



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES®

IPC-9592

Performance Parameters for Power Conversion Devices

Final Draft

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IPC-9592, Performance Parameters for Power Conversion Devices

1 SCOPE

1.1 Statement of Scope This document standardizes the performance parameters for power conversion devices including but not limited to the computer and telecommunications industries. The phrase “power conversion devices” refers to AC to DC and DC to DC modules, converters and printed circuit board assemblies. This specification sets the requirements for design; qualification testing; conformance testing; manufacturing quality processes; and regulatory requirements but does not include the functional requirements of the specific equipment.

1.2 Description Power Conversion Devices addressed in this document are used in the electronics industry to provide conversion of mains power sources, usually AC, to lower DC voltages either for direct use of electronic circuits, or as a secondary source for additional DC to DC power conversion devices to provide several DC voltage levels for various electronic devices in a product.

Performance Parameters are comprised of mechanical, electrical, environmental, quality/reliability, and regulatory requirements:

Mechanical requirements include form and size, connector and wiring configurations, and cooling needs.

Electrical requirements define the electrical interface, including power source (AC or DC), input voltage, frequency and current needs, output voltages and current capabilities, and, where applicable, logic controls.

Environmental requirements entail both operating and shipping temperatures, humidity, shock and vibration limits.

Quality/Reliability Assurance requirements include definitions and requirements for the design and testing of the quality and reliability of power conversion devices.

Regulatory requirements are international standards for safety, electronic interference, and environmental impact of power conversion devices.

Methods This document describes specific methods to meet the defined performance parameters. These methods are **Design for Reliability, Design Qualification Testing, Manufacturing Conformance Testing, and Quality Processes**. In addition, this document specifies key **Regulatory Requirements** pertaining to power conversion devices.

1.3 Purpose The purpose of this document is to create a set of consistent specifications and methods to assure suitability, quality, safety and reliability of power conversion devices for the electronics industry. These specifications will apply to suppliers of power conversion devices, including their design and testing, and will provide guidelines for the end user to ensure adequate specifications for use in their products. All of the specifications and requirements defined in this document are intended to be part of suppliers’ Power Conversion Devices Certifications outlined by the customers and will ship with first article and any design changes to the power conversion device.

1.4 Order of Precedence When Purchasing

In the event of conflict when this document is utilized for purchasing a product addressed by this IPC standard, the following order of precedence **shall** apply:

- a. Purchase order
- b. Master drawing
- c. This standard
- d. Applicable documents (see 2)

2 APPLICABLE DOCUMENTS AND TERMS AND DEFINITIONS

2.1 IPC

IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies
IPC/EIA/JEDEC J-STD-002 Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires
IPC-A-610 Acceptability of Electronic Assemblies
IPC-9701 Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments

2.2 INTERNATIONAL

2.2.1 CANADIAN STANDARDS ASSOCIATION (CANADA)

CAN/CSA C22.2 No. 60950-1 Safety of Information Technology Equipment, Including Electrical Business Equipment

2.2.2 INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 3741 Determination of Sound Power Levels of Noise Sources - Precision Methods for Broad-Band Sources in Reverberation Rooms (Equivalent to ANSI/NAIS S12.51)
ISO 3744 Determination of Sound Power Levels Noise Sources Using Sound Pressure - Engineering Method in an Essentially Free Field Over a Reflecting Plane (Equivalent to ANSI/NAIS S12.54)
ISO 10302 Method for the Measurement of Airborne Noise Emitted by Small Air-Moving Devices (Equivalent to ANSI S12.11)

2.2.3 GB CHINA

GB 4943-2001 Safety of Information Technology Equipment (Including Electrical Business Equipment)

2.2.4 INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60529 Degrees of Protection Provided by Enclosures (equivalent to EN 60529)
IEC 60950-1 Safety of Information Technology Equipment, Including Electrical Business Equipment, including all national deviations as specified in the current CB Bulletin
IEC 61000 Electromagnetic Compatibility (EMC) – consists of over 30 documents covering electromagnetic and radio interference, power line interference, ESD, immunity and ground (earth connection) testing
IEC 61000-3-2 Electromagnetic Compatibility (EMC) – Part 3-2 Limits – Limits for Harmonic Current Emissions (Equipment Input Current \leq 16A per Phase)
IEC 61000-4-2 Electromagnetic Compatibility (EMC) – Part 4-2 Testing and Measurement Techniques – Electrostatic Discharge Immunity Test
IEC 62040-1-1 1st edition and IEC 62040-1-2 1st edition Components and Subassemblies used in Uninterruptible Power Systems (and their equivalent adapted standards such as EN 62040-1-1 or UL 1778, etc. in different countries)

2.2.5 NORMA OFICIAL MEXICANA

NOM-019-SCFI Safety requirements for Information Technology Electronical Devices

2.2.6 EUROPEAN UNION

EN 50116 Information Technology Equipment. Routine Electrical Safety Testing in Production
EN 55022 Information Technology Equipment – Radio Disturbance Characteristics – Limits and Methods of Measurement
EN 55024 Electrostatic Discharge Requirements

2.3 UNITED STATES

2.3.1 TELCORDIA

SR332-1 Reliability Prediction Procedure for Electronic Equipment

2.3.2 JEDEC

EIA/JESD22-A101 Steady State Temperature Humidity Bias Life Test

JESD22-A108 Temperature, Bias and Operating Life

JESD22-A114 Electrostatic Discharge (ESD) Sensitivity Testing - Human Body Model (HBM)

2.4 TERMS AND DEFINITIONS The definition of all terms used herein **shall** be as specified in IPC-T-50 and as defined below.

AABUS - (As an Acronym): As Agreed Between User and Supplier

- (As a Term): Indicates additional or alternate requirements to be decided between the user and the supplier in the procurement documentation. Examples include contractual requirements, modifications to purchase documentation, and information on the drawing. Agreements can be used to define test methods, conditions, frequencies, categories or acceptance criteria within a test, if not already established.

ARRHENIUS RELATIONSHIP – Mathematical model for relation of failure rate to temperature – see Appendix E.

BOM - Bill of Material

BMP - Board Mount Power: Refers to encapsulated and open PWB power converters that are mounted on larger PWBs.

C_p - Process Capability: An indicator of process capability using the ratio of specification width to process variation.

C_{pk} - Process Capability Index: Adjustment of C_p for the effect of a non-centered distribution. Measures how close a process is running to its specification limits, relative to the natural variability of the process and center of the distribution.

DFMEA - Design Failure Modes and Effects Analysis

DL - Destruct Limit: The stress level at which product will fail. When the stress level is reduced, the failure will not recover (i.e., This is a hard failure).

DMTBF - Demonstrated Mean Time Between Failure: The value of MTBF determined from a life test. This test does not measure the actual reliability.

DoC - Declaration of Conformity: The proof of compliance provided by a manufacturer or importer that the information technology equipment being imported into those countries requiring said compliance, meets the requirements.

DVT - Design Verification Test: a qualification test to assess if design specifications are met.

EDVT - Electrical Design Verification Test: a qualification test to assess electrical design specifications are met

EMC - Electro-Magnetic Compatibility

EMI - Electro-Magnetic Interference

ESD – Electro-Static Discharge

FET - Field Effect Transistor: includes power MOSFETS commonly used in power converters

Grms - Root Mean Square value of G, where G is acceleration due to gravity – a measure of dynamic acceleration used in vibration testing.

HALT - Highly Accelerated Life Test: Design test used to improve the robustness/reliability of a product through test-fail-fix process where applied stresses are beyond the specified operating limits.

HASA - Highly Accelerated Stress Audit; performed via sample testing as opposed to 100% that is done with HASS.

HASS – Highly Accelerated Stress Screening: Used to improve the robustness/reliability of a product through test-fail-fix process where the applied stresses are beyond the specified operating limits. This is applied to 100% of the manufactured units.

LDL - Lower Destruct Limit, e.g., -50C. – See DL.

LIFE TEST - A test run specifically to determine reliability (or failure rate) over time of a component or product.

LOL - Lower Operational Limit, e.g. -20C. – See OL.

LTPD - Lot Tolerance Percent Defects

MDVT - Mechanical Design Verification Test

MRA - Mutual Recognition Agreement/Arrangement

MTBF - Mean Time Between Failure (may be estimated from methods such as Telcordia SR332, or from hardware tests).

OL - Operational Limit: The stress level at which a product may lose its function. However, when the stress level is reduced, the function will recover.

ORT - Ongoing Reliability Test

PCB - Printed Circuit Board; same meaning as PWB (Printed Wiring Board)

PCD – Power Conversion Device: refers to AC to DC and DC to DC modules, converters and printed circuit board assemblies.

PFMEA - Process Failure Modes and Effects Analysis

POWER TRAIN – Components that directly transform input power into output power in a power conversion device.

PRODUCT SPECIFICATION – The comprehensive description of form, fit and function for a product, often expressed in a product data sheet (although some data sheets are only excerpts of key specifications).

PWB - Printed Wiring Board; same meaning as PCB (Printed Circuit Board)

RD – Reliability Demonstration Test – It is typically performed once prior to the release of a new product.

STATISTICAL CONFIDENCE LIMITS – Mathematical bounds on distribution estimates made from a sample.

STATISTICAL PROCESS CONTROL - Methods using statistical techniques to assess the stability of processes in order to take appropriate action to reduce defects, and to determine the quality level of components, assemblies and products. Often called SPC and also called SQC (Statistical Quality Control).

STATISTICAL QUALITY CONTROL – See Statistical Process Control.

STRIFE - Stress + Life test: Design test used to improve the robustness/reliability of a product through test-fail-fix process where applied stresses are beyond the specified operating limits.

SUB-TIER SUPPLIER – In this document, applies to a component/subassembly supplier to the power conversion device supplier.

SUPPLIER – In this document, applies to a power conversion device supplier.

UDL - Upper Destruct Limit, e.g., 150C or 40Grms Vibration. – See DL.

UOL - Upper Operational Limit, e.g., 100C or 30Grms Vibration. – See OL.

USER – In this document, applies to the customer of the power conversion device supplier.

3 PRODUCT REQUIREMENTS SPECIFICATION

3.1 Data Sheet Information – Form, Fit and Function The supplier **shall** provide complete specifications of form, fit and function, including all electrical specifications, mechanical drawings with dimensions and tolerances, pin-out definitions, logic input and output definitions when applicable, derating curves, application notes, trim equations & schematic, reliability data (MTBF with conditions of use), and regulatory certification information. The datasheet **shall** be dated and have revision level marked at the bottom of the sheets. A list of typical data sheet information is shown below – not all of these elements will necessarily apply to a given power conversion device. Specific values for these parameters cannot be defined in this section as they will depend on the particular device application and requirements. Typical examples of Power Conversion Device data sheets are shown in Appendix B.

3.2 Input Power Specifications

3.2.1 AC/DC PCD Data Sheet shall include nominal input voltage, input voltage range, input frequency range, inrush current (primary inrush and subsequent pulses), typical & minimum efficiency, power factor and power factor correction circuit operation, turn-on time, auto-restart specifications, input over-current protection and fuse type, AC input receptacle type (defined with an IEC rating), EMI filter standard, harmonic distortion suppression (EN61000-3-2), isolation voltage, AC leakage current, radiated EMI, slow line transient performance (sag and surge), AC line dropout response, full cycle ride thru frequency, and Energy Star requirements where applicable.

3.2.2 DC/DC PCD Data Sheet shall include number of voltage inputs, input voltage range(s), typical & minimum efficiency, input over-current/reverse voltage protection and fuse requirements, input filter capacitance requirements, and radiated EMI as applicable.

3.3 Logic, Indicator, and Control Specifications

(As applicable) Data Sheet **shall** include remote on-off signal requirements, power-good signal specifications, I2C port specifications, control logic timing requirements, control and logic signal ripple and noise requirements, fan speed control specifications, and LED indicator specifications.

The Power Conversion Device supplier **shall** provide trim equations and schematics, and a table showing the trim resistor values. Additionally, detailed information and recommendation on Trim Control via external voltage or current source (D/A converter) **shall** be provided on request (example: the interface to parts like the Summit SMM665, Analog Devices ADM1062, Lattice ispPAC, etc.).

3.4 Output Specifications

3.4.1 AC/DC PCD Data Sheet shall include thermal stabilization time, DC output voltages, output current capability, minimum load requirements, DC voltage output tolerances, output load regulation, output temperature coefficient, output ripple and noise, common-mode voltage and common-mode current, output/output isolation, voltage adjustment range, output transient response to dynamic loading, closed loop stability and capacitive loading capability, turn-on overshoot characteristics, over-current protection, short circuit protection, over-voltage and under-voltage protection, reverse voltage protection, thermal protection, reset after shutdown conditions, remote sense specifications, current sharing/parallel operation requirements, and output connector specifications.

3.4.2 DC/DC PCD Data Sheet shall include number of outputs, nominal output voltage(s), voltage tolerance (each output), line regulation (each output), load regulation, noise & ripple, short circuit protection time, transient response, switching frequency, temperature coefficient, I/O isolation voltage, and isolation resistance.

3.5 Environmental Specifications

AC/DC and DC/DC Power Conversion Device Data Sheet shall include storage temperature, operating temperature, non-operating humidity, operating humidity, non-operating altitude, operating altitude, cooling requirements (method and versus altitude), output derating versus temperature, shipping/storage vibration, operating vibration, shipping/storage shock, and operating shock.

3.6 Reliability and Warranty

AC/DC and DC/DC Power Conversion Device Data Sheet shall include MTBF (and operating conditions), operational life, and warranty.

3.7 Safety and Regulatory

AC/DC and DC/DC Power Conversion Device Data Sheet shall include acoustics measurements and methods, worldwide certifications for safety, EMI/EMC/RFI compliance, Lead-Free and restricted materials compliance such as RoHS/WEEE certification.

3.8 Physical Dimensions and Electrical Connections

AC/DC and DC/DC Power Conversion Device Data Sheet shall include complete dimensions, weight, electrical connector definitions, and drawings of power conversion device and of shipping & packaging configurations as applicable.

(See Appendix B for detailed examples of data sheet content)

4 DESIGN FOR RELIABILITY

This section describes how a power conversion device supplier should specify, design, and document the performance and reliability of a power conversion device. The power conversion device user can require that these methods be used.

4.1 Reliability (MTBF) With user's operating specifications provided, the supplier **shall** define expected reliability of a power conversion device and the conditions under which the reliability is specified. The MTBF **shall** be supplied and **shall** be calculated using Telecordia Technologies SR-332, *Reliability Prediction Procedure for Electronic Equipment* (Method 1: Parts Count with or without stress test, AABUS). The supplier **shall** specify the quality level used. The supplier **shall** also verify reliability of all power conversion device designs by test.

4.2 Component Selection The power conversion device supplier **shall** have a documented process in place to select all components for product designs and **shall** provide information on all components and all component suppliers to the power conversion device user as described below. The component selection process **shall** incorporate the following factors:

- The supplier **shall** assure that electrical, mechanical, and thermal specifications for all components meet the requirements of the **Derating Guidelines**, described in 4.3 and Appendix A, for the operating conditions of the power conversion device design.
- The supplier **shall** assure that all **Safety critical components** comply with relevant UL, CSA, IEC and other Agency Standards as listed in Sections 2 and 9. The power conversion device supplier **shall** provide a Needle Flame Test Report or proof that all components are 94V-0 or better flame rating.
- The supplier **shall** assure that effects of all component failure modes have been considered in the **DFMEA** analysis and that appropriate corrective action has been taken where required. Supplier **shall** provide a report to the power conversion device user, as described in 4.4.
- The supplier **shall** develop and implement a quality management system that will define quality and technical requirements to their component suppliers (sub-tier suppliers). Quality and technical requirements are defined as quality programs, engineering drawings, specifications and functions to be performed by sub-tier suppliers. The power conversion device supplier may elect to use a contract, purchase order or other suitable means in defining these requirements, as long as the quality and technical requirements are fully documented and that the sub-tier supplier verify understanding and implementation of such requirements.
- The supplier **shall** perform a quality review of all proposed sub-tier suppliers prior to awarding business to a sub-tier supplier as described in section 6.2.
- The supplier **shall** define component reliability requirements to their sub-tier suppliers. These requirements **shall** align with those of the power conversion device user. The supplier **shall** implement testing as required to verify performance and reliability of components, or **shall** assure that the sub-tier supplier implement and report on such testing. These tests **shall** include (as a minimum) functional testing of all critical parameters, measurement and monitoring of Statistical Process Control variables, and ongoing reliability testing (ORT). Test reports should be provided on a regular basis as agreed upon by supplier and user.
- The power conversion device supplier **shall** adequately monitor component supplier's quality systems and performance for all components used in a design. This includes assuring there is a sub-tier quality management program that **shall** provide for quality goals, the performance of site surveys and audits, quality program requirements, change or revision control requirements, tests and inspections, and component qualification before production in the case of new components.
- The power conversion device supplier **shall** submit a list showing all components used, mechanical and electrical, along with an Approved Source List for each of the components. During the design and development phase of the power conversion device the manufacturer **shall**, in the case of multiple supply sources, submit samples that are representative of all different component sources. In particular, *all possible sources* for connectors, fans, capacitors and switching power FET's **shall** be built into samples used for supplier testing and provided to the user during development.

4.2.1 Fans (Air Moving Devices) Where required in high power AC/DC power conversion designs, fans and blowers present several challenges in design and regulatory requirements. The supplier **shall** assure that any air moving device used in a power conversion device design meets cooling performance, electromagnetic interference, acoustical, safety, and reliability goals applicable to the overall design. See IPC 9591, *Performance Parameters For Air Moving Devices*, for guidance on fans and blowers.

4.3 Derating Guidelines In order to provide a long-life and reliable power conversion product the supplier **shall** use a method of component derating in all electrical designs and **shall** provide details on the derating methods, conditions and results to the power conversion device user upon request.

Derating is a technique used to ensure that component ratings are not exceeded, either under steady state or transient conditions. The intent of component derating is to improve reliability of electrical components in electronic products by compensating for many variables inherent in a design. Proper component derating will lower failure rates through reduced stresses, reduce the impact of material, manufacturing, and operational variability, and enable continued circuit operation with long-term part parameter shifts.

An example of an electrical component derating chart is shown below in Table 4-1. Note that the derating numbers shown are typical for these types of capacitors, but variations exist in some companies. This example is for only a few types of capacitors – a complete derating guideline must include all components required for a design. **Appendix A** contains a suggested derating guide for all common electrical components that are likely to be used in a power conversion device.

Table 4-1 Capacitor Derating Chart Example

Device Type	Parameter	Stress Factor ¹
Capacitors		
Fixed Ceramic – MLCC Note: Do Not use a surface mount part larger than a 1210 body size due to potential for cracking	DC Voltage	≤ 80%
	Temp below Max Limit	≥ 10°C
Fixed Solid Tantalum NOTE – NOT recommended in power designs due to fire hazard – should be used with at least 3Ω/Volt series resistance.	DC Voltage	≤ 40%
	Ripple Current	≤ 60%
	Reverse Voltage - Peak	≤ 2%
	Temp below Max Limit	≥ 20°C
Fixed Paper, Plastic	DC / AC Voltage Nominal	≤ 70%
	Temp below Max Limit	≥ 10°C
	Power Supply X-Y cap Voltage	Note 2
Fixed Aluminum Electrolytic Use 5,000 hour load life ratings (at Max Temp) when possible	DC Voltage	≤ 80%
	Ripple Current	≤ 70%
	Temp below Max Limit	≥ 10°C

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress ratio.

2. Components with Certified Safety Agency approvals may be used up to 100% of their approved ratings.

Applying derating to an entire power conversion device design is a meticulous and comprehensive effort. Every critical parameter, including voltages, currents, temperatures, and other stress factors, **shall** be considered. Note that there may be *mechanical* considerations for electrical component deratings. For example, multiple layer ceramic capacitors (MLCC) are sensitive to mechanical bending, which can cause cracks and electrical failure. **See Appendix A** for comprehensive and specific derating requirements.

Derating considerations **shall** be considered before designs are finalized and before components are selected. The choice of component parameters will be affected by the derating level (stress factor) used, as well as by considerations from **Design Failure Modes and Effects Analysis**, discussed below.

Examples of hypothetical and comprehensive reliability specifications are shown below in Table 4-2. Actual values would be different for a given power conversion device. Note that for custom power conversion devices, the specifications will be provided by a power conversion device user to the supplier in a request for quote (RFQ) or some other design specification:

Table 4-2 Two Examples: Reliability and Application Conditions

EXAMPLE 1:

The reliability required for this device is 98% per year, equivalent to an MTBF of 425,000 hours. These reliability requirements are based on the following product usage/application conditions:

- Normal usage of rated output load 80%
- Input Voltage (min and max) Any voltage between 90 VAC and 264 VAC
- Input Frequency 60 Hz
- Nominal Relative Humidity 44% +/- 10% non-condensing
- Altitude Sea Level
- Temperature 40° C
- On/Off Cycles per Year 52
- Reliability 98% per year, 90% in 5 years; 100% duty cycle (8,760 hours per year)
- Expected Operating Life 5 years

- A. no preventive maintenance is acceptable to meet the MTBF value.
- B. MTBF calculations assume 100% duty cycle.
- C. Includes all limited life item failures occurring within the specified Operating Life for the power conversion device.

EXAMPLE 2:

A shorter reliability specification example that includes the necessary operating conditions:

Reliability

- MTBF 400,000 hours @ 100% duty cycle, 40°C ambient, 45% RH +/- 10%, 90% total output load, any specified input voltage and frequency, sea level operation per Telecordia Technologies, SR-332
- Operational Life 5 years with less than 10% failure in 5 years.

(See Appendix B for examples of reliability statements on data sheets)

4.4 Design Failure Modes and Effects Analysis (DFMEA) Power Conversion Device suppliers **shall** complete a Design Failure Mode and Effects Analysis for each power conversion device design and **shall** provide results of the analysis, and of any corrective actions, to the customer upon request.

Design Failure Mode and Effects Analysis is a technique to find the weaknesses in a design before the design is realized, either in prototype or production. The technique is a preventive form of problem solving, and can be used in a large range of engineering disciplines.

The DFMEA activities are designed to:

1. Recognize and evaluate the potential failure modes of each component in a product and its effects on the product.
2. Identify actions that could eliminate or reduce the chance of the potential failure occurring.
3. Document the process for improvement of future designs.

