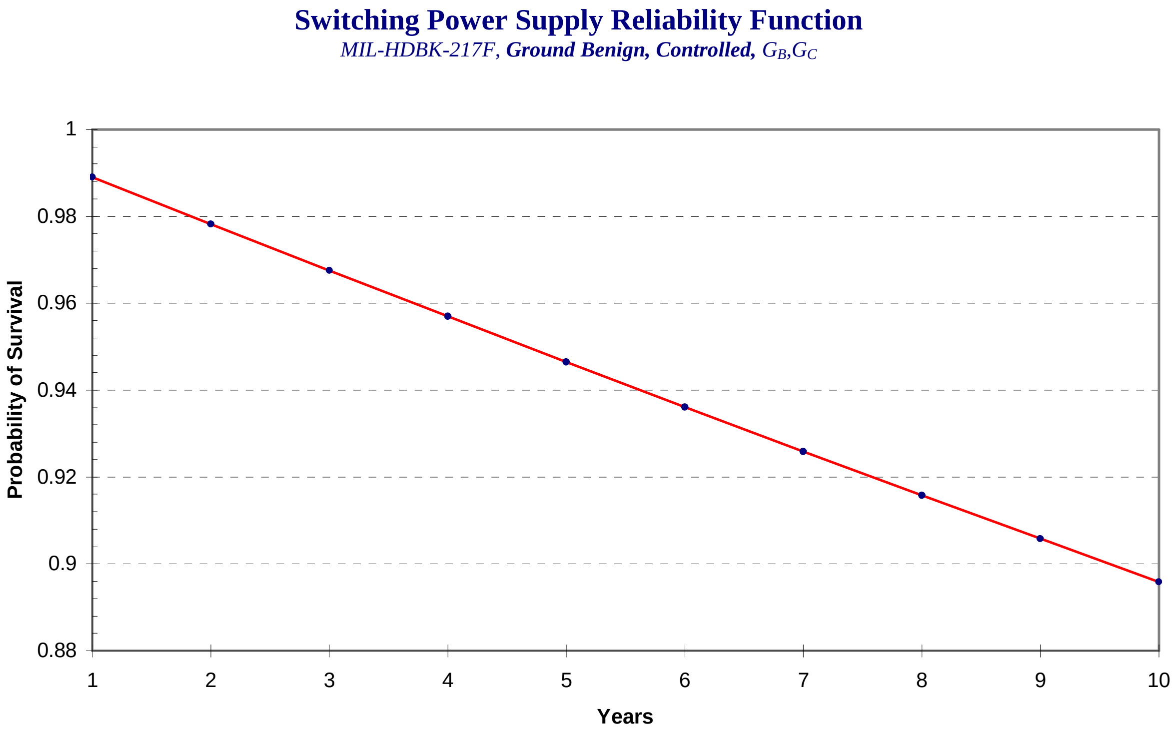
Temperature	MTBF (hours)	MTBF (years)	Failure Rate (FIT*)
25°C	495,148	56.5	2020
40°C	355,816	40.6	2810

*FIT is Failures in 10^9 hours.

All the information in this document was obtained in specific environments, and is presented as an illustration. The results obtained in other operating environments may vary.

1.1 Reliability Function Plot - Probability of Survival

The following plot shows the Probability of Survival, that is the percentage of Failure Free product, as a function of time.



We can expect that 98.9% of product will survive year one, whereas, 89.5% of the product will survive 10 years.

2.0 Margin Analysis

Margin analysis where operating temperature is varied between low and high limits. MTBF and Failure Rate are presented graphically over the range of temperature.