A DFMEA is a team-based systematic approach that examines the effects of Single Point Failures (SPF) on overall system performance and mitigates system failure risk by corrective action implementation.

Key features of a DFMEA are:

1. DFMEA is a team oriented analysis of a system design
DFMEA elements are the building blocks of related information that comprise an analysis. The team approach is essential in identifying DFMEA elements. Although actual document preparation is often the responsibility of an individual, FMEA inputs should come from a multi-disciplinary team. These contributors are also the major beneficiaries of the document and the knowledge gained in the DFMEA process.

2. DFMEA is a weakness-oriented, bottoms-up approach
To begin, the lowest levels of the system are outlined; this can be the individual components or the lowest assemblies in the system. For each lowest level element, a list of potential failure modes is generated; their local effects, next high-level effects and/or end effects are then determined. DFMEA focuses on failure mode consequences to the product’s end use and assesses risk of each.
3. DFMEA is NOT a design review, but always works on the assumption that the design is nominally correct. It addresses single point failure modes. It does not cover improper usage, incorrect problem diagnosis or any software incompatibilities.

The DFMEA *method* consists of defining the DFMEA scope and the system to be investigated, identifying team members, and beginning the DFMEA process itself.

The DFMEA *process* includes assignment of roles and responsibilities for team members, defining the scope of the DFMEA (finalizing DFMEA target areas, subsystem level interrelationships, and level & type of the approach), differentiating between Causes, Failure Modes, and Effects (being aware that failure modes can drive multiple effects, so that each unique end level effect should be separated and causes for each end level effect should be grouped), and defining severity, occurrence, and detection rating scales for the DFMEA at hand.

One common format for a DFMEA worksheet report is shown below, in Figure 4-1. The supplier may share this detail of analysis with the power conversion device user, or may provide a summarized report listing all failure modes, effects and severity, and corrective actions where effects are unacceptable to the operation of the power conversion device. Figure 4-2 below shows a table of Severity, Occurrence, and Detection Ranking used in a DFMEA process. The ranking numbers are used in calculating the value of RPN, which is the product of the severity, occurrence, and detection rank numbers. RPN stands for Risk Priority Number, and provides a relative measure of the importance of each effect. The higher the RPN, the higher the priority of its associated failure mode as needing to be resolved. Note that if the severity of a failure mode is a critical safety hazard (fire, electrical shock hazard, or other life threatening issue) the RPN value is overruled by a note in the Class column that the failure mode **must** be eliminated before a design is released.

DFMEA Worksheet

Item/Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occurrence	Current Design Controls	Detection	Recommended Action(s)	Responsibility & Target Completion Date	Action Results	RPN
											Action Taken	
Control Chip U1	pin 1-2 short pin 2-3 short pin 3-4 short pin 4-5 short	no effects, however, need VRM supplier Test Plan to verify if they can detect these shorts	1 1 1 1		bad component, solder bridge	1			Need VRM supplier Test Plan to verify if they can detect these shorts	DJW – 10/20/06		0 0 0 0
	pin 5-6 short	shuts down the output	4	Signif	bad component, solder bridge	1		5	Improve Solder Process & Inspec	LBJ – 11/15/06		20
	pin 6-7 short	V < 5v, goes to some artificial V point	4	Signif	bad component, solder bridge	1		5	Improve Solder Process & Inspec	LBJ – 11/25/06		20
	Pin 7 to Gnd short	short to ground, V goes up, output V high, full duty cycle (80%-90% of 12v), firing SCR & blowing fuse, possible smoke	5	Smoke Hazard		2		5	Change Layout Mask	QRT – 11/30/06		50 Must Address because of Smoke Hazard

Figure 4-1 DFMEA Worksheet Form Used by Many Companies

NOTE: In Figure 4-1, the final failure mode, pin 7 to ground short, may result in emission of smoke (indicated in the Potential Effects of Failure column and in the Class column), a situation that for this example, and for power conversion devices in general, is an unacceptable hazard condition. Acceptable and unacceptable effects must be defined for each product type as required by the power conversion device user.

Severity, Occurrence, and Detection Ranking Chart

Severity			Occurrence			Detection		
Ranking	Description	Interpretation	Ranking	Description	Interpretation	Ranking	Description	Interpretation
5 *	Hazardous	Safety related catastrophic failure *	5	Very High	Failure is almost inevitable, < 1 in 3	5	Absolute Uncertainty	Undetectable until catastrophic failure occurs, or there is no design control
4	High	Product is totally inoperable	4	Frequent	Repeated failure, < 1 in 8	4	Remote	Remote chance the Design Control will detect a potential Cause of failure or subsequent Failure Mode
3	Moderate	Product is operable, but at reduce level of performance	3	Moderate	Occasional failure, < 1 in 80	3	Low	Low chance the Design Control will detect a potential Cause of failure or subsequent Failure Mode
2	Low	Product is operable, but comfort or convenience items(s) are inoperable or at reduce level of performance	2	Infrequency	Relatively few failures, < 1 in 150,000	2	Moderate	Moderate chance the Design Control will detect a potential Cause of failure or subsequent Failure Mode
1	None	No effect	1	Rare	Failure is unlikely, < 1 in 1,500,000	1	High	High chance the Design Control will detect a potential Cause of failure or subsequent Failure Mode

* When there is a safety hazard as a result of a failure, the failure mode MUST be eliminated

Figure 4-2 DFMEA Ranking Chart Used by Many Companies

4.5 Voltage Spacing Design Requirements

The basis of the design rules is the following chart, labeled Figure 4-3 from UL478 and IEC435 (now retired).

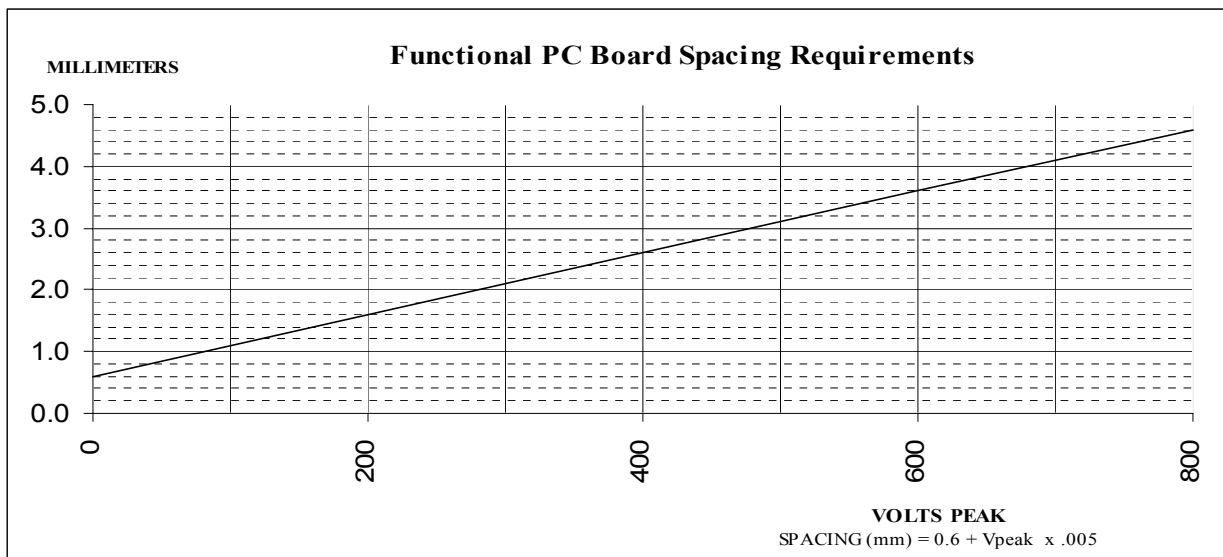


Figure 4-3 UL Voltage-Spacing Requirements for PC Board Conductors (Uninsulated)

All PC board conductors (uninsulated) and all component leads must meet the voltage-spacing requirements of Figure 4-3. Features with spacings not meeting the above voltage-spacing requirements must be insulated, for example by RTV, conformal coating, sleeving or their combinations.

NOTE: Engineering exceptions may be taken to the above criteria based on a risk/cost analysis. Careful review of that decision is recommended.

Board-to metal chassis spacings must meet the criteria of Figure 4-3. For these situations, a guard band to the Figure 4-3 criteria is recommended. The guard band should account for reasonable device lead length variability.

NOTE: Insulation is highly recommended between the underside of PC mother boards and chassis sheet metal, even if the above bolt-spacing requirement criterion is met.

The creepage and clearance requirements of IEC 60950 **shall** take precedence over this document.

5 DESIGN, DEVELOPMENT AND QUALIFICATION TESTING

This section addresses goals, requirements, and types of testing used to develop, improve, and qualify a new design, or qualify an existing design in a new application. It covers several distinct types of testing and the methodology for each type.

Furthermore the following apply to all testing detailed in 5:

Any failures occurring during functional test, either specification failures or permanent hard failures, **shall** be documented, and root cause **shall** be determined (specific component drift or failure mode) and permanently resolved. A corrective action process **shall** be applied with actions and results documented. For standard product, developed internally by a power conversion device supplier, documentation of failures and corrective action are quality systems information that may be shared with a user upon request. For custom Power Conversion Device development, when a supplier develops a design specified by one customer, reports of observed failures, root cause analysis, and corrective action reports **shall** be provided to that customer on a regular basis, within 1 week of observing the failure in its own testing, or within one week of receiving the failed unit from a customer who runs independent external tests.

- Under **no conditions shall** smoke, burning, the smell of burning or flames be permitted as a result of failures found in any testing! Any failure causing these symptoms, even if it is not a true safety hazard, **shall** be root-cause analyzed and permanently resolved.
- The sample size for functional testing **shall** be adequate to determine functional parameters and their distribution means and standard deviations, and **shall** be no less than 12 units. Statistical confidence limits (For example, using Fisher matrix or Likelihood Ratio Bounds) **shall** be applied to test results for any test using less than 60 samples.

5.1 Functional Testing shall be applied to complete power conversion devices and to subassemblies, as required, to assure operation to specification. In general, the parameters to be measured will include all pertinent specifications of the power conversion device under test as described in 3, above. All data taken in the functional tests **shall** be analyzed to find the minimum, maximum, average, and statistical limits. The data **shall** be compared with the specified limits for each critical parameter to determine if the test passed, failed, if additional testing is needed, or if a design change is required.

The functional test can use a manual (bench testing) or automated test setup system. The test will be a thorough check to ensure that the power conversion devices operate within the specified limits. The same functional tests used to verify the initial operation of the sample power conversion devices will be used to verify continued performance after environmental tests, stress tests, and life test.

5.2 Required Elements for Functional Testing of AC/DC Devices

5.2.1 Input Conditions

- **AC/DC Power Conversion Device:** Functional test **shall** be performed at all combinations of minimum, nominal, and maximum specified AC input voltage and frequency for each applicable input voltage range.

5.2.2 Output Conditions (Load Combinations for AC/DC Power Conversion Devices)

- For power conversion devices with 3 or fewer DC outputs, all combinations of minimum (L) and maximum (H) specified load **shall** be tested. Testing a 3-output power conversion device requires 8 combinations (for example, LLL, LLH, LHL, LHH, HLL, HLH, HHL, AND HHH).
- For power conversion devices with more than 3 DC outputs, the following methods may be used to determine the load combinations to be tested:
 1. If possible, run all load combinations of minimum and maximum load on each DC output *on a single sample*. Find the load combinations that give the worst case (minimum and maximum) output voltages on each DC output. These load combinations **shall** make up the test conditions to be used for the Functional Test on the sample power conversion devices.
 2. Alternately, examine the design of the Power Conversion Device and determine the interactions between the various DC outputs. Based on these interactions, load combinations which give the worst case output voltages on each DC output are defined. These load combinations **shall** make up the test conditions used for the Functional Test on the sample power conversion devices.

Note: the load combination of all DC outputs at their minimum rated load, and the load combination of all DC outputs at their maximum rated load, **shall** always be tested (for example, LLLL and HHHH).

5.2.3 Temperature Conditions (AC/DC Power Conversion Devices)

- Testing **shall** be performed at the minimum and maximum temperatures specified in the data sheet and 5 C *below minimum* and 5 C *above maximum* data sheet values to provide a safety factor on results.

5.2.4 Measurements

- **AC/DC Power Conversion Device:** The following **shall** be measured and recorded for every input/output and temperature condition tested on an AC/DC device:
 1. AC Input Current, Voltage, and Power input
 2. Power Factor
 3. Peak Inrush Current
 4. Input Current Harmonic Content
 5. Efficiency of the Power Conversion Device
 6. Output Load Current on each DC Output
 7. Output Regulation on all DC outputs versus Load Current
 8. Output Regulation on all DC outputs versus Input Voltage
 9. Hold-Up time (hold up time for each of the DC outputs after Input voltage is removed)
 10. Temperature Drift (drift of each DC output due to changes in operating temperature)
 11. Dynamic Loading of the DC outputs
 12. Ripple and Noise Voltage on each DC output
 13. Output Overshoot on Power Up (must not exceed the upper limit specified in Specification on any DC output)
 14. No Load Operation to assure the power conversion device starts and operates with no load on all of the DC outputs that do not specify a minimum load
 15. Minimum Load Operation to assure the power conversion device starts and operates with specified load on all of the DC outputs that require a minimum load
 16. Dynamic Response to Loading
 17. Sweep Stability
 18. Loop Stability
 19. Mechanical Drawing Compliance Test

REQUIREMENTS: All parameters measured above **shall** stay within the limits specified in the data sheet or by the contracted requirements of the user.

5.2.5 Abnormal Testing (Protection, Brownout, Load and Startup Tests) - AC/DC Devices Only

NOTE: Under **no conditions shall** smoke, burning, the smell of burning or flames be permitted as a result of failures found in any testing.

- The Power Conversion Device **shall** pass all Over-Current Protection tests. The Over-Current Protection test finds the load current on each DC output at which the over-current protection circuitry is activated and the power conversion device shuts down. The power conversion device **shall** operate within its specified limits after a single power-up after the test. No component **shall** be damaged, physically or electrically, from this test.
- The Power Conversion Device **shall** pass all Short Circuit Protection tests. The Short Circuit Protection test insures that the power conversion device is not damaged when any of the DC outputs is shorted to ground. If this test leaves the power conversion device in its powered up state, passing this test requires that the power conversion device **shall** operate within its specified limits after, at most, one power OFF/ON cycle. If this test leaves the power conversion device in the powered off state, passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.

- The Power Conversion Device **shall** pass all Output Over-Voltage Protection testing. The Output Over-Voltage Protection test finds the output voltage at which the power conversion device shuts down if any DC output exceeds the upper limit of the specified regulation range. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Output Under-Voltage Protection testing. The Output Under-Voltage Protection test finds the output voltage at which the power conversion device shuts down if any DC output drops below the lower limit of the specified regulation range. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Turn-on/Turn-off Points testing. The Turn-on/Turn-off Points (Input Under Voltage) test finds the minimum input voltage at which the power conversion device will power on and maintain regulation. This test also finds the low input voltage at which the power conversion device powers off. The power conversion device **shall** operate within its specified limits after a single power up after the Turn-off test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Brownout testing. The Brownout testing subjects the power conversion device to a decreasing input voltage until units shuts down one or more outputs. The power conversion device **shall** provide protection circuitry such that the application of an input below the minimum specified voltage **shall** not cause damage to the power conversion device. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the brownout test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Cold Start tests. The Cold Start test verifies that the power conversion device starts in a cold environment (low temperature specified in the data sheet or specified by contracted requirements). Power Conversion Device **shall** start normally at the cold start test temperature.
- The Power Conversion Device **shall** pass all Hot Start tests. The Hot Start test verifies that the power conversion device starts in a hot environment. (high temperature specified in the data sheet or specified by contracted requirements). Power Conversion Device **shall** start normally at the hot start test temperature.
- The Power Conversion Device **shall** pass thermal Protection testing. The thermal protection test detects the protection capability for abnormal thermal conditions within the device. No component **shall** be damaged, physically or electrically, during the test.

5.2.6 Additional Abnormal Testing (Dropout, Missing Cycles, Line Transients) - AC/DC Devices Only

NOTE: Under *no conditions shall* smoke, burning, the smell of burning or flames be permitted as a result of failures found in any testing.

- Line Voltage Dropout and Missing Cycle testing **shall** be performed and passed, with adequate margin, for the requirements of standard EN61000.4.11 “Voltage dips, short interruptions and voltage variations immunity tests”.
- Transient testing **shall** be applied according to IEC 61000-4-4 Electrical fast transient/burst immunity test, level 3 and IEC 61000-4-5 Surge immunity test, level 3, and IEC 61000-4-12 Oscillatory waves immunity test. The power conversion device **shall** continue to operate with no component failures during and after repeated applications of the applied line transients and **shall** continue to operate in a safe manner during and after transient application. The power conversion device output voltages **shall** not go out of specified limits, for any length of time however short, during application of any transient voltage to the input.

5.2.7 Sequencing Tests for AC/DC Devices

- The Power Conversion Device **shall** pass all Power On Sequence testing. The Power On Sequence test verifies that the power conversion device powers on for all valid power on sequences. The power on timings of all DC outputs and logic signals (if applicable) are checked to insure the timing requirements of the Product Specification are met. Power Conversion Device **shall** power on correctly for all valid power on sequences.
- The Power Conversion Device **shall** pass all Power Off Sequence testing. The Power Off Sequence test checks the fall times of the DC outputs. The timings and values of the power conversion device's logic signals are also checked (if applicable). Finally, this test verifies that the power conversion device is not damaged when shut down by any of the possible power off sequences. Power Conversion Device **shall** power off correctly for all valid power off sequences.

5.2.8 Logic Signal Tests (AC/DC Devices as Applicable)

- The Power Conversion Device **shall** pass all Input/Output Logic Signals testing. The Input/Output Logic Signals test verifies that the input and output logic signals operate as required by the Product Specification. Power Conversion Device **shall** meet all specifications for input and output logic signals.
- The Product Specification **shall** describe the logic signals generated and used by the power conversion device. The Product Specification and/or test plans **shall** also define requirements for these signals if they have to be controlled or monitored during any functional, environmental or stress testing.

5.2.9 Testing for Power Conversion Devices Used in Redundant (High Reliability) Applications

For power conversion devices used in equipment requiring redundant power through load sharing of multiple power supplies, the following additional tests **shall** be required.

Current Sharing / Hot Plug Test (If Applicable – AC/DC devices)

- Current Sharing test **shall** be completed to check the output voltage on all DC outputs for all valid operating conditions of the power conversion device when two or more outputs are connected in parallel.
- Two or more supplies connected in parallel **shall** meet the regulation requirements of a single supply. There **shall** be no adverse effect on a good supply if a faulty supply is in parallel with it. With active current sharing, outputs **shall** share the load current within 10% of the average current at maximum rated load across all output loads.
- The Hot Plug test **shall** demonstrate that removal or insertion of a supply must not generate faults within system or within the units themselves. Transient conditions **shall** not cause a false over-current or error logic signal.
- The Hot Plug test **shall** be performed at minimum and maximum input Voltages with the output load varied minimum to maximum. Maximum load **shall** be used when testing for false trigger due to transients.
- If Oring FET's are used, supplier **shall** demonstrate that no shoot through occurs on the bus when the output line is shorted on the non bus side of the FET by monitoring the bus voltage, power good logic signal, and the point where the output is being shorted.
- Power Conversion Device supplier **shall** apply methods of IEC 62040-1-1 1st edition and IEC 62040-1-2 1st edition for Components and Subassemblies used in Uninterruptible Power Systems, as applicable.

(See Appendix C for additional test details and methods for functional requirements testing.)

5.3 Required Elements for Functional Testing of DC/DC Devices

5.3.1 Input Conditions

DC/DC Power Conversion Device

Functional test **shall** be performed at minimum, nominal, and maximum specified DC input voltage for single input designs, and **shall** be performed at all combinations of minimum, nominal, and maximum specified DC input voltage for multiple input designs.

5.3.2 Output Conditions (Load Combinations for DC/DC Power Conversion Devices)

- For power conversion devices with 3 or fewer DC outputs, all combinations of minimum (L) and maximum (H) specified load **shall** be tested. Testing a 3-output power conversion device requires 8 combinations (for example, LLL, LLH, LHL, LHH, HLL, HLH, HHL, AND HHH).
- For power conversion devices with more than 3 DC outputs, the following methods may be used to determine the load combinations to be tested:
 1. If possible, run all load combinations of minimum and maximum load on each DC output *on a single sample*. Find the load combinations that give the worst case (minimum and maximum) output voltages on each DC output. These load combinations **shall** make up the test conditions to be used for the Functional Test on the sample power conversion devices.

2. Alternately, examine the design of the Power Conversion Device and determine the interactions between the various DC outputs. Based on these interactions, load combinations which give the worst case output voltages on each DC output are defined. These load combinations **shall** make up the test conditions used for the Functional Test on the sample power conversion devices.
- Note: the load combination of all DC outputs at their minimum rated load, and the load combination of all DC outputs at their maximum rated load, **shall** always be tested (for example, LLLL and HHHH).

5.3.3 Temperature Conditions (DC/DC Power Conversion Devices)

- Testing **shall** be performed at the minimum and maximum temperatures specified in the supplier's data sheet and 5°C below minimum and 5°C above maximum data sheet values to provide a safety factor on results.

5.3.4 Measurements

- **DC/DC Power Conversion Device:** The following **shall** be measured and recorded for every input voltage and output load condition, and temperature condition tested, for each input and each output, as applicable, on a DC/DC device:
 1. DC Input Voltage and Current
 2. Inrush Current
 3. Input Reflected Ripple Current
 4. Input Capacitance requirement
 5. Input Protection
 6. Brown Out
 7. Efficiency
 8. Output Voltage and Current
 9. Set Point Voltage and Accuracy
 10. Output Capacitance requirements
 11. Output Regulation on all DC outputs versus Load Current
 12. Output Regulation on all DC outputs versus Input Voltage
 13. Cross Regulation
 14. Ripple and Noise Voltage
 15. Hold-Up time (hold up time for each of the DC outputs after Input voltage is removed)
 16. Temperature Drift (drift of each DC output due to changes in operating temperature)
 17. Long Term Stability as defined by product application
 18. Dynamic Response to Loading
 19. Sweep Stability
 20. Loop Stability
 21. Turn On Delay
 22. Output Overshoot and Undershoot on Power Up and Power Off (must not exceed the upper limit specified in Specification on any DC output, no dip allowed)
 23. Monotonic Output at Start Up (no dip)
 24. No Load Operation to assure the power conversion device starts and operates with no load on all of the DC outputs that do not specify a minimum load
 25. Minimum Load Operation to assure the power conversion device starts and operates with specified load on all of the DC outputs that require a minimum load
 26. If applicable, Output Pre-Biased Test
 27. If applicable, Trimming Equation Verification Test
 28. Mechanical Drawing Compliance Test

Requirements: all parameters measured above **shall** stay within the limits specified in the data sheet or by the contracted requirements of the power conversion device user.