Table 2.0

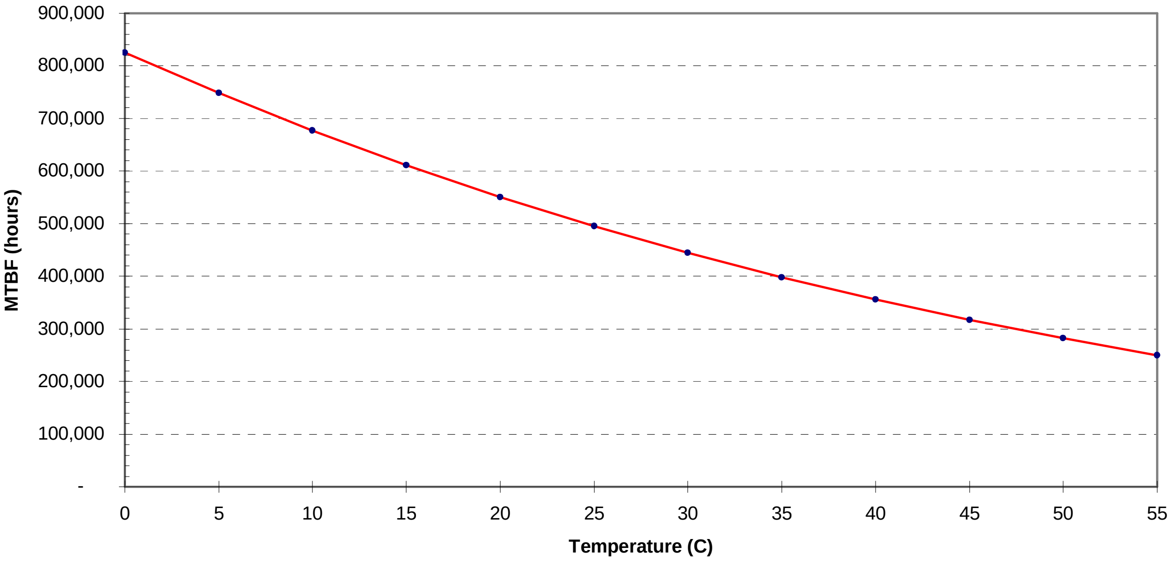
Switching Power Supply
MTBF & Failure Rate
MIL-HDBK-217F, ***Ground Benign, Controlled,*** *G_B,G_C*

Temperature (^{o}C)	MTBF (hours)	MTBF (years)	Failure Rate (FIT*)
0	825,518	94.2	1,211
5	748,117	85.4	1,337
10	676,682	77.2	1,478
15	610,926	69.7	1,637
20	550,524	62.8	1,816
25	495,148	56.5	2,020
30	444,454	50.7	2,250
35	398,116	45.4	2,512
40	355,816	40.6	2,810
45	317,253	36.2	3,152
50	282,151	32.2	3,544
55	250,253	28.6	3,996

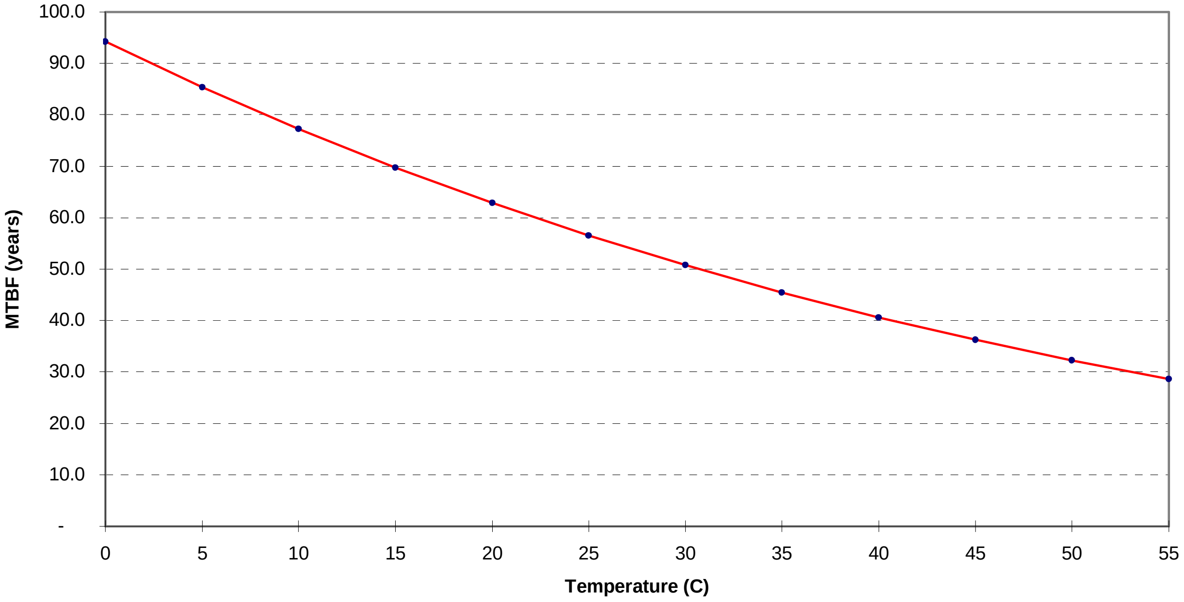
*FIT is Failures in 10^9 hours.