(See Appendix C for additional test details and methods for functional requirements testing.)

5.3.5 Abnormal Testing (Protection, Brownout, Load and Startup Tests) for DC/DC devices

The Power Conversion Device **shall** pass all Over-Current Protection tests. The Over-Current Protection test finds the load current on each DC output at which the over-current protection circuitry is activated and the power conversion device shuts down. The power conversion device **shall** operate within its specified limits after a single power-up after the test. No component **shall** be damaged, physically or electrically, from this test.

- The Power Conversion Device **shall** pass all Short Circuit Protection tests. The Short Circuit Protection test insures that the power conversion device is not damaged when any of the DC outputs is shorted to ground. If this test leaves the power conversion device in its powered up state, passing this test requires that the power conversion device **shall** operate within its specified limits after, at most, one power OFF/ON cycle. If this test leaves the power conversion device in the powered off state, passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Output Over-Voltage Protection testing. The Output Over-Voltage Protection test finds the output voltage at which the power conversion device shuts down if any DC output exceeds the upper limit of the specified regulation range. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Output Under-Voltage Protection testing. The Output Under-Voltage Protection test finds the output voltage at which the power conversion device shuts down if any DC output drops below the lower limit of the specified regulation range. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Turn-on/Turn-off Points testing. The Turn-on/Turn-off Points (Input Under Voltage) test finds the minimum input voltage at which the power conversion device will power on and maintain regulation. This test also finds the low input voltage at which the power conversion device powers off. The power conversion device **shall** operate within its specified limits after a single power up after the Turn-off test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Brownout testing. The Brownout testing subjects the power conversion device to a decreasing input voltage until units shuts down one or more outputs. The power conversion device **shall** provide protection circuitry such that the application of an input below the minimum specified voltage **shall** not cause damage to the power conversion device. Passing this test requires that the power conversion device **shall** operate within its specified limits after a single power up after the brownout test. No component **shall** be damaged, physically or electrically, during the test.
- The Power Conversion Device **shall** pass all Cold Start tests. The Cold Start test verifies that the power conversion device starts in a cold environment (low temperature specified in the data sheet or specified by contracted requirements). Power Conversion Device **shall** start normally at the cold start test temperature.
- The Power Conversion Device **shall** pass all Hot Start tests. The Hot Start test verifies that the power conversion device starts in a hot environment. (high temperature specified in the data sheet or specified by contracted requirements). Power Conversion Device **shall** start normally at the hot start test temperature.
- The Power Conversion Device **shall** pass thermal Protection testing. The thermal protection test detects the protection capability for abnormal thermal conditions within the device. No component **shall** be damaged, physically or electrically, during the test.

5.3.6 Sequencing Tests for DC/DC devices

- The Power Conversion Device **shall** pass all Power On Sequence testing. The Power On Sequence test verifies that the power conversion device powers on for all valid power on sequences. The power on timings of all DC outputs and logic signals (if applicable) are checked to insure the timing requirements of the Product Specification are met. Power Conversion Device **shall** power on correctly for all valid power on sequences.
- The Power Conversion Device **shall** pass all Power Off Sequence testing. The Power Off Sequence test checks the fall times of the DC outputs. The timings and values of the power conversion device's logic signals are also checked (if applicable). Finally, this test verifies that the power conversion device is not damaged when shut down by any of the possible power off sequences. Power Conversion Device **shall** power off correctly for all valid power off sequences.

5.3.7 Logic Signal Tests (DC/DC devices as applicable)

- The Power Conversion Device **shall** pass all Input/Output Logic Signals testing. The Input/Output Logic Signals test verifies that the input and output logic signals operate as required by the Product Specification. Power Conversion Device **shall** meet all specifications for input and output logic signals.
- The Product Specification **shall** describe the logic signals generated and used by the power conversion device. The Product Specification and/or test plans **shall** also define requirements for these signals if they have to be controlled or monitored during any functional, environmental or stress testing.

5.3.8 Testing for Power Conversion Devices used in Redundant (High Reliability) Applications

For power conversion devices used in equipment requiring redundant power through load sharing of multiple power supplies, the following additional tests **shall** be required.

Current Sharing / Hot Plug Test (If Applicable – DC/DC devices)

- Current Sharing test **shall** be completed to check the output voltage on all DC outputs for all valid operating conditions of the power conversion device when two or more outputs are connected in parallel.
- Two or more supplies connected in parallel **shall** meet the regulation requirements of a single supply. There **shall** be no adverse effect on a good supply if a faulty supply is in parallel with it. With active current sharing, outputs **shall** share the load current within 10% of the average current at maximum rated load across all output loads.
- The Hot Plug test **shall** demonstrate that removal or insertion of a supply must not generate faults within system or within the units themselves. Transient conditions **shall** not cause a false over-current or error logic signal.
- The Hot Plug test **shall** be performed at minimum and maximum input Voltages with the output load varied minimum to maximum. Maximum load **shall** be used when testing for false trigger due to transients.
- If Oring FET's are used, supplier **shall** demonstrate that no shoot through occurs on the bus when the output line is shorted on the non bus side of the FET by monitoring the bus voltage, power good logic signal, and the point where the output is being shorted.
- Power Conversion Device supplier **shall** apply methods of IEC 62040-1-1 1st edition and IEC 62040-1-2 1st edition for Components and Subassemblies used in Uninterruptible Power Systems, as applicable.

(See Appendix C for additional test details and methods for functional requirements testing.)

5.4 Stress Testing shall be performed on components, subassemblies, and complete power conversion devices to assure margin to specified stress levels, and as a means to find weaknesses in designs for corrective action prior to design release.

Stress testing is called by several names, STRIFE (Stress+Life), HALT (Highly Accelerated Life Test), and HAST (Highly Accelerated Stress Test, probably the most accurate description since stress testing is usually not a life test). The purpose of stress testing is not to predict life or reliability over time, but to force failures for consideration in design improvement activities. The HAST process is an environmentally biased, overstress-to-failure test. Temperature and vibration levels are increased, usually in a step fashion, until failure point is reached. At the same time, input voltage and output loads may be increased. The failures are analyzed, and if determined to be realistic failures under end-user use, corrective action (design, process or component change) is developed and applied. Stress testing methods vary from company to company, but if run as a test-fix-test methodology, the result will always be a more robust product.

Suppliers **shall** provide their specific stress test plans and results to the power conversion device user as part of the reports required in 4.1. Elements of a useful stress test are listed below:

Stress testing is normally performed in an environmental chamber. It **shall** be possible to vary product input and output signals to levels outside of those specified for normal product operation while controlling temperature, and optionally, applying vibration to the units under test. During stress testing, the product **shall** be powered up and operated, and **shall** be monitored to ensure functionality. Test setups **shall** be optimized to maximize functional test coverage. The test setup should also allow for remote operation of the test and product from outside of the environmental chamber.

Stresses **shall** be stepped or ramped from levels within specifications to levels exceeding specifications. All failures are considered worth investigation, and if a failure is found to be reasonable under normal use conditions (and not from unrealistic overstress such as melted plastic parts) then analysis of the root cause **shall** be made, and a design or part change **shall** be required to increase design strength.

Table 5-1 shows several typical stress types and stress application modes:

Table 5-1 Stress Types and Application Modes

<i>I/O - Stress Type</i>	<i>Parameter type</i>	<i>Stress</i>
Input	AC or DC voltage	increase voltage over time
		decrease voltage over time
		cycle voltage (typ 2000-5000 times)
Output	DC voltage load	increase load over time
		decrease load over time
		cycle load (dynamic loading)
		cycle shorts with normal load
Environmental	Temperature	increase temperature over time
		decrease temperature over time
		temperature cycling
	Vibration	Apply increasing vibration over time

Actual levels for voltages, loads, temperature and vibration will depend on the design being tested and material used in the design. The goal of a stress test is to create failures in a short time without causing ‘foolish’ failure modes.

(See Appendix D for additional information on stress testing methods and requirements.)

5.5 Environmental Testing shall be applied to a sample of each power conversion device design to assure operation over and beyond full data sheet conditions. Environmental testing applies temperatures, humidity levels, shock and vibration and other stresses beyond the data sheet values in order to provide margin for part variation, user environment and measurement variation.

Environmental testing **shall** be applied to samples representative of production. If any significant design or component changes are made to a power conversion device design, environmental testing **shall** be re-applied AABUS.

Unless specifically noted, the sample size for environmental testing **shall** be adequate to determine distribution parameters such as mean and standard deviation, and **shall** be no less than 12 units. However, a minimum sample of 32 units is preferred for DC-DC converter applications when long life (10 or more years) is considered. Sample size can be derived on a family basis. Statistical confidence limits (using Fisher matrix or Likelihood Ratio Bounds) **shall** be applied to test results for any test using less than 60 samples.

Environmental testing for this standard includes:

(Temperature: Environmental tests **shall** verify operation at a high temperature 5 C hotter and at a low temperature 5 C colder than the data sheet specification. Humidity: Environmental tests **shall** verify operation at a maximum humidity 5% greater and at a minimum humidity 5% below levels specified in the data sheet.)

TEMPERATURE & HUMIDITY BIAS (THB) (per JESD22 – A101)

- THB **shall** be performed at the following conditions:
 - 72 hour soak at maximum operating temperature
 - Device operating at minimum load
 - Duration: 1000 hours minimum
 - Humidity: 85% non-condensing
- Front-End Power: Temperature **shall** be rated high ambient with a sample size of 3
- Board Mounted Power Module (BMPM): Temperature **shall** be 85 C or AABUS.

The THB test is used to test for moisture induced failures and dendrites growth. Voltage cycling may be required to prevent the device from heating up and to prevent moisture effects. Units after test **shall** be electrically tested for any changes in electrical performance, visually inspected for solder cracking, dendrite growth and other defects, AABUS.

Thermal shock: Thermal shock **shall** be performed at the following minimum conditions:

- Device non-operating
- High temperature: 70 +/- 5 C
- Low temperature: -40 +/- 5 C
- Number of cycles: 500
- Dwell at each temperature: 20 minutes
- The thermal ramp rate: >20 C / minute
- Sample size: 5
- Units under test **shall** be removed from the oven and tested after 100 and 500 cycles. All test units **shall** pass all functional specifications.

Condensation: The un-powered product **shall** be stabilized at 25 C, 50% relative humidity; then quickly placed in an environment of 40 C, 95% relative humidity. The product will dwell un-powered for five (5) minutes then power will be applied with a 100% load on each output. The product **shall** operate within specification within fifteen (15) minutes and suffer no permanent damage (delay in start-up is acceptable). Condensation **shall** be tested on a sample of at least 3 Power Conversion Devices.

Altitude: The Power Conversion Device **shall** operate normally at an operating altitude of from zero to 6,000 feet above sea level with no output power derating required; operation from 6,000 to 10,000 feet may require power derating which **shall** be specified by the supplier in the product data sheets. The survival altitude **shall** be 0 to +50,000 feet in a non-operating mode. The altitude capability **shall** be tested on a sample (3 units minimum) of Power Conversion Devices under test.

HIGH TEMPERATURE OPERATIONAL BIAS (HTOB) (with power cycling) (per JESD22 – A108)

HTOB **shall** be performed at the following conditions:

- 72 hour soak at maximum operating temperature
- Device operating at 95% load and maximum operating temperature
- Power Cycles: 1 min off each 12 minutes
- Duration: 500 hrs

VIBRATION & SHOCK

RANDOM VIBRATION (The purpose of random vibration testing is to ensure that the module, components and solder joints are sufficiently rugged.)

Random (operating): The Power Conversion Device **shall** withstand the following random vibration for ten (10) minutes per axis, on all three axes, and **shall** meet all specifications. The Power Conversion Device **shall** be operating at full load throughout the test.

Vibration level **shall** be 2.60 Grms with the spectral densities per Table 5-2:

Table 5-2 Vibration Spectral Density for Operating Mode

Frequency [Hz]	Power spectral density [g ² /Hz]	Slope [dB/octave]
5-350	0.015	0.0
350-500		-6.0
500	0.0074	0.0

Random vibration **shall** be tested on a sample of at least 3 Power Conversion Devices.

Random (survival): The Power Conversion Device **shall** meet all specifications during the testing and not sustain any permanent damage. The test consists of random vibration on a non-operating Power Conversion Device, with the following power spectral density, for ten (10) minutes per axis. After each axis has been vibrated, the Power Conversion Device **shall** be required to demonstrate functionality within all specifications.

Vibration level **shall** be 6.06 Grms with the spectral density per Figure 5-1 per NAVMAT P-9492, section 3.0, Figure 5:

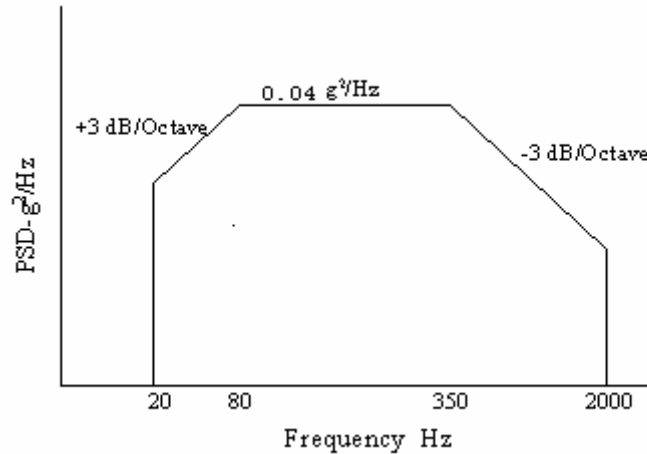


Figure 5-1 Vibration Spectral Density for Survival Mode

(Random survival vibration **shall** be tested on a sample of at least 3 Power Conversion Devices.)

SWEPT SINE The non-operating Power Conversion Device samples **shall** survive, without permanent damage, being subjected to a sine wave of 0.75 G, zero to peak amplitude from 5 to 450 Hz, at a rate of one octave per minute. The four largest amplitude resonating frequencies **shall** be noted and the product **shall** be subjected to ten (10) minutes at each of those frequencies. This procedure **shall** be repeated for each axis. Swept sine **shall** be tested on a sample of at least 3 Power Conversion Devices.

SHOCK

Shock (operational): The Power Conversion Device **shall** be operated at full load and subjected to a one half sine wave shock pulse of 3.0 ms duration with an effective acceleration of 20g's. The Power Conversion Device **shall** be tested at all acceptable operating orientation(s). The Power Conversion Device **shall** perform within specification throughout the test and not sustain any permanent damage. Operating shock **shall** be tested on a sample of at least 3 Power Conversion Devices.

Shock (non-operational): While un-powered, the Power Conversion Device **shall** be subjected to a one half sine wave shock pulse of 3.0 ms duration with an effective acceleration of 80g's. This procedure **shall** be performed on each of the six power conversion device faces. The power conversion device **shall** perform within specification after each face is shocked and not sustain any permanent damage. Survival shock **shall** be tested on a sample of at least 3 power conversion devices.

Transportation Simulation (non-operational) Trapezoidal shock:

Acceleration: 50 g delta V: 746 cm/sec

Minimum of 3 shocks on each of 6 faces and the power conversion device **shall** be unpowered.

Trapezoidal shock **shall** be tested on a sample of at least 3 power conversion devices. The power conversion device **shall** perform within specification after each face is shocked and not sustain any permanent damage.

Drop Test (operational and non-operational): Drop Height is 3.3 feet (1.0 m) and Impact Surface is Concrete:

The test shall be performed a total of 28 times on the same unit [two times for all faces (6) + all corners (8)]. The power conversion device **shall** perform within specification throughout the test and not sustain any permanent damage [no impact on Safety (Hi-Pot) and no damage to any solder joints].

SUSCEPTIBILITY & INTERFERENCE

Supplier **shall** confirm adequate performance for the following legal requirements using appropriate sections of IEC 61000 Electromagnetic Compatibility or other referenced standards – a qualified regulatory engineer **shall** approve all test methods and reports.

Radiated Susceptibility: Power Conversion Devices **shall** be tested according to EN55024.3 - 1991/ IEC 801.3 - 1994 (3V/m)

Conducted Susceptibility: Power Conversion Device **shall** be tested using 30Hz to 50kHz, 3 Vrms from power source capable of 50Ω into 0.5 Ω load, and from 50 kHz to 400 MHz with 1 Vrms from 50 Ω, 1 Ω source.

Magnetic Field Susceptibility: Power Conversion Device **shall** be tested from 47 Hz to 198 Hz, 1 gauss peak to peak while operating from all nominal power sources.

Electrostatic Discharge: Power Conversion Devices **shall** be tested according to IEC 61000-4-2 Electrostatic Discharge Standard - Operating: ±12.5kV Air Discharge, ±8kV Contact Discharge. Board mounted power modules **shall** be tested in accordance with JESD22-A114 and meet or exceed 500V HBM. Sample size 3 units.

Non-Operating Magnetic Interference : Product magnetic field strength <5.25 mgauss measured at 15 feet.

HI POT Supplier **shall** complete appropriate dielectric voltage withstand testing (Hi Pot) according to UL, CSA, CE, EN, IEC and any other required international safety agency methods. The Power Conversion Device **shall** pass all hi pot requirements and **shall** perform within specification after hi pot testing and not sustain any permanent damage.

CORROSION RESISTANCE Corrosion resistance **shall** be specified AABUS.

DUST RESISTANCE Suppliers **shall** provide the category of dust protection as described in NEBS-GR63 standard or AABUS.

- Relative Humidity: 70%<RH <85RH%
- Sample size: 3 units

METALLIC CONTAMINATION MITIGATION (AC/DC EXTERNAL AND MODULAR DEVICES)

The Power Conversion Device AC power connector **shall** be evaluated for strength and attachment to the chassis. The AC power connector **shall** not break or pull out of the chassis if the power cord is pulled out from any angle to the appliance inlet's face.

ACOUSTICS Suppliers shall conduct acoustic measurements to prove compliance with customer's acoustic specifications. Following method shall be used unless specified otherwise by the customer.

Power supplies or adapters should be placed on the floor of the hemi-anechoic chamber, raised by small elastic mounts as described for hard drives in ISO 7779 and/or ECMA 74. The EUT (equipment under test) should be hooked up to appropriate loads so as to be driven in a manner representative of the target product, and in operational states representative of actual usage. Any peripheral equipment used for this purpose should be outside of the measurement area (or outside of the chamber itself) so as not to corrupt EUT measurement with its own noise. A 30-second time-averaged Lw measurement should be taken for each operational state, and corrected by K1 and K2 factors, as specified in ISO 3744. When a batch of EUTs are measured, the final results should be calculated and communicated as declared values (LwAd) per ISO 9296.

ATTACHMENT RELIABILITY (L2)

and SOLDERABILITY Attachment reliability testing applicable to surface mount board mounted power module (BMPM) only **shall** be per IPC-9701. Specific detail on the quality of the solder joint **shall** be per J-STD-001 and the solderability of component leads shall be per J-STD-002. Attachment reliability **shall** be performed at the following conditions:

- 4000 cycles (0 to 100C)
- Cycle: 30 min per cycle with 5 min dwell at temperature extremes.
- Duration: 1000 hours minimum

5.6 Component Source Qualification Matrix

The purpose of the mixed build plan is to ensure a representative mix of components from all sources throughout the phases of product development. The supplier must ensure that the build includes parts sourced from all intended sub-tier suppliers. This will facilitate part/sub-tier supplier identification in case of failures.

Subsequent addition of new sources for parts will follow the PCN process and require the supplier to submit a fresh plan and complete new tests for supplier approval. The use of new sources for components will not be permitted without prior completion of a mixed build plan that includes these new sources.

5.6.1 Detailed plan

A random mix of parts from different sources is permissible as long as all sources are included. To accommodate all sources, the build should be sub-divided into sections, each with its own detailed plan. The supplier is required to submit a detailed plan of the mix used for each section as described below.

It is strongly recommended that power devices such as MOSFETs and diodes placed in parallel in any one detailed plan should all be from the same sub-supplier in order to ensure equal current sharing. Similar remarks apply to series connected components, such as bulk capacitors and MOVs placed across the input bus, to ensure equal voltage sharing.

5.6.2 Critical components

Components identified as critical from the list contained in Table 5-4 must be included in the detailed mixed build plans as seen in Table 5-5. In addition, the suppliers may include any other components they consider to be critical.

5.6.3 Part Tracking

The detailed plan as seen in Table 5-4 must include the information for all the critical components used, as per table 5-3.