2.1 MTBF vs. Temperature

Switching Power Supply MTBF
MIL-HDBK-217F, ***Ground Benign, Controlled,*** *G_B,G_C*

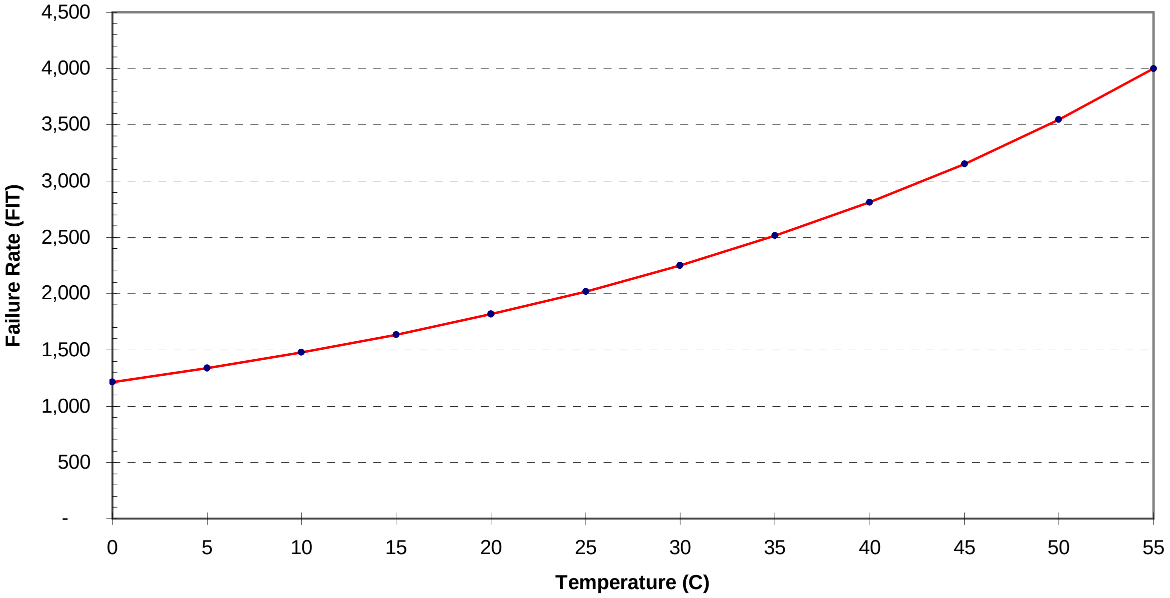


2.1 MTBF vs. Temperature (continued)


Switching Power Supply MTBF

MIL-HDBK-217F, ***Ground Benign, Controlled,*** *G_B,G_C*

2.2 Failure Rate vs. Temperature


Switching Power Supply Failure Rate

MIL-HDBK-217F, ***Ground Benign, Controlled,*** *G_B,G_C*

3.0 Revision History

A. Initial release, 06/20/02.
B. Update 10/18/10.
C. Miscellaneous corrections, 12/7/17.

Appendix A

An Overview of Reliability

Why You Need Reliability Prediction

In today's very competitive electronic products market, a commitment to product quality and reliability is a necessity: customers have high expectations for the reliability of the products they buy, and the companies that don't meet those expectations lose. You already know the advantages to your company of building reliable products: when the products you sell operate reliably, your reputation grows, your costs shrink, and your business prospers.

The most successful companies meet these market demands for quality by using design for reliability principles: integrate reliability considerations into the entire product design process, right from the start. This way reliability is designed into the product, not patched on later, when problems arise. The companies that practice design for reliability find that it results in fewer design changes and iterations, lower manufacturing costs, lower warranty and service costs, more profit, and, most importantly, happy customers.

An important element of the design for reliability process is reliability prediction, which allows you to predict product failure rates.

Uses of Reliability Prediction

Reliability predictions provide a quantitative basis for evaluating product reliability. The information a reliability prediction gives can be used to guide your design decisions throughout the development cycle.

Feasibility Study: When an initial design concept is proposed, a reliability prediction can give you an idea of the feasibility of the design as far as reliability is concerned. Even though these early stage predictions are based on limited design information, and thus are approximate at best, they can give direction to your design decisions; many of these early design decisions may be critical to the success of the product. In addition, it can really pay to discover potential problems early, on paper, before time and money is spent on detailed design and development.

You will usually start with a reliability requirement, which may be given by your customer, or dictated by competitive products. You might have a requirement of a 20,000 hour MTBF for a product. If your predicted value is 3,500 hours, the current design concept may not be feasible; at this point you can modify the design concept, or revise the requirement. If your predicted value is 50,000 hours, this can give you confidence in your design concept, at least as far as reliability is concerned.

Compare Design Alternatives: As your design moves through the early stages into more detailed design, you will make many decisions on design alternatives. Reliability predictions, along with other factors such as performance and cost, can be used as a basis for your decisions. For instance, you may be able to implement a given circuit function in a number of ways, all performing and costing about the same; if one alternative is estimated to be much more reliable than the others, it would stand out.

Find Likely Problem Spots: At the detailed design level, reliability predictions can help you identify likely problem areas. As part of the prediction process, you will go over your parts lists, do stress analysis, and note part quality levels; this detailed examination can expose overstressed parts and misapplied parts. The predicted failure rates will point you to parts, or part groups, which are high contributors to the product failure rate; these problem areas can then be addressed and improved.

Trade-Off System Design Factors: There are many factors that determine the overall value of a product; functional performance, cost, size, weight, reliability, and other parameters must all be integrated for a successful design. The design process will thus involve many trade-offs among these factors; reliability predictions can offer a quantitative measure of reliability to guide your trade-off decisions.

Track Reliability Improvement: As you progress through the design, reliability predictions can offer evidence of improving reliability, allowing designers, management, and customers to track progress toward reliability goals.

Ways to Improve Reliability

As you design your product, you can improve reliability by using the following ideas; note that reliability predictions allow you to quantitatively measure the effects of improvement steps.

Reduce Part Count: In general, reducing part count will increase reliability. You can use innovative design ideas, and more highly integrated functional parts, to reduce the number of parts without affecting circuit performance; part count reduction can also lead to lower cost and less board space required.

Part Selection: The quality and reliability of the components you select for your product is very important; select suppliers that produce high quality, high reliability parts.

Derating: Part failure rates generally decrease as applied stress levels decrease. Thus, derating, or operating the part at levels below it's ratings (for current, voltage, power dissipation, temperature, etc.) can increase reliability. Part derating can be achieved by circuit design (minimize applied part stress), part selection (use part with ratings well above given applied stress), and thermal design (reduce part operating temperature).

Burn-In: Burn-in is operation in your factory, at elevated temperature, to accelerate the rate of infant mortality failures; burn-in allows you to weed out failure prone devices in your factory, rather than in the field. Note that burn-in can be done at the part, board, or system level.

Redundancy: Product reliability may also be enhanced by using redundant design techniques.

How Reliability Can Pay Off

To give you an idea of how the reliability of your product can impact your company's fortunes, consider an example. We will assume: the typical customer operates your product for 300 hours per month; your product warranty is for 1 year; an exponential reliability function. We will tabulate the expected failures of field units in one year, based on product MTBF in hours.

MTBF	Failure Free	Failure
5,000	48.7%	51.3%
10,000	69.8%	30.2%
20,000	83.5%	16.5%
40,000	91.4%	8.6%

Note that at 5,000 hours MTBF, over half of the units can be expected to fail in the one year period. When you consider that every failure costs you repair dollars, and also represents a potentially unhappy customer, you can see how your business literally depends on your product's reliability.