Table 5-3 Critical Component Selection Guidelines

1	Bulk Electrolytic Capacitor
2	Output filter Electrolytic Capacitor
3	Metal Oxide Varistors (transient surge suppressors)
4	Power FET/Transistor
5	Power Diode
6	High Voltage FET/Transistor
7	High Voltage diode
8	Integrated circuits including operational amplifiers
9	High Voltage integrated circuits (such as MOSFET's integrated with control circuit)
10	Series and shunt regulators, including programmable Zeners
11	Thermistors
12	Opto-couplers
13	Magnetic cores for transformers and chokes
14	Electromechanical parts (relays)
15	Fans
16	Output connectors and terminals
17	Input AC connector
18	Printed Circuit Board

Table 5-4 Detailed Plan Template**Sample Mix plan Template**

Pin	XXXX
Model:	XXXX
Vendor Rev:	Rev XX.XX
	Date: 3/6/2006

	Plan 1		Plan 2	
C13, C15	NICHICON 147423310433 CAP AL 450V 330uF M 25*50 SI10	LGU2W331MEL	NCC 147423310437 CAP AL 450V 330uF M 25*50 SI10	KMQ450VSSN3
D251	VISHAY 201003070023 DIO FRD 10A 200V TO-220AB-3P 25nS C.C.	UG10DCT-E3/	ST 201003070108 DIO FRD 10A 200V TO-220-3P 30nS C.C.	STPR1020CT
D11	ST 201022860008 DIO FRD 8A 600V TO-220AC-2P 45nS	STTH8R06D	ST 201022860008 DIO FRD 8A 600V TO-220AC-2P 45nS	STTH8R06D
D151, D153 D154	SDN 202074120010 DIO SBD 40A 60V TO-247AC-3P C.C.	S60SC6M-700	SDN 202074120010 DIO SBD 40A 60V TO-247AC-3P C.C.	S60SC6M-700
Q301	VISHAY 242001420031 FET 30V 70A 9mohm LL TO-220-3P	SUP70N03-09	VISHAY 242001420031 FET 30V 70A 9mohm LL TO-220-3P	SUP70N03-09
Q901	TOSHIBA 242018300206 FET 900V 3A 4.3ohm TO-220F-3P	2SK3564(Q)	TOSHIBA 242018300206 FET 900V 3A 4.3ohm TO-220F-3P	2SK3564(Q)
D10	VISHAY 205351610023 1 DIO SI 3A 600V DO-201AD-2P	1N5406-E3/7	VISHAY 205351610023 1 DIO SI 3A 600V DO-201AD-2P	1N5406-E3/7
IC301	ON 2510005313 B IC PWM 8PIN	UC3843BN	ON 2510005313 B IC PWM 8PIN	UC3843BN
RL1	Tyco 0720010201 RELAY 240VAC 12VDC 16A SPST	OZ-SS-112LM1.	Tyco 0720010201 RELAY 240VAC 12VDC 16A SPST	OZ-SS-112LM1.
T1 2800118900 MV-HPD5013	TDG 4130402700 CORE MN-ZN EER42 42.5*43.2*14.7 TP4 U230	EER42CTP4	ZHEJIANG DONGYANG 4130402800 CORE MN-ZN EER42 42*43.2*14.7 DMR40 U230	EC42DDMR40
T901 2802208400 DV-HPD5008	ZHEJIANG DONGYANG 4120611200 CORE MN-ZN EE25 25.4*31.7*6.35 DMR40 U23	EE25EDMR40	ZHEJIANG DONGYANG 4120611200 CORE MN-ZN EE25 25.4*31.7*6.35 DMR40 U23	EE25EDMR40
DC Fan	Delta 3620916111 Fan	AFB0912VH-SE30	SUNON 3620918223	PMD1209PTB2-AF.2.B2010.GN
Output Connectors P1 3679057607	Molex Housing: P/N 3051203200 Molex Crimp Terminal: 39-00-0059, P/N 3040070300	39-01-2245	CVILUX Housing: P/N 3051203243 CVILUX Crimp Terminal: CP-01100104, P/N 3040070143	CP-01124030

5.7 Regulatory and Safety Agency testing shall be performed on a sample of completed power conversion devices and, as required by any Agencies, on a sample of safety-critical components such as transformers to assure compliance with appropriate Agency requirements. All power conversion devices **shall** be designed to be Agency compliant and be shippable worldwide for installation in the environments specified by data sheet limits. The power conversion device supplier **shall** be fully responsible for ensuring the compliance of the device to all applicable Agency requirements, to transportation stresses, and to the specified end-use environment.

Tests such as radiated susceptibility, conducted susceptibility, non-operating magnetic interference, and insulation breakdown (hi pot) are regulatory/safety issues that are normally verified during environmental testing (see 5.4). Regulatory and safety issues may need to be verified by a regulatory Agency on final design unless the supplier is self-certified by that Agency. Some countries require Agency approval and do not accept self-certification. Any issues regarding Agency requirements **shall** be the responsibility of authorized Product Regulations Managers at the Power Conversion Device supplier and Power Conversion Device user organizations.

The manufacturer **shall** demonstrate initial and continued compliance to the latest edition, revision, and amendment of all applicable Agency standards. See **9 Regulatory Requirements**, **2 Applicable Documents**, and **10 References** of this document for some applicable tests and standards. All issues regarding Agency requirements **shall** be the responsibility of the authorized Product Regulations Managers at the Power Conversion Device supplier and Power Conversion Device user organizations.

5.8 Life (Reliability) testing shall be applied to power conversion devices to assure that predicted MTBF has been achieved and that data sheet values are backed up by the testing of physical hardware. There are two basic life test approaches: normal stress level and high stress level (accelerated testing). To demonstrate a reasonable reliability, for example 99% reliability in 8,760 hours (one year of 24/7 operation) requires that over 1,100 units be run for one month (30 days) with no failure. Since this is not usually a practical quantity for testing, high stresses such as high temperature and loading, are often applied. If stresses can arguably increase the expected failure rate by a factor of 20, for example, the requirements above can be demonstrated using 60 units in a test lasting less than a month. One technique to increase acceleration more severely is to use thermal cycling and power-on/power-off cycles. The difficulty with adding these kinds of stresses is that there is no agreed upon acceleration factor that can be applied to a variety of power conversion device designs.

A Life Test is not the same as a Stress Test since the desired result from a life test is an estimate of power conversion device reliability over time under normal operating conditions.

Life testing **shall** be completed on an adequate sample size of samples representative of production – see **Appendix E** for examples of required test times, sample size and temperatures to demonstrate the required MTBF or annual failure rate.

Note that the tables in **Appendix E** assume an approximately constant failure rate as expected during the normal operating lifetime of a product. Reliability tests should verify if observed failures are occurring at approximately constant rates, or if there is evidence of a rapidly decreasing failure rate over the test time which indicates Infant Mortality failures. A Weibull model can be applied to test data to determine the characteristics of failures over time, with Weibull Beta values in the range of 1.0 indicating approximately constant failure rates.

Note that if a Weibull model finds low Beta values (typically 0.3 to 0.8) the failures observed are Infant Mortality failures. These kinds of failures are caused by defective material or defective assembly processes. If infant mortality failures are observed in a reliability test, root cause **shall** be determined and corrective action taken to eliminate the cause. Production burn-in should not be used as a substitute for removing design, assembly and component defects from a product design.

If Weibull Beta values over approximately 1.5 are observed from test data, it indicates wear-out failures are occurring (often showing Beta values from 2.5 to 5). Wear-out failures should not be observed in any short or medium time test – If wear-out failures are observed, root cause **shall** be determined and corrective action taken with subsequent retesting to confirm the fix. In long-term testing and high stress testing, wear-out failures are only acceptable if the equivalent time to wear-out exceeds the operating life specified for the power conversion device in its data sheet.

Results of all reliability testing, including analysis of all failure distributions using Weibull or other valid statistical modeling **shall** be provided by the supplier to the user on request.

The power conversion device user's company may perform its own tests at any time to confirm operation to the power conversion device supplier's published specifications. Additionally, all information required from suppliers **shall** be provided before any new AC/DC or DC/DC power converters are used in production runs of the user's products.

6 QUALITY PROCESSES

This section addresses the requirements for quality processes at the supplier and sub-tier supplier facilities.

6.1 Quality Management Systems The Power Conversion Device Supplier **shall** have a documented process in place to control all material and processes in its manufacturing operation and **shall** provide information on all quality and manufacturing systems to the user upon request. The supplier's quality plan **shall** include:

- Locations where product will be manufactured/assembled; user will qualify and approve these locations at its option
- Implementation and corrective action results for PFMEA (Process Failure Modes and Effects Analysis)
- Supplier's plan to support user's Line Reject Rate (LRR), Initial Field Incident Rate (IFIR) and long term reliability goals (LTR)
- Statistical Process Control plans with required data collection and quality metrics
- Process capability assessment
- Measurement capability assessment
- Corrective Action Process
- Design for reliability methods as described in 4 of this document
- Development methods and testing for improving and verifying product design as described in 5 of this document
- Manufacturing Process Flow Chart, operating procedures, process control points, quality goals by stage
- Manufacturing conformance testing methods as described in 7 of this document
- In Circuit Test (ICT) plan as described in 7.2 of this document
- Maverick control/Rework/screening process plans for all components and subassemblies
- Supply Chain Management Process – potential problem control
- Out of Box Audit (OBA) plans as described in 7.3.4 of this document
- Ongoing Reliability Test (ORT) plans as described in 7.3.5 of this document
- Supplier Failure Analysis and reporting plan for user's return of verified failed product/components
- Change/Revision Control
- Product Identification and Lot Traceability
- Documentation development
- Production Test Equipment Calibration Process
- Continuous Improvement Process
- Providing regular reports of Quality Metrics defined in the Quality Plan

See **Appendix G** for more elements of a Quality Management System. See J-STD-001 and IPC-A 610 for additional workmanship details.

6.1.1 Process Failure Modes and Effects Analysis The supplier **shall** use Process Failure Modes and Effects Analysis (PFMEA) to optimize its processes, and provide documentation of issues resolved to the user upon request. A PFMEA is nearly identical to a Design Failure Modes and Effects Analysis except that potential failures at each **process stage** are reviewed to determine how they might affect downstream process stages (defect rate, rework & scrap). PFMEA uses the same RPN measure of relative importance for addressing each potential failure type (see section 4.4 of this document). PFMEA is a systemized group of activities intended to:

1. Recognize and evaluate the potential failure of an activity in a process step, and its effect on other stages of the process
2. Identify actions which could eliminate or reduce the occurrence, or improve detectability, of the potential failure
3. Document the process changes to reduce impact of failure
4. Track process changes incorporated to avoid potential failures and the results on the process

6.1.2 Statistical Process Control The supplier **shall** use appropriate Statistical Process Control methods such as the use of Shewhart control charts, custom charts, moving averages, sampling theory and other statistical techniques to assess the stability of processes in order to take appropriate action to reduce defects, and to determine the quality level of components,

assemblies and products. Data to be monitored and recorded includes all parameters measured in ICT (all critical-to-function component parameters) and all parameters measured in ATE testing (essentially all product specifications – see 7.2 and 7.3). Other data that may be of use to improving process yield and eliminating defects, such as stress test data, should also be recorded and analyzed.

Control charts **shall** monitor key process variables. Control charting **shall** be accomplished on a real time basis in order to provide a dynamic feedback loop to the process that is being monitored. When an out-of-control condition is present in the process, manufacturing engineering **shall** identify the assignable cause responsible for the out-of-control condition. Once the assignable cause is determined corrective action **shall** be taken to prevent the problem from recurring. Verification that the corrective action mitigated the assignable cause is required to allow the process to continue normal operation and eliminate the out-of-control point from the chart plot.

The supplier **shall** keep records of all SPC measures and provide summaries and reports to the user on request.

6.1.3 Process Capability Assessment After assuring stability of a process (using methods such as control charts, 6.1.2) the capability of the process **shall** be assessed. A Cpk capability index will be calculated for all processes deemed to be in statistical control. Cpk relates the process mean to the nominal value of the specification. Cpk values **shall** be greater than or equal to 1.33 to indicate that a process is capable and is to be considered acceptable.

The calculations that are required to calculate Cpk are shown below. Note that USL is Upper Spec Limit and LSL is Lower Spec Limit, the process mean is determined from SPC methods such as a variable control chart, and Z_{\min} is calculated as shown. Cpk is simply Z_{\min} divided by 3. This metric takes into account any non-centered process, that is, if the process mean is not at the specification center.

$$Z_{USL} = \frac{USL - \mu_x}{\sigma_x}, \quad Z_{LSL} = \frac{LSL - \mu_x}{\sigma_x}$$

$$\text{let, } \mu_x = \text{process mean or } \bar{X} \text{ (centerline from control chart); } \sigma_x = \frac{\bar{R}}{d_2}$$

Select the minimum of the following values :

$$Z_{\min} = \min [Z_{USL}, -Z_{LSL}]$$

The Cpk index is found by dividing this minimum value by 3 :

$$C_{pk} = \frac{Z_{\min}}{3}$$

The supplier **shall** keep records of all process capability studies and provide summaries and reports to the user on request.

6.1.4 Measurement Capability Assessment All measurement equipment and gages utilized for inspection that deal with the determination of conformance to engineering specifications will require a measurement system evaluation. Suppliers **shall** conduct a Gage R&R for every critical measurement device. Measurement variation is associated with numerous sources:

- 1) Accuracy – how well does the measurement agree with certifiable standards, such as the inch or the volt? Addressed by periodic calibration traceable to national standards.
- 2) Reproducibility – can different people or different machines get the same results for the same parts? Associated with the human error element (bias), or equipment-to-equipment variation. Poor reproducibility would indicate a need for operator training in the use of the measurement instrument or better calibration of multiple test sites.
- 3) Stability – does the measurement capability remain the same over time? Associated with wear, environmental conditions, deterioration that produces slow monotonic or periodic variation.
- 4) Repeatability – does the same part always measure the same? Associated with the complexity of the measurement system or short-term equipment variation. This measurement variation is derived from one operator measuring the same dimension multiple times, with the same gage. Poor repeatability indicates a need for gage maintenance, gage redesign or the selection of another type of measuring instrument.
- 5) Linearity – does the measurement accuracy and repeatability stay the same over total measurement range? Associated with the precision of the measurement equipment and its specifications.

Accordingly, the combination of accuracy, reproducibility, stability and repeatability is combined into one metric that is utilized to assess the suitability of the measurement tool(s). Gage acceptability is the quotient of total gage capability (Repeatability and Reproducibility) divided by the specification tolerance.

The following criteria **shall** be used to evaluate gage acceptability:

Under 10%: Acceptable measurement instrument.

0% to 30%: Marginally acceptable measurement instrument – should be investigated.

Over 30%: Measurement instrument is unacceptable and should be corrected or replaced.

This criteria is only approximate because the actual magnitude of the erroneous readings, and thus the correct differentiation of in-spec and out-of-spec parts, depends on the *Process Capability* as well as on the measurement error. Table 6-1 shows a selection of process capability levels and a range of measurement precision values. Process capability is indicated in the table by Cpk – see 6.1.3 above for definitions and methods for determining process capability.

In the table below, measurement capability is specified by the ratio of the part variation standard deviation (σ_p) to the measurement variation standard deviation (σ_m) as described above for the measurement capability criteria. *Note both process and measurement noise are assumed normally distributed for this illustration.*

Table 6-1 Part Discrimination Example

Effect of Measurement Noise on Correct Discrimination of In-Spec to Out-of-Spec Parts (Stable, Normally-Distributed Process)				
Process Capability C_{pk}	Measurement Capability σ_p / σ_m	Reject Good	Accept Bad	Total Error
0.66	1:1	12.9%	1.6%	14.5%
0.66	3:1	2.2%	1%	3.2%
0.66	10:1	0.5%	0.5%	1%
1.0	1:1	3.2%	0.1%	3.3%
1.0	3:1	0.3%	0.05%	0.3%
1.0	10:1	0.06%	0.04%	0.1%
1.33	1:1	0.4%	<0.01%	0.4%
1.33	3:1	< 0.1%	<0.01%	< 0.1%
1.33	10:1	<0.01%	<<0.01%	<0.01%

Note that Cpk = 0.66 is a “two-sigma” process with 95.5% of product in spec.
 Cpk = 1.0 is a “three-sigma” process with 99.7% of product in spec.
 Cpk = 1.33 is a “four-sigma” process with 99.99% of product in spec.

Table 6-1 shows that for a 2-sigma process (considered an unacceptable process) a 10:1 part-to-measurement variation ratio will create about 1% erroneous measurements, and a 3:1 measurement ratio will yield over 3% errors.

A 10:1 part-to-measurement capability with a 3-sigma process will incur only 0.1% measurement errors and with a highly capable process (4-sigma) will incur less than 0.01% measurement errors. A 10:1 ratio is generally desirable – even with a marginal 2-sigma process it reduces the shipped defectives from 4.5% (untested defect level) to 0.5%, and with a 3-sigma process it reduces the shipped defectives from 0.27% (untested defect level) to 0.04%. In each case a 10:1 measurement capability falsely rejects a small percentage of good material, about the same size as the shipped defectives. The 4-sigma process is so good that any measurement error only rejects good material. One might argue that if you have a 4-sigma process, you don’t need to make measurements.

But in order to develop a 4-sigma process in the first place, and to assure that you still have a 4-sigma process, you’ll need excellent measurement capability.

The supplier **shall** keep records of all measurement capability studies and provide summaries and reports to the user on request.

6.1.5 Corrective Action Process The supplier **shall** develop and implement a corrective action process that utilizes structured problem solving techniques to:

- Investigate the root causes of nonconforming product and identify the corrective actions needed to prevent a recurrence.
- Analyze all processes, work operations, quality records, service reports, and user complaints to detect and eliminate potential causes of nonconforming product.
- Apply controls to ensure that corrective actions are taken and that they are effective.
- Implement and record change in procedures as a result of corrective actions taken.

Additionally, the supplier's corrective action process **shall** provide for documentation that identifies the following in unit under test as well as similar products and processes as applicable.

- Specific defect
- Technical investigation/analysis
- Root cause
- Containment for defect
- Corrective action plan
- Preventive actions to preclude a recurrence
- Verification of effectiveness of actions

The supplier **shall** keep records of all corrective action issues and provide summaries and reports to the user on request.

6.1.6 Documentation Requirements Prior to evaluation of engineering first article samples, the supplier **shall** provide the user with copies (hard and soft copies) of all pertinent documentation relating to the following: (early prototypes may not include all of these documents):

- Theory of operation
- Applicable schematics.
- Qualification test plan
- Shipping test plan
- EMC Reports
- Reliability data and calculation
- Design checklist.
- Sample Qualification test report.
- DVT report
- Second Level Qualification report
- Failure Mode and Effect Analysis (FMEA)
- BOM. Must have a minimum of 2 sources that have been qualified for each component part. Any exceptions require written approval from Company Component Engineering.
- Approved supplier list for all components
- PWB artwork
- Component drawings, including magnetic
- Manufacturing drawings
- Regulatory reports (if applicable)
- Change History
- Mechanical Dimension Measurements

6.1.7 Calibration The supplier **shall** develop and maintain a system to assure all equipment used for the acceptance of product is calibrated with traceability to an internationally/nationally recognized Standards Institute such as the National Institute of Standards and Technology. Paragraph 4.10 of ISO 9002 may be used as a reference in developing a calibration system. Where appropriate, this should also include formal measurement capability studies. These records **shall** be made available for the user to review upon request.

Calibration Procedures

- Calibration procedures **shall** be established that define the measurements to be made, accuracy required, temperature/humidity required, and test equipment to be used in performing metrology verifications.

Recall List

- The supplier **shall** maintain a listing of all equipment requiring calibration and **shall** identify them by assigned tracking number, location, and re-calibration frequency. As a minimum, the recall system **shall** provide for early notification that an instrument is due for calibration.

Calibration Records

- The supplier **shall** maintain records of all calibrations performed. Calibration records **shall** as a minimum address the calibration procedure used, personnel performing the calibration, results, calibration status, and traceability to a Primary or Secondary Standard. These records **shall** be made available for the user to review upon request.

Out of Tolerance (Calibration) Notices

- In the event that tools or equipment used for product manufacturing, testing, or inspection are found to be out of tolerance or out of calibration, the supplier **shall** implement a system that will provide for the review of all product produced and accepted by the defective instrument. The supplier **shall** also implement a plan to repair/replace the equipment. The user **shall** be notified of the results of any such review and determination will be made at that time as to status and disposition of products built for the user.

6.1.8 Continuous Improvement The supplier **shall** develop and implement a Continuous Improvement Process (CIP) that will provide for a cost-effective reduction in process-related excursions. The program at a minimum **shall** include:

- A documented, systematic approach for identifying CIP focus areas
- Design for quality initiative (i.e., HALT, FMEA, Margin Analysis, Tolerance Stack-up Analysis)
- Supplier management strategy
- Manufacturing process controls
- LRR (Line Reject Rate) and IFIR (Initial Field Incident Rate) reduction plans to achieve user requirements

The supplier **shall** provide status of the implementation and results to the user upon request.

6.1.9 Process Quality Metrics The supplier **shall** use quality metrics as a basis to monitor the quality of its products and processes. Additionally, the supplier's quality program **shall** define the metrics for a stop ship and/or stop build action. Quality metrics, as a minimum, **shall** include:

- Incoming Quality Assurance (IQA) results
- Manufacturing Yields
- Test Station Yields
- Inspection Yields
- Mean Time Between Failures (MTBF) demonstration data
- Out of Box Audits (OBA) results
- Annualized Failure Rate (AFR)/Annualized Return Rate (ARR) performance
- Reliability test results
- Initial Field Incident Rate (IFIR) and Line Reject Rate (LRR)

The supplier **shall** provide reports on its process quality metrics to the user upon request.

6.2 Sub-Tier Suppliers The supplier **shall** develop and implement a system that will define quality and technical requirements to their component suppliers (sub-tier suppliers). Quality and technical requirements are defined as quality programs, engineering drawings, specifications and functions to be performed by sub-tier suppliers. The power conversion device supplier may elect to use a contract, purchase order or other suitable means in defining these requirements, as long as the quality and technical requirements are fully documented and that the sub-tier supplier verify understanding and implementation of such requirements.

The supplier **shall** perform a quality review of all proposed sub-tier suppliers prior to awarding business to a sub-tier supplier. The approval **shall** be based on review of the sub-tier suppliers' quality programs and ability to meet the supplier's expectations. The following factors appropriate to the products to be supplied **shall** be evaluated during the review:

- Manufacturing facilities
- Inspection planning to assure that appropriate levels of inspections are implemented
- Inspection controls including sampling plans and work instructions
- Inspection capabilities including in-process and incoming inspections
- Supplier's defect prevention programs
- Past experience with the type of hardware to be supplied
- Capability and condition of manufacturing equipment
- Control of engineering drawings, specifications and changes
- Change/Revision control
- Control and maintenance of inspection equipment and production tooling
- Employee training and certifications
- Material storage and handling
- Test & measurement equipment calibration program
- Control of nonconforming hardware and materials
- Corrective and Preventive action program
- Ability to perform FMEAs (Design and Process)
- Experience in implementing Continuous Improvement Programs
- Experience and implementation of Statistical Process Control

Records of Sub-tier Supplier approvals including survey results **shall** be maintained and made available for the power conversion device user to review upon request.

- The supplier **shall** define component reliability requirements to their sub-tier suppliers. These requirements **shall** align with those of the power conversion device user. The supplier **shall** implement testing as required to verify performance and reliability of components, or **shall** assure that the sub-tier supplier implement and report on such testing. These tests should include (as a minimum) functional testing of all critical parameters, measurement and monitoring of Statistical Process Control variables, and ongoing reliability (ORT). Test reports should be provided on a regular basis.
- The power conversion device supplier **shall** adequately monitor component supplier's quality systems and performance for all components used in a design. This includes assuring a sub-tier quality management program that **shall** provide for quality goals, the performance of site surveys and audits, quality program requirements, change or revision control requirements, tests and inspections, and component qualification before production in the case of new components.

6.2.1 Materials Traceability Requirements

The supplier shall ensure material traceability system is built into the standard operating practices on the shop floor and linked to the finished goods serial numbers. This system should be capable of providing the following information:

- What raw material lot was used
- When the raw material was received
- Which supplier provided the material
- When did the supplier perform the internal QC on the outgoing material
- Which production line of the supplier was used
- What engineering change notices (if any) were applied to the product

7 MANUFACTURING CONFORMANCE TESTING

This section defines the minimum test requirements for suppliers once the power conversion device is released to Manufacturing.

7.1 Manufacturing Conformance Tests The power conversion device supplier **shall** test every parameter specified in the Functional specification during the manufacturing of all power conversion devices. At each test stage, data will be collected as described in 7.3 that follows. This data will be used for statistical process control, and included in the Quality Yield Data provided to the power conversion device user upon request.

The flowchart represented in Figure 7-1 shows various types of manufacturing conformance tests to be conducted. The exact flow detail may vary from supplier to supplier based on product and the line layout. These tests (except ORTs, possible HASA, and Outgoing Quality Sampling Tests) should be performed on every unit fabricated in manufacturing (100% test). ORTs, HASA and some QA audits are usually performed on a sample of the total manufacturing output, often for statistical process control (SPC) feedback. Note that a just-in-time manufacturing process is assumed, with no 100% incoming inspection of individual components.

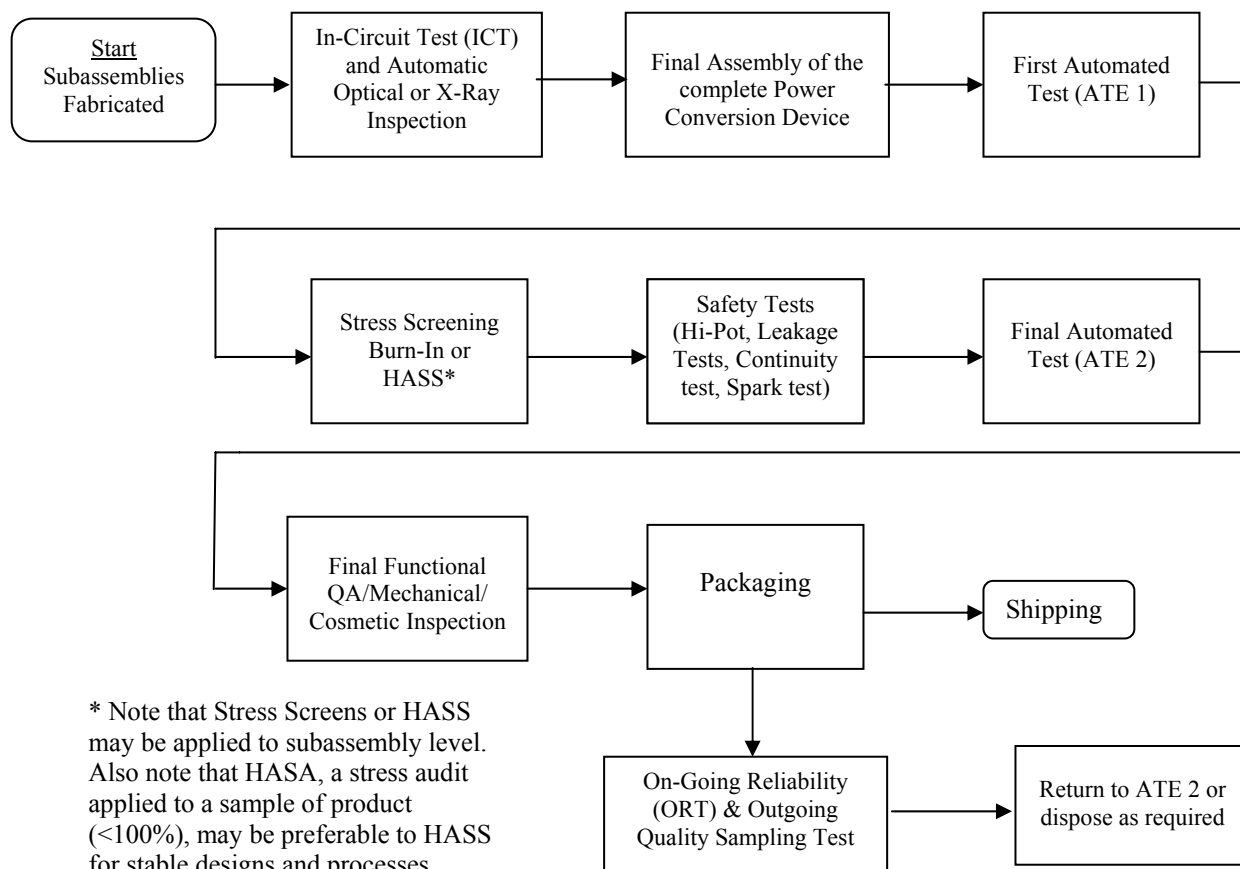


Figure 7-1 Manufacturing Conformance Test Elements

7.2 Early Manufacturing Conformance Test Requirements Referring to the test flow chart in Fig 7.1, the first tests made on any subassembly are in-circuit tests (ICT) and automated optical or high resolution x-ray testing. These tests are required before final assembly and functional testing in most fabrication processes. The power conversion device supplier **shall** provide the test plan and coverage information for all in-circuit test (ICT) and automatic optical/x-ray inspection testing to the power conversion device user at the time of Manufacturing Readiness Review.

Optical or x-ray inspection **shall** be performed on 100% of fabricated printed wiring board assemblies to assure workmanship quality, and detect, for repair, any soldering or component-placement faults. In-circuit testing **shall** be performed on 100% of fabricated printed wiring board assemblies to assure all critical-to-function component parameters are within required tolerances. Data from these tests **shall** be collected, electronically if possible, and used for statistical process control (SPC) calculations as described in 6.1.2 of this document.

7.3 Final Assembly Test Requirements As shown in Fig 7.1, there are several types of tests that may be applied to the final power conversion device. These tests fall into five categories:

- Functional Tests
- Stress Tests
- Safety Tests
- Quality Assurance
- Reliability Testing

7.3.1 Functional Tests The power conversion device supplier **shall** test every parameter specified in the functional specification on 100% of manufactured units using bench tests or, preferably, ATE (Automated Test Equipment). While in some cases the functionality may be tested at a single stage, the flow chart of Fig 7.1 shows two ATE stages, one prior to stress and safety tests, and one afterward. The method used by the power conversion device supplier depends on the systems in place at the manufacturing & test facilities. Data from these tests **shall** be collected, electronically if possible, and used for statistical process control (SPC) calculations as described in **6.1.2**.

7.3.2 Stress Tests The power conversion device supplier **shall** provide in-line (100% of units) burn-in or HASS (Highly Accelerated Stress Screen) at the power conversion device user's option. While 100% burn-in may be required with some technologies and designs, a HASA (Highly Accelerated Stress Audit) run on a sample of the production units (much less than 100%) may provide adequate feedback of process/component changes that require attention while keeping costs down. An efficient manufacturing organization can often transition from 100% HASS to a low percent HASA stress test shortly after full production is in operation. Data from burn-in, HASS or HASA testing **shall** be collected, electronically if possible, and used for yield information and statistical process control (SPC) calculations as described in **6.1.2**.

(See Appendix F on requirements for burn-in.)

7.3.3 Safety Tests All power conversion devices (100% of units) **shall** be subjected to required safety tests as defined by applicable regulatory documents as described in **9** and by the power conversion device user functional specifications. Safety tests include Hi-Pot, leakage tests, continuity and other tests to assure no electrical hazards exist in a power conversion device unit. Safety tests **shall** be performed after any final mechanical assembly such as heat sink attachment. Data from safety testing **shall** be collected and retained as required by the appropriate safety agencies.

7.3.4 Quality Assurance Final Functional Quality Assurance, Mechanical, and Cosmetic Inspection **shall** be performed to assure conformance to functional, mechanical dimensions and cosmetic requirements such as labels and marking. QA inspection/tests **shall** be performed **only after any final mechanical assembly such as frames or heat sinks have been attached**. Functional tests will usually require ATE, but may be a subset of total functional testing as agreed upon with the power conversion device user. Data from these tests **shall** be collected, electronically if possible, and used for statistical process control (SPC) calculations as described in **6.1.2**.

Additional Outgoing Quality Sampling Tests, often termed **Out of Box Audit (OBA)**, **shall** be made on samples of units after packaging for shipment to assure proper handling, packaging and documentation has been supplied. Data from these tests **shall** be collected, electronically if possible, and used for statistical process control (SPC) calculations as described in **6.1.2**.

7.3.5 Reliability Testing Ongoing reliability testing **shall** be performed on a sample basis to assure no process or component degradation has affected the long-term reliability of the product. ORT **shall** be performed **only after any final mechanical assembly such as frames or heat sinks have been attached**. ORT may subject a given unit to months of operation, often at increased stress levels, and as such, can handle only a small percentage of production units. ORT testing may be divided into short-term test units that are run long enough to detect any changes in early life failures (a few days to a few weeks), and long-term test units that are run until end-of-lifetime. Individual power conversion devices that complete long-term ORT are not salable and must be properly disposed of or recycled. Individual units that complete a short-term ORT may be cycled back through a reconditioning and re-testing process and sold as new if the combined stress level and time effects do not degrade the long-term reliability. Use of reconditioned short-term ORT units must be agreed upon by the power conversion device customer.

7.4 Material Control & Labeling The power conversion device supplier **shall** provide a documented, capable material control system for all incoming, in-process, and outgoing material. The material control system **shall** include the following elements:

- **Material Identification** All material **shall** be properly segregated and/or labeled throughout the testing and manufacturing process.
- **Discrepant Material** All discrepant material **shall** be reworked or disposed of according to the supplier’s material control system requirements. Records of all rework and scrap **shall** be kept and summary reports provided to the user on request.
- **Labeling** All power conversion devices **shall** be Labeled and each power conversion device **shall** have the following markings:
 - 1) Appropriate regulatory certification labels – see section 9 of this document.
 - 2) Manufacturer's name, part number, serial number, and lot date code in human readable text format.
 - 3) Date of latest printed circuit board artwork revision and revision level of the schematic.
 - 4) For AC/DC units, caution label located on the visible side of the power conversion device stated in English, French, German, Italian, Spanish, Portuguese and Chinese. Supplier's standard label can be used if approved by the user. The label **shall** have black lettering on a yellow background:



- 5) Country of Origin.
- 6) Model and Manufacturer Name.
- 7) AC/DC units: Nominal AC input voltages and frequencies. Maximum AC input currents.
DC/DC units: Nominal DC input voltages. Maximum DC input currents.
- 8) Nominal Output Voltages and Maximum Continuous Output Currents.
- 9) Maximum Continuous Output Power.
- 10) Separate bar-code label that can be peeled-off with the Supplier name, Model Number, Revision coded in the following format:
 - Supplier Name:
 - Model Number:
 - Revision:

AC/DC units only: HIPOT and Ground Continuity Test marking to be applied on the power conversion device after the manufacturing HIPOT and continuity tests have been successfully completed.

7.5 Revision Control All changes affecting form, fit, function, or regulatory Agency requirements **shall** cause a next level revision of the supplier’s part numbers. The revision control number **shall** be placed on the ID label away from the power conversion device part number. The user **shall** NOT ship to its customers, nor accept units for revenue that have not been released to manufacturing at the supplier’s facility. The release of units to manufacturing indicates that the power conversion device is fully Agency approved (Regulatory and Safety).

8 CHANGE NOTIFICATION

8.1 Change Authorization After first article approval of a power conversion device design by the user, there **shall** be no design, process or material changes that may affect form, fit, function, reliability or Agency compliance without written approval of the user prior to implementation. User **shall** be notified via a change request notice. Change requests **shall** be accompanied by a reproducible set of documentation that fully describes the planned change. At the user's discretion, changes may require submittal of new first article samples for evaluation.

Suppliers **shall** provide notification of any change; as examples: end of life, quality alerts or security alerts. The ability to manage this process is seen as an integral part of the supplier's quality system, and necessary to ensure accurate and efficient tracking of changes and end-of-life changes.

With the use of a sub-tier supplier, the process **shall** continue to meet all of the criteria set forth in this document and the sub-tier supplier **shall** conform to the same requirements. Any failure by the sub-tier supplier **shall** be seen as a quality issue adversely impacting the supplier's rating, as the supplier **shall** remain responsible for the sub-tier supplier's compliance to requirements. The supplier **shall** demonstrate that their sub-tier supplier(s) are under change control.

8.2 Qualification of Changes Suppliers **shall** be able to provide evidence of product qualification according to the applicable standards. Upon request, the supplier **shall** provide, a reasonable number of pieces indicated as necessary in order to qualify the new revision of the supplier product. Also, the supplier **shall** provide qualification and characterization information for each PCN as applicable. If this information is not available at the time the PCN is issued, the supplier **shall** provide a qualification plan and timeline with the initial PCN, and the final test report once it is available.

Suppliers **shall** allow users to select samples of their product for qualification. Such samples **shall** be representative for the normal production of product to be supplied.

8.2.1 Content of each Product Change Notice (PCN)/End of Life (EOL)/Product Alert (PA)

This information **shall** include the following minimum information:

- Internal Tracking Number
- Name of Supplier
- Contact Names (address, telephone/fax numbers)
- Planned Implementation Date
- Product Identification
- Detailed Description of Change / Reason
- Quantifiable Impact on Quality/Reliability (positive or negative)
- Qualification Date/ Plan
- Identification Method for Product Ordering Code Changes, if known
- Application Changes, Enhancements and/or Work-Arounds

8.2.1.1 Product Alerts The Alert timeline Notification **shall** be within 24 hours of detection of the issue. The supplier **shall** issue a written alert immediately upon the detection of any issue adversely affecting the safety, security and/or reliability of the supplier's product. If correction of the issue requires a change to the product or related processes, the supplier **shall** issue a related PCN and explicitly note the issue being corrected as well as the its impact on the safety and/or reliability of the supplier's product. The purpose of this type of notification is to provide enough information to initially ascertain the severity of an issue and involve the appropriate people, and be able contain/quarantine the affected products.

The content requirements for a PA shall be the same as a PCN, except that the PA **shall** also include the Shipping quantities, Shipping locations and the P.O. numbers.

8.2.1.2 End of Life The timeline Last Time Buy (LTB) shall be communicated to the customer within 12 months. Last Time Delivery (LTD) or ship date **shall** be 6 months. Content requirements for an EOL **shall** be the same as the PCN, except the EOL **shall** include the LTB and LTD dates, replacements part numbers, supplier names (if known) and specific package types.

8.2.1.3 Examples of Changes Requiring a PCN:

- Mechanical specification changes -Internal dimensions and associated tolerance changes
- Environmental changes (MSL, Dry pack requirements, shelf life, storage temp)
- Package Label (p/n name conventions, chg to physical product identification markings)
- Electrical characteristics (Enhancements, bug or errata fixes “firmware or software, parameter changes, reduction in test coverage, Flammability /ESD rating, Test site and or process)
- Mechanical/Material characteristics (Internal dimensions and associated tolerance changes including shape / terminal finish “lead base materials”/plating/solder ball composition/tolerance changes/molding compounds/substrate material)
- Manufacturing/Assembly change (Mask, Manufacturing location, assembly site or process, Injection mold or tooling changes)
- Thermal characteristics
- Performance characteristics
- Firmware changes, UL-impacting hardware changes (BOM changes, new power supply ref)
- Regulatory approval changes (e.g. UL to CUL or VDE to TUV etc.)
- Part Number or product Tracking (Ordering part numbering / series changes)
- (Screening engineering samples or prototypes, supplementary tests, waivers etc.)

9 REGULATORY REQUIREMENTS

Regulatory and safety agency testing **shall** be performed on a sample of completed power conversion devices and, as required by any Agencies, on a sample of safety-critical components such as transformers to assure compliance with appropriate Agency requirements. All power conversion devices **shall** be designed to be Agency compliant and be shippable worldwide for installation in the environments specified by data sheet limits. The power conversion device supplier **shall** be fully responsible for ensuring the compliance of the device to all applicable Agency requirements, to transportation stresses, and to the specified end-use environment.

Tests such as radiated susceptibility, conducted susceptibility, non-operating magnetic interference, and insulation breakdown (hi pot) are regulatory/safety issues that are normally verified during environmental testing (see 5.5). Regulatory and safety issues may need to be verified by a regulatory Agency on final design unless the supplier is self-certified by that agency. Some countries require agency approval and do not accept self-certification. Any and all issues regarding agency requirements **shall** be the responsibility of authorized product regulations managers at the power conversion device (PCD) supplier and user organizations.

The manufacturer **shall** demonstrate initial and continued compliance to the latest edition, revision, and amendment of all applicable Agency standards. See **9 Regulatory Requirements, 2 Applicable Documents, and 10 References** for some applicable tests and standards. All power conversion products **shall** meet the minimum requirements for electromagnetic compatibility (EMC) and safety for the appropriate worldwide markets, as listed below.

9.1 EMC Requirements – U.S.A and Canada

Country	Reference and Title of Standard	Regulatory Agency
United States	• Federal Communications Commission, Title 47 US CFR -- Part 2, Frequency Allocations and Radio Treaty Matters, General Rules and Regulations	FCC
	• Title 47 US CFR -- Part 15 Radio Frequency Devices	
	• ANSI C63.4 (2003) – Methods of measurement of radio noise emissions from low voltage electrical and electronic equipment in the range of 9kHz to 40GHz	
Canada	• Industry Canada, Spectrum Management, Interference Causing Equipment Standard: ICES-003 -- Digital Apparatus	ICES

In accordance with FCC rules and regulations, testing for the United States market **shall** be performed by a NVLAP or A2LA accredited EMC laboratory. In addition, laboratories that have been mutually recognized by NIST through a Mutual Recognition Agreement / Authority (MRA) or authorized for FCC: Declaration of Conformity (DoC) testing, could also be used.

9.2 EMC Requirements – Asia Pacific and Japan

Country	Reference and Title of Standard	Regulatory Agency
Japan	• Voluntary Control Council for Interference by Information Technology Equipment -- V-1 through V-7 (CISPR-22 Emissions @ 100VAC)	VCCI, PSE and JEITA
Australia	• Australian Communications Authority -- AS/NZS CISPR 22:2004, Class (B)	C-Tick, ACMA or RCM
New Zealand	• Ministry of Communications -- AS/NZS CISPR 22:2004 Class (B)	C-Tick , ACMA or RCM
South Korea	• Korean Bureau of Standards (KN22=CISPR-22 Emissions), Immunity Jan. 1, 2000 (KN24+CISPR-24)	EK
Taiwan	• Bureau of Standards, Metrology and Inspection -- CNS-13438 (CISPR –22 Emissions)	BSMI
China	• State Administration of Import and Export Commodity -- GB 9254-98 / GB 17625.1-1998, (CISPR-22 Emissions / IEC61000-3-2:1995 Current Harmonics)	CCC *

NOTE: * Indicates the Agency Mark must be displayed on the Power conversion device Label for Production.

- In accordance with VCCI rules and regulations, testing for the Japanese market **shall** be performed by a VCCI accredited EMC laboratory.
- In accordance with CNCA rules and regulations, testing for the Mainland Chinese market **shall** be performed by a CNCA accredited EMC laboratory.
- In accordance with MIC rules and regulations, an RRL accredited EMC laboratory **shall** perform testing for the South Korean market. (Power adapters fall under KTL safety and includes EMC standards which use the EK mark)
- In accordance with memorandum of understanding, a NVLAP or A2LA accredited laboratory **shall** perform testing for the Australian/New Zealand markets.
- In accordance with BSMI rules and regulations, testing for the Taiwan market **shall** be performed by a BSMI accredited EMC laboratory.

9.3 EMC Requirements – Europe (non-EU), Middle East, South Africa

Country	Reference and Title of Standard	Regulatory Agency
Russia	Compliance with the EU Reference EMC standards (CISPR-22 report)	GOST
	Compliance with the EU Reference EMC standards (EN55024 report)	
	TCO 99 – Near field ELF and VLF electric and magnetic emissions	
Israel	Compliance to Israeli standard SI 961	SII
South Africa	Compliance with the EU Reference EMC standards (CISPR-22 report)	SABS
Norway	Compliance with the EU Reference EMC standards (EN 55022 report)	NEMKO *
	Compliance with the EU Reference EMC standards (EN 55024 report)	

NOTE: * Indicates the Agency Mark must be displayed on the PCD Label for Production.

- Testing for these markets **shall** be performed in an accredited laboratory. It is possible to leverage off NEMKO’s agreements with regulatory agencies in other countries, e.g., Russia, Finland, Denmark, and Czech Republic. Testing for these markets **shall** be performed in an accredited laboratory. It is possible to leverage certain test companies such as ITS, NEMKO, UL etc. for their reciprocal certification agreements with regulatory agencies in other countries -- Russia, Argentina, Mexico.
- In accordance with SABS rules and regulations, testing for the South Africa market **shall** be performed by a SABS accredited EMC laboratory.
- Some additional European, Benelux, or, Nordic countries, e.g., Sweden may also request compliance with TCO-99.

NOTE: The relevant deviations in the Israeli standard SI 961 part 6.2 from CISPR publication 24 are:

Table 1 – Immunity, enclosure port

Note 2 reads:

The frequency range will be scanned as required, but if required in annex A, or when the EUT’s operation exceeds 5 sec., additional functionality tests should be conducted in the following frequencies (in MHz) : 89, 100, 107, 144, 163, 196, 244, 315, 434, 460, 600, 825, 845, 880 (±0.1%). If radiation tests will be conducted in the frequency range of 26 – 80 MHz, the following frequencies should be investigated as well : 27, 68, 40, 65 MHz.