Ways to Do Reliability Prediction

You can use various reliability prediction techniques, depending on your knowledge of the details of your design. An early estimate can be made by comparing your product with products of similar function or complexity, of known reliability; generally, this will be a crude estimate at best, as the many differences in design details between the products are not accounted for.

As more details of your design are known, more accurate methods become available. These methods utilize part failure rate models, which predict the failure rates of parts based on various part parameters, such as technology, complexity, package type, quality level, and stress levels.

Two of the better known failure rate prediction methods are MIL-HDBK-217, and Bellcore. These handbooks offer documented procedures for predicting electronic product reliability, providing a standard basis for comparing reliability numbers.

Limitations of Reliability Prediction

To use quantitative reliability prediction methods such as MIL-HDBK-217 and Bellcore wisely, you should be aware of their limitations. Like all engineering models, the failure rate models are approximations to reality. The failure rate models are based on the best field data that could be obtained for a wide variety of parts and systems; this data is then analyzed and massaged, with many simplifying assumptions thrown in, to create usable models. Then, when you use the model, you make more assumptions for the design parameters you enter, such as stress and temperature.

Thus you should not treat a reliability prediction number for your product as an absolute prediction of it's field failure rate. It is generally agreed that these predictions can be very good when used for relative comparisons, such as comparing design alternatives, or comparing products. Note also that reliability predictions do not account for substandard quality control for purchased parts, bad workmanship, poor product level quality control, overstressed field operation, etc.

Many people get caught up in the numbers game, manipulating the reliability prediction numbers for one purpose or another; you will be best served if you use reliability prediction as one of the tools that can guide you to more reliable products.

Description of Methodology

The parts count method is a technique for developing an estimate or prediction of the average life, the Mean-Time-Between-Failures (MTBF), of an assembly. It is a prediction process whereby a numerical estimate is made of the ability, with respect to failure, of a design to perform its intended function. Once the failure rate is determined, MTBF is easily calculated as the inverse of the failure rate, as follows:.

$$\text{MTBF} = \frac{1}{\text{FR1} + \text{FR2} + \text{FR3} + \text{............FRn}}$$

where FR is the failure rate of each component of the system up to n, all components.

The general procedure for determining a board level (or system level) failure rate is to sum individual failure rates for each component. For MIL-HDBK-217, the summation is then added to a failure rate for the circuit board, which includes the affect of solder joints. Component failure rates are provided by MIL-HDBK-217, "Military Handbook, Reliability Prediction of Electronic Equipment", as standard part failure rate models or directly from the manufacturers.

The failure rates presented apply to equipment under normal operating conditions, i.e., with power on and performing its intended function in its intended environment. Consideration is given to various environments, component quality, and thermal aspects.

Reliability Standards

There are several methods and standards that provide the basic core mathematical models for reliability calculations. The standards and a description of each follows.

MIL-HDBK-217

MIL-HDBK-217 is the original standard for reliability calculations. It provides reliability math models for nearly every conceivable type of electronic device. Used by both commercial companies and the defense industry, MIL-HDBK-217 provides detailed reliability equations. MIL-HDBK-217, which is updated regularly, is currently at Revision F Notice 2.

This standard uses a series of models for various categories of electronic, electrical and electro-mechanical components to predict failure rates which are affected by environmental conditions, quality levels, stress conditions and various other parameters. These models are fully detailed in MIL-HDBK-217.

Parts Count

A section of MIL-HDBK-217, known simply as the Parts Count section, provides simpler reliability math models for the various part types. Most of the part parameters requested in the main body of MIL-HDBK-217 (also known as the Part Stress section) are automatically defaulted to average values in the Parts Count section. Parts Count reliability calculations are normally used early in a design when detailed information is not available, or when a rough estimate of reliability is all that is required.

Bellcore/Telcordia

The Bellcore reliability standard, Reliability Prediction Procedure for Electronic Equipment, TR-332 is a very popular standard for commercial companies. It was originally developed at AT&T Bell Laboratories, and was based on MIL-HDBK-217. Bell Labs modified the equations from MIL-HDBK-217 to provide results which better represented what their equipment was experiencing in the field. They also added the ability to take into account burn-in testing, as well as field and laboratory testing. Bell Communications Research, formed in the divestiture of the former Bell System was the controlling organization of the Bellcore reliability standard. Presently the standard is known as Telcordia SR-332 and Telcordia is the controlling organization.