Table 2 – Immunity, signal ports and telecommunication ports

Note 1 reads:

The frequency range will be scanned as required, but if required in annex A, or when the EUT’s operation exceeds 5 sec., additional functionality tests should be conducted in the following frequencies (in MHz) : 0.2, 0.53, 1, 1.5, 7.1, 13.56, 21, 27.12, 40.68 ((±0.1%).

Note 3 reads

The test is applicable to the interface parts, intended to support telecommunication cables for distances exceeding 3m.

Table 3 – Immunity, input d.c. power port (excluding equipment marketed with a ac/dc power converter)

Note 1 reads:

The frequency range will be scanned as required, but if required in annex A, or when the EUT’s operation exceeds 5 sec., additional functionality tests should be conducted in the following frequencies (in MHz) : 0.2, 0.53, 1, 1.5, 7.1, 13.56, 21, 27.12, 40.68 ((±0.1%).

Table 4 – Immunity, input a.c. power ports (including equipment marketed with a separate ac/dc power converter)

Note 1 reads:

The frequency range will be scanned as required, but if required in annex A, or when the EUT’s operation exceeds 5 sec., additional functionality tests should be conducted in the following frequencies (in MHz) : 0.2, 0.53, 1, 1.5, 7.1, 13.56, 21, 27.12, 40.68 ((±0.1%).

9.4 EMC Requirements, European Community

The Power conversion device Application Engineer **shall** contact Regulatory Engineering to determine Test Level applicable for the product under consideration.

Power Conversion Device	EU Reference	Title of Standard	International Reference	Test Level for Heavy Industrial	Test Level for Light Industrial	Test Level for 48 VDC p/s
AC-DC, DC-DC, Power Supplies	EN55022:1998 To be soon updated to EN55022:2006	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement	CISPR 22:1997	Class "B" 4dB of margin Class "A" or Class "B" for servers	Class "B" 4dB of margin Class "A" or Class "B" for servers	Class "B" 4dB of margin Class "A" or Class "B" for servers
DC-DC, DC-DC Power Supplies	EN55024:1998 (EN50082-2:1995 updated to EN61000-6-2:2001 for -48 VDC supply)	Information technology equipment – Immunity characteristics – Limits and methods of measurement	CISPR 24:1997			Different tests and limits for DC power supplies
AC-DC, AC-DC Power Supplies	EN61000-3-2:2000 <i>(PFC Power Supplies ONLY if rated greater than 75W)</i>	Electromagnetic compatibility (EMC) – Part 3: Limits – Section 2: Limits for harmonic current emissions (Equipment input current up to and including 16 A per phase)	IEC 61000-3-2:2000	Must meet Class D requirements	Must meet Class D requirements	N/A
AC-DC, AC-DC Power Supplies	EN61000-3-3:1995 <i>(PFC Power Supplies ONLY)</i>	Electromagnetic Compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current up to and including 16A	IEC 61000-3-3:1994	Meet specification	Meet specification	N/A
AC-DC, DC-DC, Power Supplies	EN61000-4-2	Electromagnetic Compatibility (EMC) – Part 4: -- Section 2: Electrostatic discharge immunity test	IEC 1000-4-2	(+/-) 2, 4, 8, 12 and 15kV air (+/-) 2,4,6,8 kV contact discharge	(+/-) 2, 4, 8, 12 and 15kV air (+/-) 2,4,6,8 kV contact discharge	(+/-) 2, 4, 8, 12 and 15kV air (+/-) 2,4,6,8 kV contact discharge
AC-DC, DC-DC, Power Supplies	EN 61000-4-3 + Israeli Deviations in SI 961 part 6.2 See	Electromagnetic Compatibility (EMC) – Part 4: -- Section 3: Radiated, radio-frequency electromagnetic field, immunity test	IEC 1000-4-3 Basic Standard ENV 50140	10V/m 80-1000MHz, 80% AM 900 +/-5MHz, 50%, 200Hz	3V/m 80-1000MHz, 80% AM 900 +/-5MHz, 50%, 200Hz	10V/m 80-1000MHz, 80% AM 900 +/-5MHz, 50%, 200Hz
AC-DC, DC-DC, Power Supplies	EN 61000-4-4	Electromagnetic Compatibility (EMC) – Part 4: -- Section 4: Electrical fast transient/burst immunity test	IEC 1000-4-4	1, 2, 4kV - Power 0.5, 1, and 2kV - Signal	1, 2 kV - Power 0.5, 1 kV - Signal	1, 2 kV - Power 0.5, 1, and 2kV - Signal
AC-DC, DC-DC, Power Supplies	EN 61000-4-5	Electromagnetic Compatibility (EMC) – Part 4: -- Section 5: Surge Immunity Test	IEC 1000-4-5	1, 2kV differential 2, 4kV common	0.5, 1 kV diff. 0.5, 1, 2, 2.5 common	0.5, 1kV differential 0.5, 1kV common
AC-DC, DC-DC, Power Supplies	EN 61000-4-6 + Israeli Deviations in SI 961 part 6.2	Electromagnetic Compatibility (EMC) – Part 4: -- Section 6: Conducted disturbances induced by radio-frequency fields – immunity test	IEC 1000-4-6 Basic Standard ENV 50141	10V/m 80% AM (1kHz)	3 V/m 80% AM (1kHz)	10 V/m 80% AM, (1kHz)
AC-DC, DC-DC, Power Supplies	EN 61000-4-8	Electromagnetic Compatibility (EMC) – Part 4: -- Section 8: Power-frequency magnetic field immunity test	IEC 1000-4-8	30 A/m (r.m.s.)	1 A/m (r.m.s.)	30 A/m (r.m.s.)
AC-DC, DC-DC, Power Supplies	EN 61000-4-11	Electromagnetic Compatibility (EMC) – Part 4: -- Section 11: Voltage dips, short interruptions and voltage variations immunity test	IEC 1000-4-11	30% for 0.5 S >95% for 10 mS >95% for 5 S	30% for 0.5 S >95% for 10 mS >95% for 5 S	30% for 0.5 S >95% for 10 mS >95% for 5 S

Light Industrial: EN55022:1998 (Emission) and EN 61000-6-1:2001 (Immunity)

Heavy Industrial: EN55011 (Emission) and EN 610006-2:2005 (Immunity)

NOTE: Some tests above are only required for AC/DC power conversion devices using Power Factor Correction (PFC). Harmonics required unless the rated power is less than 75W; usually requires PFC to meet Class D.

NOTE: The Agency Mark (CE) must be displayed on the Power conversion device Label for Production sold in European Union countries.

9.5 Product Safety Requirements The power conversion device supplier **shall** assure that all products delivered conform to the following list of seven safety standards:

1. IEC 60950-1 First Edition with CB (Certified Body) Report and Certificate (Including all national deviations)
2. EN 50116
3. GB4943-2001. Safety of Information Technology Equipment including Electrical Business Equipment (China)
4. BSMI – CNS14336 Note: The supplier **shall** be responsible for being aware of all up coming changes and design the product to comply with the current and future standards.

9.6 Agency Approvals The power conversion device supplier **shall** assure that the appropriate agency approvals for the specific product and region are obtained before shipping production level Power Conversion Devices. A comprehensive listing of Agency approvals are shown next:

Regulatory Body	Country	Standard	Submission Responsibility	Mark on Label
CSA Certified	Canada	IEC-60950-1	OEM	Y
UL Listed	United States	IEC 60950-1	OEM	Y
CE	EU	IEC 60950-1 EN 55022 EN 55024	OEM	Y
TUV/VDE GS Licensed	Germany	IEC 60950-1	OEM	Y
RTCA/DO160D/e Mark/TUV GS	EU	TBD	OEM	Y
GOST	Russia	TBD	OEM	Y
NEMKO-CB	Norway	IEC 60950-1 EN 55022 EN 55024	OEM	N
PSE	Japan	IEC-60950	OEM	Y
NOM/NYSE	Mexico	IEC 60950-1	OEM	Y
N-MARK / V-MARK	Australia	IEC 60950-1	OEM	Y
e-K mark (KTL/KETI)	Korea	IEC 60950-1 EN 55022	OEM	Y
SABS	South Africa	IEC 60950-1 EN 55022	OEM	N
SPRING	Singapore	IEC 60950-1	OEM	N
CCC	China,	GB4943-2001 EN 55022	OEM	Y
IRAM	Argentina	IEC 60950-1	OEM (NEMCO)@	Y
Uksertcomputer	Ukraine	IEC 60950-1 EN 55022 EN 55024	OEM (NEMCO)@	N
Koncar	Croatia	IEC 60950-1 EN 55022 EN 55024	OEM (NEMCO)@	N
SII	Israel	IEC 60950-1 EN 55022 +	OEM (NEMCO)@	N
SIRIM	Malaysia	IEC 60950-1 MS EN 60742:1998	OEM	N
BSMI	Taiwan	IEC 60950-1 EN 55022	OEM	Y

9.7 Required Documentation The power conversion device supplier **shall** provide copies of the following items to the power conversion device user:

1. All agency approval certificates
2. UL Descriptive and Nemko-CB Test Reports
3. Schematics
4. BOM (Bill of Material)
5. Temperature ratings of all components and printed circuit boards

NOTES: a) Schematics and BOM revision numbers must correlate, and the model designation must be specified on each page of the schematics and BOM.

- b) The following are required to be incorporated in each test report:
- If the power conversion device can be removed from the product without disconnecting the power cord, the UL Conditions of Acceptability (C of A) must contain a statement that no energy hazard exists at the outputs in the removed condition (i.e. 40VA is not available).
 - UL C of A and the Nemko-CB report must reflect that proper engineering consideration has been made for operation at an elevation of 3100 meters. Currently 60950-1 covers operation up to 2000 meters. Suppliers must use Annex G to show compliance to 3100 meters
- c) The Nemko-CB Report must include input current, leakage and heating test data performed at 134V (required to meet the Saudi Arabia requirements).
- d) The Nemko-CB report must include abnormal testing of the voltage selector switch (if present). If the power conversion device is rated 100-120V / 200-240V but does not have a voltage selector switch (auto range circuit instead), then a statement must be present in the abnormal tests that the auto range circuit did not constitute a hazard.

9.8 AC to DC Leakage Test The power conversion device supplier **shall** confirm that power mains connected power conversion devices intended for the following final product applications comply with the required leakage current specification.

Servers or Other Permanently Connected Equipment

In addition to the agency safety requirements, the leakage current from AC to safety ground **shall** not exceed 1.3mA at 240VAC, 60Hz. Test method is per IEC 60950-1.

Office Equipment – Desktops and Peripheral Equipment

Normal Leakage Current: Chassis Leakage Current **shall** not exceed 3.5mA in accordance to IEC 60950-1 Class I equipment

9.9 Flammability Parts used within a Power Conversion Device **shall** meet the following flammability ratings:

Printed circuit boards, including all daughter cards: V-0

Magnetic assemblies must be constructed of materials with a UL flame class of VW-1, V-1 or better, or meet the flammability requirements of V-1 or better when tested per the procedures as specified in IEC 60695. The test is to be applied to the magnetic assembly (not a material sample) without the assembly being preconditioned prior to the test.

Power connectors on the Motherboards: V-0

All other connectors, other than Motherboard power connectors: V-2 or better

Plastic fabricated parts **shall** be made of a material with a UL recognized flame class of V-1 or better. However, small mechanical parts such as cable ties, washers, and PC board mounts may be made with a UL recognized flame class of V-2.

9.10 Dielectric Strength Testing (mains connected AC/DC units) Every production unit (100% of production) **shall** pass a 2,121V DC production hi-pot test between primary to chassis ground. The voltage must be ramped up to 2,121V DC within 0.8 second and it must be maintained at that level for a minimum of 1 second without failure. Each unit must be marked to indicate it passed the test.

9.11 Ground Continuity Testing (mains connected AC/DC units) Every production unit (100% of production) **shall** pass a ground continuity test with less than 0.1 ohm from the safety ground (third wire) input pin to the power conversion device chassis. Each unit must be marked to indicate it passed the test. Reference Standard EN 50116.

9.12 Metal Oxide Varistors Any Metal Oxide Varistors (MOVs) used from Line to Line **shall** be UL recognized and IEC 61051-1,-2 or CECC42200 approved components. MOV's must be properly placed or shielded to prevent a compromise of safety insulation in the event of a failure. MOVs cannot be used in any application where either lead is connected to ground.

9.13 Gas Discharge Tubes Gas discharge tubes **shall not** be used in any application where either lead is connected to ground.

9.14 SELV Output Requirements If any outputs do not meet the requirements of Level III SELV and non-energy hazard, the supplier **shall** clearly identify these outputs to the regulatory engineering staff. These outputs must be identified even if they are already specified under Section 2 as not being Level III SELV.

9.15 Mains Fuse Mains Fuses of greater than 16 amp rating **shall** not be used.

9.16 Batteries Safety requirements of any batteries used in a power conversion device **shall** be addressed and documented with the following conditions:

- a) Power Conversion Device supplier **shall** review and follow all safety precautions and special uses considerations provided by manufacturer. Note: Lithium battery selection demands extreme care when selecting due to risk of fire.
- b) Power Conversion Device supplier **shall** assure that design of battery connector/holder will prevent or reduce the risk of the battery being connected or installed incorrectly (wrong polarity).
- c) When selecting replaceable batteries, UL approval **shall** be a requirement.
- d) If a battery is not designed for recharging, then the battery circuit **shall** provide two levels of protection to prevent charging.
- e) Battery protection circuits **shall** be designed so that the proper charge level/rate under any single fault condition is maintained. Charge level/rate for rechargeable batteries is critical for safety.
- f) Power Conversion Device supplier **shall** assure proper marking for countries requiring special marking of equipment containing batteries.
- g) Manufacturer **shall** provide a copy of its Agency Certificates/License and a copy of “Conditions of Acceptability.”
- h) Battery use **shall** require applicable standards such as IEC 60086 series, UL 1642 and others.

9.17 Energy Efficiency Requirements: Energy star rating for AC-DC power supplies, adapters EPS V1.1– developed by EPA- US Environment Protection Agency & DOE US Department of Energy

(NOTE: Does not appear to have a standard requirement yet for DC-DC power modules)

9.18 RoHS/WEEE Compliance Lead-Free and restricted materials compliance such as RoHS/WEEE certification

EU RoHS Directive, 2002/95/EC and WEEE Directive 2002/96/EC, 2003/108/EC

9.19 SUMMARY: Power Conversion Regulatory and Safety Requirements (Defined per PCD-Type)

Section	Title	Power Conversion Devices
9.1	EMC Requirements – U.S.A and Canada	AC-DC, DC-DC Power Supplies (If deployed to this region)
9.2	EMC Requirements – Asia Pacific and Japan	AC-DC, DC-DC Power Supplies (If deployed to this region)
9.3	EMC Requirements – Europe (non-EU), Middle East, South Africa	AC-DC, DC-DC Power Supplies (If deployed to this region)
9.4	EMC Requirements, European Community	AC-DC, DC-DC Power Supplies (If deployed to this region)
9.5	Product Safety Requirements	AC-DC, DC-DC Power Supplies
9.6	Agency Approvals	AC-DC, DC-DC, Power Supplies
9.7	Required Documentation	AC-DC, DC-DC, Power Supplies
9.8	AC to DC Leakage Test	AC-DC, AC-DC Power Supplies
9.9	Flammability	AC-DC, DC-DC, Power Supplies
9.10	Dielectric Strength Testing (mains connected AC/DC units)	AC-DC, AC-DC Power Supplies
9.11	Ground Continuity Testing (mains connected AC/DC units)	AC-DC, AC-DC Power Supplies
9.12	Metal Oxide Varistors	Power Supplies
9.13	Gas Discharge Tubes	Power Supplies
9.14	SELV Output Requirements	DC-DC, DC-DC Power Supplies
9.15	Mains Fuse	Power Supplies
9.16	Batteries	Power Supplies
9.17	Energy Efficiency Requirements	AC-DC, AC-DC Power Supplies (No Standard for DC-DC)
9.18	RoHS/WEEE Compliance	AC-DC, DC-DC, Power Supplies

10 REFERENCES

- ANSI C63.4 (1992) – Methods of measurement of radio noise emissions from low voltage electrical and electronic equipment in the range of 9kHz to 40GHz
- ANSI S12.10 Methods for the Measurement and Designation of Noise Emitted by Computer and Business Equipment
- ANSI S12.11 Methods for the Measurement of Noise Emitted by Small Air-Moving Devices
- AS/NZS CISPR 22:2002, Class (B): Australian Communications Authority --
- AS/NZS CISPR 22:2002, Class (B): Ministry of Communications – New Zealand
- CAN/CSA C22.2 No. 60950-1 Safety of Information Technology Equipment, Including Electrical Business Equipment
- CNS-13438 (CISPR –22 Emissions) -- Bureau of Standards, Metrology and Inspection – Taiwan
- ECMA 74, Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment (9th edition)
- Energy Star Programs
- ETSI European Telecommunications Standards Institute
- Federal Communications Commission, Title 47 US CFR -- Part 2, Frequency Allocations and Radio Treaty Matters, General Rules and Regulations; Title 47 US CFR -- Part 15 Radio Frequency Devices
- Federal Energy Management Program (FEMP) – US Executive Order 13221: “1 Watt Standby”
- GB 9254-98 / GB 17625.1-1998, (CISPR-22 Emissions / IEC61000-3-2:1995 Current Harmonics) -- State Administration of Import and Export Commodity -- China
- ICES-003 Digital Apparatus: Industry Canada, Spectrum Management, Interference Causing Equipment Standard
- IEC 60065 7th edition Amendment 1 - Audio, video and similar electronic apparatus - Safety requirements (and their equivalent adapted standards such as EN 60065, UL 60065, etc., in different countries of the world)
- IEC 60695 -11-10:1999 Fire hazard testing
- IEC 60896 - 22 - Ed. 1.0 -- Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements
- IEC 61051-1 Ed. 1.0 b:1991 - Varistors for use in electronic equipment
- IEC 62040-1-1 Uninterruptible power systems (UPS) Part 1-1: General and safety requirements for UPS used in operator access areas 1st edition and IEC 62040-1-2 1st edition (and their equivalent adapted standards such as EN 62040-1-1 or UL 1778, etc., in different countries of the world)
- ISO/DIS 10302 Method for the measurement of Airborne Noise Emitted by Small Air-Moving Devices
- ISO 3744, Determination of Sound Power Level of Noise Sources Using Sound Pressure
- ISO 7779: Measurement of Airborne Noise Emitted by Information Technology and Telecommunications Equipment (Equivalent to ANSI S12.10)
- ISO 9296, International Noise Emission Declaration Standard for Information Technology Equipment
- ISO 11469:2000 - Plastics -- Generic identification and marking of plastics products
- ISO 14001 Environmental Management Systems -- Requirements with Guidance for Use
- ISO 14004 Environmental Management Systems -- General Guidelines on Principles, Systems and Support Techniques
- ISO 9000:2000 Quality Management Systems - Fundamentals and Vocabulary
- ISO 9001:2000 Quality management systems - Requirements
- ISO 9004:2000 Quality Management Systems Guidelines for Performance Improvements
- Korean Bureau of Standards (CISPR-22 Emissions), Immunity Jan. 1, 2000
- NOM-019-SCFI Safety requirements for Information Technology Electronical Devices (Mexico)
- RoHS and WEEE Directives: Restricted materials **shall** meet the applicable standards for restricted materials but **shall** not be limited to only these Directives.

Telcordia SR332 Reliability Prediction Procedure for Electronic Equipment

Voluntary Control Council for Interference by Information Technology Equipment -- V-1 through V-7 (CISPR-22 Emissions @ 100VAC) – Japan

Appendix A Derating Guidelines

The intent of this appendix is to provide a standard derating factor for worst-case conditions to be applied to each class of component. As part of the design process, a bill-of-materials analysis should be performed to ensure that **every component** of the design conforms to this standard. Any deviations from this standard should be documented, along with an analysis of the risk of the deviation. Any derating curves provided in product data-sheets themselves should always be followed or improved upon. The *Stress Factor* term is defined in note 1 below each table. For voltage, current, and power derating, this factor is used, with the design goal to be at or below this factor. For temperature derating, the suggested temperature is lower than the rated temperature by the value listed in the “Temp below Max Limit” row. Notes on specific component application issues appear below each table.

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Capacitors			
Fixed Ceramic – MLCC <i>Note: A surface mount part larger than a 1210 body size is not recommended due to potential for cracking</i>	DC Voltage	≤ 80%	≤ 80%
	Temp below Max Limit	≥ 10°C	≥ 10°C
Fixed Solid Tantalum <i>NOTE – series resistance may be needed to assure that when the capacitor short circuits there will be no more than 6 amps of current through the cap. Investigate the use of tantalum polymer caps instead.</i>	DC Voltage	≤ 40%	≤ 60%
	Ripple Current	≤ 60%	N/A
	Reverse Voltage - Peak	≤ 2%	≤ 2%
	Temp below Max Limit	≥ 20°C	≥ 20°C
Fixed Plastic	DC/AC Voltage Nominal	≤ 70%	≤ 70%
	Temp below Max Limit	≥ 10°C	≥ 10°C
	Power Supply X-Y cap Voltage	Note 2	Note 2
Fixed Aluminum Electrolytic	DC Voltage	≤ 80%	≤ 85%
	Ripple Current	≤ 70%	N/A
	Temp below Max Limit	≥ 10°C	N/A
	Life/Endurance (using life cap equations)	≥ 10 years at 25 C Full Load	≥ 5 years at 25 C Full Load
Fixed Conductive Polymer Tantalum or Aluminum	DC Voltage	≤ 70%	≤ 85%
	Ripple Current	≤ 80%	N/A
	Temp below Max Limit	≥ 10°C	N/A
	Life/Endurance (using life cap equations)	≥ 10 years at 25 C Full Load	≥ 5 years at 25 C Full Load

5 Year Stress

Device Type	Parameter	10 Year Stress Factor¹	Factor¹
Fixed Organic Semi-conductive Electrolyte Type	DC Voltage	$\leq 80\%$	$\leq 85\%$
	Ripple Current	$\leq 80\%$	N/A
	Temp below Max Limit	$\geq 20^{\circ}\text{C}$	N/A
	Life/Endurance (using life cap equations)	≥ 10 years at 25 C Full Load	≥ 5 years at 25 C Full Load
Fixed Mica, Glass Not recommended - Fragile	DC Voltage	$\leq 70\%$	$\leq 70\%$
	Temp below Max Limit	$\geq 10^{\circ}\text{C}$	$\geq 10^{\circ}\text{C}$
Variable Capacitors Not recommended - Unreliable	N/A	N/A	N/A

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.
2. Components with Certified Safety Agency approvals may be used up to 100% of their approved ratings.