Mechanical

The Handbook of Reliability Prediction Procedures for Mechanical Equipment, NSWC-94/L07, provides models for various types of mechanical devices including springs, bearings, seals, motors, brakes, clutches, and much more. This relatively new standard is the only one of its kind - providing detailed reliability math models for mechanical devices. This latest issue date of this mechanical standard is March 1994.

CNET

The CNET reliability standard from France T,l,com is the French reliability standard for telecommunications equipment. CNET, developed in 1983, was originally based on MIL-HDBK-217. The most recent revision of the document, RDF 93, provides many enhancements.

The Equations

A sample calculation for integrated circuits taken from MIL-HDBK-217 is as follows:

$$\text{Failure Rate} = (C1 * PiT + C2 * PiE) * PiQ * PiL$$

Each factor in this equation is dependent upon a certain part parameter. The end result of this equation is the failure rate of the integrated circuit.

Failure Rate & MTBF

For this discussion, we will assume that the resulting failure rate is shown in failures per million hours. This is simply the number of failures that you would expect to have in a million hours of operation of your equipment. Failure rates for many basic devices are well below 1 failure per million hours, so these values may seem insignificant. But if you have hundreds of parts in your design and have a thousand systems operating in the field, you can see that the failure rates will quickly add up. MTBF, or Mean Time Between Failures, is the inverse of the failure rate and is the average time between failures. It is calculated from the failure rate as follows:

$$\text{MTBF} = 1{,}000{,}000/\text{Failure Rate}$$

You can choose the units in which the failure rate is shown. Another common unit used, besides failures per million hours, is failures per billion hours which is known as FITs.

MIL-HDBK-217F Environmental Conditions

Ground, Benign, GB
Nonmobile, temperature and humidity controlled environments readily accessible to maintenance; includes laboratory instruments and test equipment, medical electronic equipment, business and scientific computer complexes, and missiles and support equipment in ground silos.

Ground, Fixed, GF
Moderately controlled environments such as installation in permanent racks with adequate cooling air and possible installation in unheated building; includes permanent installation of air traffic control radar and communications facilities.

Ground, Mobile, GM
Equipment installed on wheeled or tracked vehicles and equipment manually transported; includes tactical missile ground support equipment, mobile communication equipment, tactical fire direction systems, handheld communications equipment, laser designations and range finders.

Naval, Sheltered NS
Includes sheltered or below deck conditions on surface ships and equipment installed in submarines.

Navel, Unsheltered NU
Unprotected surface shipborne equipment exposed to weather conditions and equipment immersed in salt water. Includes sonar equipment and equipment installed on hydrofoil vessels.

Airborne, Inhabited, Cargo AIC
Typical conditions in cargo compartments, which can be occupied by an aircrew. Environment extremes of pressure, temperature, shock and vibration are minimal. Examples include long mission aircraft such as the C130, C5, B52 and C141. This category also applies to inhabited areas in lower performance smaller aircraft as the T38.

Airborne, Inhabited, Fighter AIF
Same as AIC but installed on high performance aircraft such as fighters and interceptors. Examples include the F15, F16, F111, F/A18 and A10 aircraft.

Airborne, Uninhabited, Cargo, AUC
Environmentally uncontrolled areas, which cannot be inhabited by an aircraft, crew during flight. Environmental extremes of pressure, temperature and shock may be severe. Examples include uninhabited areas pf long mission aircraft such as the C130, C5, B52 and C141. This category also applies to uninhabited areas pf lower performance smaller aircraft such as the T38.

Airborne, Uninhabited, Fighter, AUF
Same as AUC but installed on high performance aircraft such as fighters and interceptors. Examples include the F15, F16, F111, and A10 aircraft.

Airborne, Rotary Winged, ARW
Equipment installed on helicopters. Applies to both internally and externally mounted equipment such as laser designators, fire control systems, and communications equipment.