Capacitor Design Guidelines

- Electrolytic capacitors fail due to excess voltage, reverse voltage, ripple current, operating temperature, and the evaporation of electrolyte.
- The breakdown voltage of an electrolytic is not at an abrupt voltage, but rather it is related to the thickness of a chemically generated oxide on the electrodes. If the working voltage slowly increases, the oxide thickness, and therefore the voltage capability of the capacitor, increases. Similarly the reverse is true if the working voltage reduces. The DC voltage + low frequency AC ripple should not exceed the rated DC voltage.
- Aluminum electrolytic types are used for bulk low frequency filtering.
- Care must be taken when placing capacitors, especially electrolytic, in the vicinity of high temperature components.
- Capacitors that operate at high humidity should be hermetically sealed.
- Capacitors must have a temperature rating of at least 105°C and should have 5,000 hour load life ratings when possible.
- Solid tantalum capacitors have been observed to fail short if they are not slowly charged to a voltage greater than the circuit requirements after the solder reflow. Heavy derating on the voltage might reduce the failure rates, but see next item.
- Solid tantalum capacitors, when they fail as a short, can ignite and burn due to use of MnO₂, the material used in pyrotechnic mixtures, causing serious damage to printed wiring boards and nearby components. Solid tantalum capacitors should never be used in high current or high power applications. Use polymer tantalum or polymer aluminum capacitors instead.
- Solid tantalum capacitors have been identified to have potential for influencing Electromagnetic characteristics of system. Change in component type should be reviewed for EMC impact.
- Polymer capacitors like OsCon, Poscap, Ta polymers and Al polymers are observed to have fewer failures in the field than solid tantalum and electrolytics.
- Larger size SMD ceramic capacitors can develop cracks during assembly process. Certain series of ceramic capacitors from some manufacturers contain a safety margin in their internal plate construction. Capacitor designs with a safety-designed part do develop cracks but these cracks do not lead to shorting.
- All SMD ceramic capacitors used in high energy applications should be of Fail-Open type.

- Z5U type is not recommended due to higher temperature coefficient, lower temperature range and weak structure.
- SMD ceramic capacitors should not be located on the PWB in areas that are subject to board flexing such along the edge of a board or in a location where mating of connectors, mating of test fixtures, or transportation induced vibration causes board flexing.
- SMD ceramic capacitors of sizes larger than 1206 should not be used in circuits with output voltages greater than 24 Volts, and packages larger than 1812 should never be used due to danger of cracking.
- Solid Niobium capacitors have unstable leakage characteristics and are flammable like solid Tantalum capacitors, and several manufacturers have recently discontinued production of these devices. Solid Niobium capacitors should not be used in power conversion devices where high current or high energy is applied to the capacitor.
- Niobium Oxide capacitors have better stability and require far more energy to cause ignition than solid Tantalum or solid Niobium devices. However, their long-term reliability is unknown at this time since the technology is emerging. They should be used with caution, only in low energy circuits.

Appendix A (continued)
Derating Guidelines

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Resistors			
Fixed Film (Discrete and SMD Thin-Film, Thick-Film and Metal Oxide)	Power Dissipation	≤60%	≤ 70%
	Max Working Voltage	≤ 70%	≤ 70%
	Below Max Temp. Limit	≥ 25°C	≥ 25°C
	SMD Max Body Temperature	100°C	N/A
Zero Ohm	Current	≤ 85%	≤ 85%
Carbon Composition	Power Dissipation	≤60%	≤ 70%
	Max Working Voltage	≤ 60%	N/A
	Below Max Temp. Limit	≥ 25°C	≥ 25°C
Wirewound Power	Power Dissipation	≤70%	≤ 70%
	Max Working Voltage	≤ 60%	N/A
	Below Max Temp. Limit	≥ 6°C below	≥ 6°C
Variable	Power Dissipation	≤40%	≤ 70%
	Max Working Voltage	≤ 50%	≤ 50%
	Wire-Wound Below Max Temp. Limit	≥ 20°C below	≥ 20°C
	Non-wirewound Below Max Temp. Limit	≥ 30°C below	≥ 30°C
Thermistor	Power Dissipation	≤ 50%	≤ 50%
	Max Working Voltage	≤ 80%	N/A
	Below Max Temp. Limit	≥ 50°C	≥ 50°C
Metal Oxide Varistors	Hot Spot Temperature	≤ 130°C	N/A
	Power Dissipation	≤ 60%	≤ 60%
	Operating Voltage/Clamping Volt	30%	30%
	Max Current	≤ 90%	≤ 90%
	Max Energy for All Timings	≤ 90%	≤ 90%
Thick Film Network	Power Dissipation	≤ 70%	≤ 70%
	Below Max Temp. Limit	≥ 24°C	≥ 24°C
	SMD Max Body Temperature	≤ 100°C	N/A

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.

Resistor Design Guidelines

- Failures in resistors are caused by excessive power dissipation, high ambient temperature, or excessive joules in pulsed in applications.
- All film resistors and to a lesser extent other types of resistor have a limited capability to handle high peak power pulses even though the average power dissipation may be within rating. Refer to the manufactures data sheet for peak powers versus time and duty cycle. If high pulse powers are expected, a solid element composition, ceramic-carbon or wire wound resistor may be more appropriate.
- Leaded film resistors are trimmed to their final value by cutting a spiral in the film. High value resistors used in high voltage applications are subject to a number of reliability issues: spiral turns count is high leading to a very narrow element width and hot-spot problems – cut is very narrow leading to high voltage field levels and ionization between turns.
- Chip film resistors are trimmed by making a cut or series of cuts across the resistor. Excessive trimming will lead to narrow sections that will develop into hot spots.
- Metal film resistors are recommended over carbon types.
- Wire wound resistors are recommended for dissipation greater than 2 Watts.
- Potentiometers are to be avoided, if possible, due to the need for adjustability in manufacturing and low reliability. Where two terminals of the potentiometer are normally connected for potentiometer operation, the variation effect could be made small and may not affect reliability. Device ratings are to be met for low or zero resistance adjustment.
- Considerations should be given to low inductance resistor types whenever necessary.
- Follow the guidelines for resistor mounting (to be away from PWB).
- The maximum stress on any resistor due to line transients, safety testing etc. should not exceed the manufacturer's 'Maximum Overload Voltage' or equivalent specification.
- Thermistors used for surge limiting have a specific capability to absorb a single power pulse when charging large bulk capacitors particularly in off line power supplies. The rating may be in the form of maximum capacitance.
- Varistors are used for shunt regulators and for transient protection:
 - Shunt regulator: working voltage is limited by power dissipation.
 - Transient protection: working voltage is limited by power dissipation over the normal voltage range and by Energy or Amps-Seconds for transients.

Appendix A (continued) Derating Guidelines

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Diodes			
General Purpose (Signal or Switching – Junction, PiN, Schottky)	Forward Current	≤ 80%	≤ 90%
	Reverse Voltage	≤ 70%	≤ 70%
	Power	≤ 75%	N/A
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
Power Rectifier (Schottky & Non-Schottky)	Avg. Forward Current	≤ 90%	≤ 90%
	Reverse Voltage	≤ 80%	≤ 80%
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
Silicon Carbide Power Rectifier	Power	≤ 70%	N/A
	Forward Current	≤ 60%	≤ 60%
Do Not Avalanche SiC Diodes	Reverse Voltage	≤ 50%	≤ 50%
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
Transient Voltage Suppressor	Power Dissipation	≤ 80%	≤ 90%
	Average Current	≤ 90%	≤ 90%
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
Voltage Regulator / Reference (including Zener)	Power Dissipation	≤ 50%	N/A
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
	Transient Energy	≤ 80%	N/A
Thyristor, SCR, and Triac	On-State Current (I _t)	≤ 90%	≤ 90%
	Off-State Voltage (V _r)	≤ 70%	≤ 70%
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
Microwave	Power	≤ 90%	≤ 90%
	Reverse Voltage	≤ 70%	≤ 70%
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$
LED GaAs GaP GaN-SiC GaAsP AlGaAs	Power	≤ 70%	N/A
	Forward Current	≤ 75%	≤ 90%
	Reverse Voltage Peak	≤ 80%	N/A
	Maximum T _j	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.

Appendix A (continued)

Derating Guidelines

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Diodes			
Photo Diode	Power Dissipation	80%	80%
	Current	75%	75%
	Voltage	75%	75%
	Maximum Tj	$0.75(T_{jmax} - 25C) + 20C$	$0.75(T_{jmax} - 25C) + 20C$
Injection Laser Diode	Power Output	75%	75%
	Maximum Tj	$0.75(T_{jmax} - 25C) + 20C$	$0.75(T_{jmax} - 25C) + 20C$
Transistors			
Silicon Bipolar – Small Signal or Power	Power	75%	N/A
	Collector-Emitter Voltage	80%	80%
	Emitter-Base Voltage	80%	80%
	Collector Current	60%	60%
	Maximum Junction Temperature (Tj)	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25C) + 20C$
Silicon FET – Small Signal	Drain – Source Breakdown Voltage	80%	80%
	Gate – Source Voltage	80%	80%
	Drain Current	80%	80%
	Maximum Junction Temperature (Tj)	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25C) + 20C$
	ESD Rating	>1000V	>1000V
	Power P_D	≤ 75%	N/A
	Drain Current / Collector Current	≤ 75%	≤ 75% / ≤ 60%
Power MOSFET and IGBT	Drain – Source / Emitter-Base Voltage	≤ 80% peak Volts ³	≤ 80% / ≤ 80%
	Gate – Source / Emitter Voltage	≤ 80% peak Volts ³	≤ 80% / ≤ 80%
	Maximum Junction Temperature (Tj)	$0.75(T_{jmax} - 25^{\circ}C) + 20^{\circ}C$	$0.75(T_{jmax} - 25C) + 20C$
	Avalanche Energy E_{AS}	≤ 50%	≤ 50%
	Power Dissipation	80%	80%
Photo Transistor	Current	75%	75%
	Voltage	75%	75%
	Maximum Tj	$0.75(T_{jmax} - 25C) + 20C$	$0.75(T_{jmax} - 25C) + 20C$

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.

3. ESD sensitive – also transient voltage spikes can damage part.

Diode Design Guidelines

- In bridge rectifiers, typical failures are due to excessive surge current and reverse voltage conditions. In universal power supplies, a minimum of 600 Volts Peak-Inverse-Voltage is recommended for the diodes.
- Switching losses and conduction losses contribute to the total power dissipation for diodes in switching circuits. When determining the rating, the PIV of the diodes at high temperatures of operation should be taken into account.
- Extreme precaution needs to be taken for assembly of diodes into a heat sink. Insulation and torque of the screws need to be properly specified to avoid any failures of the diodes.
- If diodes are in series, then, to share the break down voltage, a resistor and a capacitor **shall** be used in parallel to each diode. The maximum junction temperature for this particular case should be reduced to 100°C.
- The power dissipation in a Schottky rectifier will come from RMS current losses + average current losses + leakage current losses. There are significant components of each.
- Excessive power dissipation is the primary reason for failure of the zener diodes.
- A series resistor should be used to limit the current (power dissipation) through the zener.
- A capacitor across the zener stabilizes the zener voltage and reduces high frequency noise.
- Zeners that have a voltage rating close to 5 V have the lowest temperature coefficient for the voltage.
- Biasing the zeners at the manufacturer's test level of current provides an accurate value for the zener voltage in circuit.

Transistor Design Guidelines

- The main causes of failure in transistors are elevated junction temperatures and voltages exceeding the rated breakdown voltage of the device. The measured voltage must include all transient conditions (dynamic loading or starting conditions).
- Usage of TO220 devices is to be avoided whenever possible. If it is found necessary to use TO220 devices the leads must have insulating sleeves and an insulation coating should be applied at the intersection of the leads and the body of the device.
- For transistors, the supplier must allow for the degradation of parameters over time:
 - Gain ($\pm 50\%$)
 - Leakage Current – I_{CBO} or I_{CEO} (+100%)
 - Switching times ($\pm 20\%$)
 - Saturation Voltage ($\pm 20\%$).
- The supplier should use base to emitter resistors to reduce false turn on due to leakage.
- Extreme precaution need to be taken for assembly of semiconductors into a heat sink. Insulation and torquing for the screws need to be properly specified to avoid any failures of the semiconductors.
- Static electricity can damage or destroy a MOSFET, especially gate to source voltages. Handling and design should minimize the possibility of ESD events on the gate.
- To prevent oscillations, the supplier should use gate resistors when FETS are paralleled. The resistor provides damping to dampen the ringing due to parasitic inductance and gate capacitances.
- MOSFET device should Not be avalanched on any regular basis, and possibility of avalanching should be minimized even during worst-case (such as start-up or shut-down) or fault conditions.
- Be wary of power ratings – they are usually specified at a **case temperature** of 25°C. Apply the appropriate derating curve for higher case/ambient temperatures (provided by supplier).
- Use GaAs FETs for high temperature and for very high frequency (microwave) applications.

**Appendix A (continued)
Derating Guidelines**

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Transformers			
FET GaAs	Power Dissipation	90%	90%
	Maximum Channel Temperature	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$
Hetro Junction Bipolar GaAs	Power Dissipation	90%	90%
	Maximum Channel Temperature	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$
High Mobility GaAs	Power Dissipation	90%	90%
	Maximum Channel Temperature	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$	$0.75(T_{jmax} - 25^{\circ}C) + 30^{\circ}C$
Magnetics			
Pulse – Transformers	Peak Voltage	90%	90%
	Current	60%	90%
	Max Hot Spot Temp (Below Insulation Rating)²	25°C	25°C
	Power Per Winding	80%	N/A
Power – Transformers	Max Hot Spot Temp (Below Insulation Rating)²	25°C	25°C
	Temp below specified Fuse temperature	15°C	15°C
	Surge Voltage	90%	90%
	Surge Current	90%	90%
	Continuous Current	80%	80%
	Power	80%	80%
Coil (RF)	Current DC	90%	90%
	Voltage Surge	90%	90%
	Max Hot Spot Temp (Below Insulation Rating)²	25°C	25°C
	Max Hot Spot Temp (Below Insulation Rating)²	25°C	25°C
	Flux Density of Operation	<2500 Gauss for Ferrites	N/A
Ferrite Material Core (Incl: DC Chokes)			
NOTE: Previously, powdered iron cores were also utilized. However, powdered iron cores are now recognized as fire hazards and are not recommended for use.			

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.
 2. Insulation Ratings: Class A – 110°C Class B – 130°C Class F – 160°C Class H – 175°C.

Transformer and Inductor Design Guidelines

- In general, for linear operation, the flux density of operation should be far below the saturation flux density of the device core.
- Exceeding the rated hot spot temperature of the insulation will reduce the life of a device.
- Structural parts of a magnetics assembly should not be operated at temperatures above the temperature rating of the materials used.

Transformers

- Power transformer operation at low frequencies may result in overheating, due to lower reactance allowing large currents.
- Some power transformers generate large magnetic fields, which can couple AC signals into nearby circuits. Use appropriately shielded transformers, separate shielding and adequate spacing where needed.
- Transformers have been identified to have potential for influencing Electromagnetic characteristics of system. Change in component type should be reviewed for EMC impact.

Inductors

- Determine that power inductor core binder material does not contain stearic acid, octadecanoic acid, hexadecanoic acid or other long-chain acids that may break down over time. Use of such materials with internal spot temperatures over 130°C can lead to rapid failure after a short-to-moderate time of apparently normal operation.
- Be careful that DC current does not saturate the magnetic core, which will drastically change inductor characteristics.
- SMT inductors and filters are susceptible to damage by soldering heat. Keep temperature ramp less than 4 °C/second by gradual preheating, to avoid cracking of the internal layers.
- SMD or through-hole components with large numbers of ferrite layers are most susceptible to thermal shock and impact stresses.
- Open circuits can occur due to mechanical damage to component body or body-termination bond from vibration, shock or overload during service life; and from flexure, vibration or shock during assembly.
- Through-hole inductors may fail due to weakening of internal low temperature solder connections by assembly soldering heat. Welded internal connections avoid this risk.
- Provide conductive heat transfer paths and locate inductors for best cooling.
- Make sure that circuits driving inductive loads are characterized for their Safe Operating Area or employ appropriate transient suppression.
- Inductors have been identified to have potential for influencing Electromagnetic characteristics of system. Change in component type should be reviewed for EMC impact.

Appendix A (continued) Derating Guidelines

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Microcircuits			
Silicon Digital (MOS & Bipolar)	Output Current	80%	N/A
	Frequency	90%	N/A
	Maximum Junction Temperature	100°C (20 years EOL) 115°C (5 years EOL) 115°C (But No Higher than Manufacturer's Tj Max)	115°C
	Input Voltage	85%	N/A
Silicon Linear ICs (Bipolar)	Output Voltage ²	80%	80%
	Output Current	80%	90%
	Maximum Junction Temperature	100°C (20 years EOL) 115°C (5 years EOL) 115°C (But No Higher than Manufacturer's Tj Max)	115°C
	Input Voltage	70%	N/A
Silicon Linear ICs (JFET & MOS)	Output Voltage ²	80%	80%
	Output Current	90%	90%
	Maximum Junction Temperature	100°C (20 years EOL) 115°C (5 years EOL) 115°C (But No Higher than Manufacturer's Tj Max)	115°C
	Input Voltage	70%	N/A
Hybrid Microcircuits			
Thick Film Res	Power Dissipation	70%	70%
Thin Film Res	Power Dissipation	70%	70%
Chip Resistor	Power Dissipation	70%	70%
Chip Capacitor	Voltage	70%	70%
Gen Purp Diode	Forward Current	90%	90%
	Reverse Voltage	80%	80%
Microwave Diode	Power Dissipation	90%	90%
	Reverse Voltage	80%	80%
Bipolar Trans	Power Dissipation	90%	90%
	Voltage (Vce)	80%	80%
FET	Power Dissipation	90%	90%
	Breakdown Voltage	90%	90%
Hybrid Package	Maximum Tj	$0.75(T_{jmax} - 25C) + 20C$	$0.75(T_{jmax} - 25C) + 20C$

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.

2. Output voltage derating does Not apply to fixed voltage regulator ICs.

Monolithic and Hybrid Microcircuit Design Guideline

- Continuous Power needs to be Derated such that any Tolerance or errors in design, other components, or operating conditions never bring the actual Power above the max recommended operating power given by the device specifications or Datasheet.
- Maximum Core Voltage needs to be Derated such that any Tolerance or errors in design, other components, or operating conditions never bring the actual Core Voltage above the max recommended operating Core Voltage.
- Minimum Core Voltage needs to be Derated such that any Tolerance or errors in design, other components, or operating conditions never bring the actual Core Voltage below the min recommended operating Core Voltage.
- Maximum IO Voltage needs to be Derated such that any Tolerance or errors in design, other components, or operating conditions never bring the actual IO Voltage above the max recommended operating IO Voltage.
- Minimum IO Voltage needs to be Derated such that any Tolerance or errors in design, other components, or operating conditions never bring the actual IO Voltage below the min recommended operating IO Voltage.
- Maximum Operating Frequency needs to be Derated to below the specified Max Operating Frequency to allow for device performance degradation over time due to Hot Carrier Injection (HCI) and Negative Bias Transistor Instability (NBTI) effects. HCI and NBTI effects degrade MPU performance by causing Core transistor V_T to drift upwards with the passage of time; (absolute value of V_T for PMOS transistors). This especially affects processors and DRAMs.
- Be aware of Minimum operating frequency problems. Do not operate dynamic circuits below the minimum specified clock frequency; or they will “forget” data, particularly at high temperatures!
- The turn-on sequence (of input signals, output loads, clocks and power conversion device voltages) is often crucial. The wrong turn-on sequence (such as input voltages higher than or present before supply voltages) can result in latch-up, with permanent damage to the IC. Input clamping diodes to supply and ground may be necessary at interfaces between separately powered circuits.
- *Follow IC manufacturer’s recommendations for terminating unused inputs; in general, they should NOT be left floating.* To minimize component count, several inputs may be terminated by the same resistor(s).
- Linear ICs, both bipolar and MOS, are generally very susceptible to ESD damage. *Sub-catastrophic ESD* damage can increase noise and shift DC operating parameters, and lead to erratic operation and functional failure over time.
- The slew rate of a linear circuit may be limited by available current so that full scale output is not possible over its full bandwidth. For example, an amplifier may have a small signal bandwidth of 1 MHz and be capable of an output of 20 volts peak to peak, but to do both at once without distortion requires a slew rate capability of more than 63 volts/ μ sec.
- Linear ICs usually have parasitic thermal feedback. For example, the zero offset of the input stage of an operational amplifier or comparator will change as the output changes amplitude or polarity, because temperature changes of the output stage affect the input state on the same die. Thermally induced offset shifts, of 50 μ V to 1 mV (referred to input) are common, unless the IC layout has been designed to minimize this effect.