Space, Flight, SF
Earth orbital. Approaches benign ground conditions. Vehicles neither under powered flight nor in atmospheric reentry; include satellites and shuttles.

Missile, Flight, MF
Conditions related to powered flight or air breathing missiles, cruise missiles, and missiles in unpowered free flight.

Missile, Launch, ML
Severe conditions related to missile launch (air, ground, and sea), space vehicle boost into orbit, and vehicle re-entry and landing by parachute. Also applies to solid rocket motor propulsion powered flight, and torpedo and missile launch from submarines.

Cannon, Launch, CL
Extremely severe conditions related to canon launching of 155mm and 5 inch guided projectiles. Conditions apply to the projectile from launch to target impact.

Appendix B

Assembly and Component Failure Data

MTBF Prediction Report

P/N Detail, Sorted by TFR

Switching Power Supply

P/N:

Environment: MIL-HDBK-217, Ground Benign, Controlled, GB,GC @ 25^{o}C

Category	Mfgr. P/N	Description	P/N	Ref. Des.	Qty.	FR, Unit	Total FR	T Rise (C)	Stress (%)
	IRF840	N-Channel Power MOSFET TO-220	172-24326	Q1'	1	332.8781	332.8781	18	23
		MAIN FWR XFMR/SP668	082-100772	T1'	1	289.4788	289.4788	56	na
		IC OPTO COUPLER TSTR 6PIN	130-27413	U2 U3	2	111.9862	223.9724	15	na
		SWITCH THERM 90 DEG TO220	909-26492	TSW1	1	171.7697	171.7697	0	5
	BUZ11	N-Chan TMOS Power FET, 50V, TO220, BUZ11	170-22222	Q5	1	85.36857	85.36857	31.3	na
		Diode, REC 200mA 100V	756-24559	CR103 CR104 CR109 CR110 CR111 CR112 CR115 CR201 CR202 CR301 CR302 CR304 CR305 CR306 CR307 CR401	16	3.91002	62.56032	5.5	50
	L4981AD	IC SM PWM PFC SO20	729-27602	U201	1	59.14947	59.14947	36	na
		PWB FAB	510-100517	PCB	1	56.925	56.925	na	na
	MMBZ5232BL	DIODE ZEN 5.6V SOT23	756-27050	VR301 VR302 VR303	3	18.74454	56.23363	26.8	50
		CAP 0805 50V X7R 0.1uF	766-27154	C102 C103 C107 C201 C204 C209 C301 C304 C305 C306 C307 C313 C316 C318 C320 C322 C323 C324 C325 C326 C327 C328 C329 C331 C402 C406 C407 C408 C409 C410	30	1.870827	56.12481	3	10
	LMV431ACZ	IC ADJ SHUNT REG 1.24V 1% TO-92	130-28211	U301 U307	2	24.78688	49.57376	32.2	na
		MOSFET 900V 7A TO247	170-27942	Q2'	1	37.84186	37.84186	41	30
	BZX84C15L	DIODE ZEN 225mW 15VSOT23	756-22588	VR101	1	33.61112	33.61112	62.3	49.8
	MURS120 T3	DIODE SMB 1A/20A PK 200V	764-24972	CR101 CR102 CR106 CR108	4	8.318298	33.27319	3.3	50
		CAP EL 3900UF 6.3V 12.5X	101-26475	C20' C21'	2	12.64947	25.29895	30	52.4
	BYM26E	DIODE REC 1000V 2.3A UFR SOD64	111-21388N	CR11	1	23.6703	23.6703	37.5	2.4
		RES MO 1.00W 5% 10	158-24246N	R10 R8	2	10.42417	20.84835	5	50
		RES MO 1.00W 5% 39K	158-25983N	R2 R3	2	10.42417	20.84835	5	50
		RES MO 5.00W 5% 3.3	158-25041N	R9	1	19.5272	19.5272	10	50
	BYV26C	DIODE PW 600V 1.0A UNPERP SOD57	111-22734N	CR2	1	19.174	19.174	30	50
	MURH860CT	DIODE CT CC 600V 8A UFR TO220	140-27048	CR3'	1	18.0969	18.0969	28	4
	MMBZ5248BL	Diode, ZNR 18V SM SOT-23	756-27418	CR114 VR102	2	8.960463	17.92093	5.5	50
		CAP EL 150uF 400V 25X30	101-28694	C12'	1	2.909139	2.909139	22	3
	32CTQ030	CUST DIODE SCH 30A 15V TO-220	140-28048	CR8'	1	2.879647	2.879647	38	25

MTBF Prediction Report

P/N Detail, Sorted by TFR

Switching Power Supply

P/N:
Environment: MIL-HDBK-217, Ground Benign, Controlled, GB,GC @ 25°C

Category	Mfgr. P/N	Description	P/N	Ref. Des.	Qty.	FR, Unit	Total FR	T Rise (C)	Stress (%)
		RES MO .50W 5% MINI 1.2K	158-24825N	R14	1	2.791551	2.791551	5	50
		CAP EL 1000UF 35V 12X30	101-24770	C27'	1	2.34272	2.34272	5	34.3
		DIODE REC 45V 10.0A SCH	111-24140	CR10	1	2.300881	2.300881	30	26.7
	CMSH1-40 TR13	DIODE SCH 40V 1A SMB	764-27604	CR105 CR203	2	1.149392	2.298783	7.5	12.5
		CAP SM 0805 50VX7R 220PF	766-25642	C206 C212	2	1.078579	2.157157	3	10
		CAP CERAMIC RA 50V 0.47MF	107-26443	C23' C24'	2	1.060961	2.121922	3	6.6
	WY0472MCMCRAK	CAP AC Y 250VAC 4700PF	106-24382	C5' C6' C7' C8'	4	0.524466	2.097863	15	45.8
		RES SM 0805 .1W 1% 1.00K	746-27026	R122 R153 R321 R325 R327 R328 R332 R333 R335 R336 R339 R341 R363 R408 R409	15	0.136285	2.04427	0	0.5
	LM358D	IC SM DUAL OP AMP 8P SO8	740-24562	U102 U304 U305	3	0.67409	2.022271	na	na
	32CTQ030	CUST DIODE SCH 30A 15V TO-220	140-28048	CR9	1	1.988564	1.988564	25	25
		RES SM 0805 .1W 1% 10K	746-24714	R105 R106 R146 R160 R206 R306 R310 R315 R322 R324 R372 R381 R382 R403	14	0.136285	1.907985	0	0.5
		RES 1206 1/8W 1% 499K	748-27054	R101 R102 R107 R108 R109 R110 R111 R112 R113 R114 R117 R118	12	0.148676	1.784116	0	0.5
		LED HARNESS GRN	084-100839	DS1	1	1.471861	1.471861	4.9	na
		LED HARNESS AMB	084-100842	DS2	1	1.471861	1.471861	4.9	na
		RES SM 0805 .1W 1% 10.0	746-27018	R103 R115 R145 R218 R219 R303 R346 R356 R404 R405	10	0.136285	1.362847	0	0.5
		RES SM 0805 .1W 1% 3.01K	746-27112	R149 R202 R211 R212 R213 R307 R312 R353 R357 R377	10	0.136285	1.362847	0	0.5
		CAP EL 22UF 35V 6.3X7	101-24470	C25'	1	1.335265	1.335265	13.7	14.3
		POT CC 2K HOR MTG S-TRN	154-24248	R13 R21	2	0.615307	1.230614	5	0.5
		CAP CERAMIC RA 50V 0.47MF	107-26443	C34'	1	1.127362	1.127362	3	24
		RES SM 0805 .1W 1% 5.11K	746-24711	R301 R302 R314 R317 R330 R338 R350 R384	8	0.136285	1.090277	0	0.5
	BCP69T1 OR BCP69T3	TSTR P SM 20V 1A SOT223	776-28086	Q201	1	1.078156	1.078156	62.5	25
		JUMPER 0.800L 22AWG TEFL	261-20721	W2	1	1	1	0	na
		CONN PC 3PIN .045SQ TIN	899-21486	J1	1	1	1	0	na
		CAP DK RA 500V 100000PF	105-21129	C16'	1	0.921851	0.921851	3	2.4