**Appendix A (continued)
Derating Guidelines**

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Miscellaneous			
Circuit Breakers	Current	≤ 60%	≤ 80%
	Voltage	≤ 60%	N/A
Fuses (Metal Element)	Current (Normal Blow)	≤ 80%	≤ 80%
	Current (Time Delay – Slow Blow)	≤ 85%	≤ 85%
	Operating Control/I_{Holding}		N/A
	I²t Rating	≤ 70%	≤ 70%
Fuses (Resettable Poly-Element Fuses) Note these Degrade over Time	Operating Current/I_{Holding}	≤ 50%	≤ 80%
	Fault Current of I_{Max}	≤ 50%	≤ 80%
	Voltage	≤ 70%	≤ 80%
Fans – See IPC 9591 Performance Parameters For Air Moving Devices	RPM Average	90% to 100% MAX	N/A
	Bearing Load	See Supplier Specs	See Supplier Specs
	Temperature Below Max Limit	≥ 25°C	N/A
Connectors (Circular / PWB / Coaxial)	Voltage	≤ 70%	≤ 70%
	Current	≤ 70%	≤ 70%
Connectors – Power	Insert Temp below Max Limit For Primary Voltages	≥ 25°C Note 2	≥ 25°C Note 2
	Min Dry Circuit Voltage	12V	12V
Connectors, Relays, & Switches with oxidizing contacts Relays	Min Dry Circuit Current	100mA	100mA
	Resistive Load Current	≤ 75%	≤ 75%
	Capacitive Load Current	≤ 75%	≤ 75%
	Inductive Load Current (Non-clamped)	≤ 40%	≤ 40%
	Inductive Load Current (Clamped)	≤ 75%	≤ 75%
	Motor Load Current	≤ 20%	≤ 20%
	Filament (Lamp) Current	≤ 10%	≤ 10%
	Contact Voltage (AC or DC)	≤ 50%	N/A
	Contact Power	≤ 50%	≤ 50%
	Drive Voltage Minimum/Rated Min V	≥ 110%	N/A
	Drive Voltage Max/Rated Max	100% Max	N/A
	Coil Dropout Voltage/Rated	≤ 90%	N/A
	Temp Below Max Limit	≥ 20°C	N/A

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.
2. Components with certified safety agent approvals may be used up to 100% of their approved ratings.

Circuit Breakers and Fuses

- Both **circuit breakers and fuses** used in primary (line-voltage) circuits need to meet appropriate regulatory (safety) standards – see your product regulations engineer before specifying parts.
- Action of both circuit breakers and fuses is temperature dependent – be sure to review manufacturer’s data sheet for effect of temperature.
- Circuit breakers come in many styles with varied trip mechanisms – use supplier specifications to determine appropriate types for your application, including current rating, voltage rating, breaking capacity, trip speed versus current level, and temperature sensitivity.
- Circuit breakers have been identified to have potential for influencing Electromagnetic characteristics of system. Change in component type should be reviewed for EMC impact.
- Never use a fuse to directly protect an electronic component (such as a fuse in series with the output of a power transistor). The electronic component can be destroyed much faster than a fuse can react.
- Keep in mind that a fuse or circuit breaker takes time to operate with over-current situations; the higher the over-current level, the faster the reaction time. There are specifications for each type of fuse and circuit breaker that describe the time to open under a given condition. Very high overloads can open a fuse in a fraction of a second, but your circuitry must not be damaged by these conditions or the fuse is offering no real protection.
- Fuses are NOT all rated and tested the same – be wary of differences from one manufacturer to another.
- SMT versions of fuses may have poorer heat dissipating capability than otherwise identical thru-hole or clip-mount versions and may require additional temperature derating. See manufacturer’s data sheet.
- Resettable Poly-Element Fuses do not provide fuse-like resistance when operating at normal currents – resistance may be less than 0.1 ohm for some devices, but may be as high as tens of ohms. Check device data sheet.
- Resettable Poly-Element Fuses do not provide an “open” circuit when tripped – their resistance increases a few orders of magnitude from their “on” state (a factor of 1,000 to 10,000 times typically).
- Avoid operating Resettable Poly-Element Fuses without current limiting in a fault case – currents over their maximum current ratings can cause arcing, burning, and destruction.
- Polymer Resettable Fuses do not provide stable “on” or “off” resistances with repeated use – take this into account in your circuit design. There are Ceramic Resettable Fuses that provide more stable “on” resistance with repeated operation and repeatable “off” resistance at constant ambient temperatures, but Ceramic Resettable Fuses cost more than Polymer Resettable Fuses.

Fans

- Modern DC **fans** are complex devices with both mechanical and electronic components. See *IPC-9591 Performance Parameters (Mechanical, Electrical, Environmental and Quality/Reliability) for Air Moving Devices* for comprehensive details on fan applications.
- Fans have been identified to have potential for influencing Electromagnetic characteristics of systems and acoustic levels that may impact use in many environments. Change in component type should be reviewed for impact.

Connectors

- **Connector** pins can be connected in parallel to increase the current capacity. Allow additional 10% derating for multiple pins in parallel. Airflow through the connector should help in lowering the hot spot temperature.
- High current pins can be positioned to be at the ends of connector rather than the middle for better heat transfer.
- Smaller width and multiple connectors may be preferred rather than one longer width connector for radiated emissions reduction.
- Temperature, moisture, excessive contact currents, and vibration may cause connector failures. Fretting corrosion can cause intermittent connections. Contacts can also be welded because of surge currents in the circuit.

**Appendix A (continued)
Derating Guidelines**

Device Type	Parameter	10 Year Stress Factor ¹	5 Year Stress Factor ¹
Miscellaneous			
Switches (General Purpose)	Contact Current – Resistive Load	≤ 75%	≤ 90%
	Contact Current – Capacitive Load	≤ 75%	≤ 90%
	Contact Current – Inductive Load	≤ 40%	≤ 75%
	Inductive Load Current (Clamped)	≤ 75%	≤ 75%
	Contact Current – Motor Load	≤ 20%	≤ 30%
	Contact Current – Filament (Lamp) Load	≤ 10%	≤ 20%
	Contact Power	≤ 50%	≤ 70%
	Contact Voltage (AC or DC)	≤ 50%	N/A
	Contact Surge Current	≤ 80%	≤ 80%
	Temperature below Max Limit	≥ 20°C	≥ 20°C
	Crystals	Current	≤ 70%
Drive Level Power		33%	Follow Spec Manufacturer's
Oscillators	Voltage	Follow Spec Manufacturer's	Follow Spec Manufacturer's
	Temperature below Max Limit	≥ 30°C	Follow Spec Manufacturer's
Opto-Isolators	Peak Voltage	≤ 75%	≤ 75%
	Current	≤ 70%	≤ 70%
	Power	≤ 80%	≤ 80%
	Junction Temperature	0.75(Tjmax – 25°C) + 20°C	0.75(Tjmax – 25°C) + 20°C
	CTR	≤ 75%	≤ 75%
	Isolation Voltage	≤ 80%	≤ 80%
	Fiber Cable	Bend Radius (% min. Rating)	≥ 200%
	Cable Tension (% Rated Strength)	≤ 50%	≤ 50%
	Fiber Tension (% Proof Test)	≤ 20%	≤ 20%
Coax Cable	Bend Radius (% min. Rating)	≥ 110%	≥ 110%
Lamp – Incandescent	Voltage	≤ 94%	≤ 94%
	Temperature	≤ 175°C	≤ 175°C
Lamp – Neon	Current	≤ 98%	≤ 98%
	Temperature	≤ 150°C	≤ 150°C
Printed Wiring (Circuit) Board	Temperature (Trace or Component Lead)	≤ 100°C	N/A
	Absolute Maximum Temperature	10°C less than UL rating specification of the laminate materials	UL rating specification of the laminate materials
	Minimum Creepage and Clearance	Safety Agency Mandated	Safety Agency Mandated

1. Stress Factor is the applied level divided by rating: a 12 volt rated part used at 9 volts has a 75% stress factor.

Miscellaneous Design Guidelines

Relays

- The usage of a diode across the **relay** coil to clamp the turn-off voltage is recommended to avoid damaging transistors driving the coil from inductive voltage spikes.
- Paralleling the relays and contacts for increasing the current capacity of contacts is not recommended because one may close or open before the other.
- The number of cycles of operation should not exceed the rated number.
- Vibration testing needs to be done to ensure reliable operation. For environments with vibration or temperature cycling, contacts must be prevented from microscopically moving. Displacements on the order of 100 μm will cause fretting which can lead to corrosion and failure.
- Test processes for testing of relay functionality **shall** consider the design requirements for the relay. As an example, certain relays can be damaged if they are opened when current is passing through the relay.

Switches

- Extreme care should be taken to look into specifications to differentiate AC and DC inputs. A switch that is rated for AC applications may not be suited for DC inputs and must be evaluated accordingly. The derating **shall** be applied to the appropriate rated AC input or the DC input rating.
- High surge currents can weld the contacts of a switch.
- Use of Agency ratings is acceptable.
- For environments with vibration or temperature cycling, contacts must be prevented from microscopically moving. Displacements on the order of 100 μm will cause fretting which can lead to corrosion and failure.

Crystals and Oscillators

- Use crystals and oscillators “ruggedized” for shock and vibration. This will help both in handling bare parts during assembly and in long term reliability by protecting against shock and vibration during shipping, installation and operation.
- Be careful with crystal and oscillator packages, especially in SMT designs. They are brittle and can be cracked by excessive board flexing.
- Take ESD precautions when handling and assembling boards with crystals and oscillators.

Opto-Isolators

- Opto isolators are used for providing isolation between primary and secondary circuits either in the feedback loop area or for passing status information across the isolation boundary.
- Failures can occur due to excessive voltage ratings or junction temperatures.
- The CTR (Current Transfer Ratio) can vary wildly (6 to 1) and the design should take this into account to meet the stability (Higher CTR) and the transient response requirements (Lower CTR).
- The diode current can be specified at the lowest possible level but still should be close to one of the specified operating points.
- If the base is connection available, use a resistor across the base to emitter of the output transistor to reduce the noise pick-up.
- Use a resistor in series with LED to limit the current through the diode. Proper circuit layout should be considered to reduce stray capacitance coupling. Keep the opto-isolator away from magnetic components.

Appendix B

Typical Comprehensive Data Sheets

The datasheet **shall** be dated and have revision level marked at the bottom of the sheets. An example of minimum data sheet information is shown below. Values in examples are realistic but hypothetical. The first example is for an AC-to-DC power supply with multiple DC outputs:

Input Specifications

Input voltage	85- 265 VAC;
Frequency	47- 440 Hz
Inrush current	25 A peak max.
Efficiency	75% min. @ full load
Power factor	0.99 typ. meets EN61000-3-2
Turn-on time	AC on 1.0 sec typ., 1.8 sec max. Inhibit / Enable 150 ms typ., 200 ms max.
EMI filter standard	CISPR 22 EN55022 Level “B”
Harmonic distortion	Meets IEC 61000-3-2
Isolation	Meets IEC 60950
Leakage current	2.0 mA max. @ 240 VAC
Radiated EMI	CISPR 22 EN55022 Level “B”
Holdover storage	20 ms minimum (independent of input VAC)
AC OK	>5 ms early warning before outputs lose regulation. Full cycle ride thru (50 Hz)
Global Inhibit/Enable	TTL, Logic “1” and Logic “0”
Input fuse (internal)	20A
Warranty	3 years

Output Specifications

Number of Outputs	Three
Nominal Output Voltages	+5 VDC, -15 VDC, +15 VDC
Adjustment range	±5% min. all outputs
Margining	±2-3% nominal
Overall regulation	0.25% or 15 mV max.
Ripple	RMS: 0.1% or 10 mV, whichever is greater – bandwidth limited to 20 MHz Pk-Pk: 1.0% or 50mV, whichever is greater – bandwidth limited to 20 MHz
Dynamic response	<2% or 100 mV, with 25% load step.
Recovery time	To within 1% in <200 μsec.
Overcurrent protection	105-120% of rated output current
Short circuit protection	Protected for continuous short circuit, automatic recovery
Overvoltage protection	Separate, each output
Reverse voltage protection	100% of rated output current
Thermal protection	All outputs disabled when internal temp exceeds safe operating range
Remote sense	Up to 0.5 V total drop
Single wire parallel	Current share to within 2% of total rated current
DC OK	-2% to -8% of nominal for any monitored output
Minimum load	Not required
Module inhibit	TTL, isolated
Switching frequency	250 kHz
Output/Output isolation	>1 Megohm

Environmental Specifications

Storage temperature	-40°C to +85° C
Operating temperature	-20°C to 50°C (start @ 0°C) (derate power of each output linearly starting at 50°C to 50% power at 70°C)
Thermal shock (non-operating)	-40 (+/-5) to +70 (+/-5) degrees Celsius, transition time not to exceed 5 minutes.
Storage vibration	2.2 Grms, 5-500Hz, 15 minutes per side
Operating vibration	0.5 Grms, 5-800Hz, 30 minutes per side
Non-operating shock	142 G +/- 5% with pulse duration of 2 msec +/- 10%
Operating shock	82 G +/- 5% with pulse duration of 2 msec +/- 10%
Humidity	95% non-condensing
Temperature coefficient	0.02% per °C
Cooling:	Internal DC fan

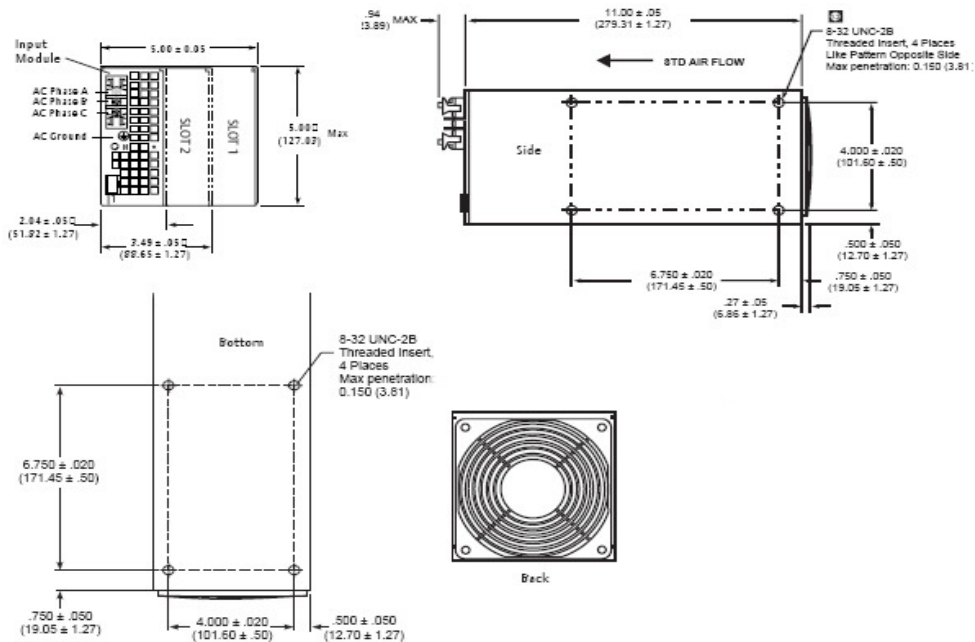
Reliability

MTBF	400,000 hours, 100% duty cycle at 40°C ambient, 45% RH +/- 10%, 90% total output load, any specified input voltage, sea level operation per Telecordia Technologies, SR-332
Operational Life	5 years, less than 10% failure in 5 years.

Safety & Regulatory

UL	UL1950
CSA	CSA22.2 No. 234 Level 5
IEC	IEC 60950-1 Class 1
VDE	IEC 60950-1
BABT	Compliance to IEC 60950-1, BS 7002
CB	Certificate and report
CE	Mark
EMI/EMC Characteristics	IEC 61000-4-5 level 2, EN 55022, class B
ESD	IEC 61000-4-2 level 4

Physical Dimensions and Electrical Connections



Weight: 5 kg / 11 pounds

(These drawings were originally published by Aztec/Emerson in their literature.)

The following example is for a DC-to-DC power converter with multiple DC outputs:

Input Specifications

Number of inputs	2
Input voltage range	10.8 - 13.2 VDC
Input reverse voltage protection	Fuse recommended
Input filter	Capacitor Low ESR
Efficiency	60-80% typical; 55% minimum

Output Specifications

Output 1 voltage	-12 VDC
Output 2 voltage	+12 VDC
Voltage tolerance, each output	±2.0%
Line regulation, each output	± 1.0%
Load regulation	±0.5%
Noise/ripple	1% mV P-P (20 MHz bandwidth). Note: An external 0.1µf ceramic Capacitor is recommended to be placed from +V out to -V out.
Short circuit protection	20 Second Duration
Transient response	200 µsec max (50% load change to within 1% VO Nom)
Switching frequency	25kHz typ
Temperature coefficient	± 0.025%/° C

Isolation

I/O isolation	>500 VDC
Isolation resistance	>1 x 10 ⁹ ohms

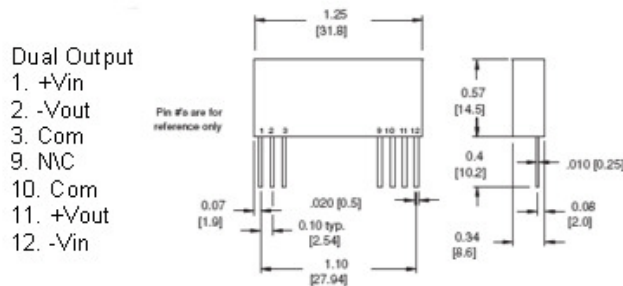
Environmental

Operating ambient temperature	-25°C to +85°C (full load)
Auto-shutdown temperature	95°C minimum
Storage temperature	-55°C to +105°C
Thermal shock (non-operating)	-40 (+/-5) to +85 (+/-5) degrees Celsius, transition time not to exceed 2.5 minutes.
Operating humidity	5% to 95% (non-condensing)
Cooling method	Convection
Storage vibration	2.5 Grms, 5-500Hz, 15 minutes per side
Operating vibration	0.75 Grms, 5-800Hz, 30 minutes per side
Non-operating shock	175 G +/- 5% with pulse duration of 2 msec +/- 10%
Operating shock	90 G +/- 5% with pulse duration of 2 msec +/- 10%
MTBF	>1,000,000 hours, 100% duty cycle at 30°C ambient, 45% RH +/- 10%, 100% total output load, any specified input voltage, sea level operation per Telecordia Technologies, SR-332

Agency Approvals

Safety	UL1604, IEC 60950-1 CE Marked Low Voltage Directive
EMI/EMC Characteristics	IEC 61000-4-5 level 2, British Telecom BTR 2511- Issue 2, EN 55022, class B
ESD	IEC 61000-4-2 level 4

Physical Dimensions and Electrical Connections



Weight: 12 grams / 0.45 oz.
Case Material: XXX plastic

(This drawing was originally published by Aztec/Emerson in their literature.)

Appendix C

Functional Test Specification

The power conversion device manufacturer **shall** conduct a functional test and make sure functional test results are compliant with the product specification. Any exception requires documented approval from the user. The general test items for power conversion device testing include, but are not limited to, the following items. Note: PCD refers to the device under test, the power conversion device (PCD).

The AC source mentioned in this section must be a programmable AC source to supply AC input to the PCD. E-load must be a programmable load. E-load serves as a DC load to the PCD.

- **Inrush Current Test**

This test is to verify that when AC input power is applied to the PCD, any current surge or spike of input current should not exceed the limit defined by the specifications. The inrush current due to EMI filter capacitors can be ignored.

Test Condition:

Perform the test with minimum and maximum V_{in}

Perform the test with maximum load (note: inrush is not normally dependant on load. PFC turn on current is load dependant to some extent.)

Test Setup:

Set AC source output to maximum V_{in} specified by the specification

Set E-loads to maximum load which is full load of PCD but not exceed total power supply watts.

Enable PS_ON

Enable AC source output at 90° or 270° phase angle

Enable E-load

Verify PCD AC input peak current within 300ms after AC source output enable meet spec

Disable AC source output, E-loads and PS_ON

Application Note:

Make sure the inrush current is not limited by capacity/setting of AC source

Put in rush current test as the first test in test sequence to get cold in rush value.

In case of the PCD failed test and a re-test required, production must make sure the capacitors of the PCD are fully discharged and relative components return to room temperature in order that the measurement value is cold in rush current

- **Over Shoot at Turn-On**

This test is to verify the voltage over shoot of each DC output meets the specification

Test Condition:

Perform the test for normal V_{in} with specified frequency

Perform the test with minimum and maximum load

Test Setup:

Set AC source output with specified V_{in} voltage

Set E-load of each output rail according the specification

Enable PS_ON

Verify all DC outputs do not exceed overshoot spec.

Enable AC source output and E-loads

Verify Over Shoot of each output rail meet the specification

Repeat test with all conditions

Disable AC source output, E-loads and PS_ON

- **Turn-on / Turn-off Voltage Test**

This test is to verify the hysteresis of Turn-on and Turn-off voltage

Test Condition:

Perform the test with maximum load

Use AC cord of < 1 meter and 14GA wire.

Test Setup:

Set AC source output to a voltage that is 1VAC below the lower spec of Turn-on with specified frequency

Set E-loads to maximum which is full load of PCD but not exceeding total power supply watts

Enable PS_ON

Enable AC source output and E-load

Verify the PCD NOT turn-on by monitoring all DC output and P-OK signal

Set AC source output to the upper limit of Turn-on

Verify the PCD turn-on by monitoring all DC output and P-OK signal

Set AC source output to a voltage that 1Vac above the upper limit of Turn-off with specified frequency

Verify PCD NOT turn-off by monitoring all DC output and P-OK signal

Set AC source output to the lower limit of Turn-off

Verify the PCD Turn-off by monitoring all DC output and P-OK signal

Disable AC source output, E-loads and PS_ON

- **Efficiency**

This test is to verify PCD meets or exceeds the minimum efficiency and power dissipation meets or does not exceed maximum dissipation per the specification. Normally low line input is considered as worst case of efficiency and full load is the worst case of power dissipation except claimed by design.

Test Condition:

Perform the test with minimum Vin

Perform the test with maximum Load

Test Setup:

Set AC source output to minimal Vin specified by the specification

Set E-loads to maximum which is full load of PCD but not exceed total power supply watts.

Enable PS_ON

Enable AC source output and E-load

Measure PCD Pout by power meter or equivalent after P-OK signal valid

Measure PCD Pin by power meter or AC source

Calculate Pout/Pin as efficiency, Pin-Pout as maximum power dissipation and verify they meet the specification

Disable AC source output, E-loads and PS_ON

- **Standby Input Power and 1W Maximum Power Requirement**

This test is to verify the PCD stand by power dissipation does not exceed the specification

Test Setup:

Set AC source output to specified Vin

Set E-load to specified load

Disable PS_ON

Enable AC source output and E-load

Verify PCD AC input power does not exceed spec

Disable AC source output, E-loads and PS_ON

Application note:

Power meter is preferred to conduct this test when AC source does not have sufficient precision

- **Auto Restart**

When AC drop off time is longer than hold up time, power supply is capable of restarting after the input line disturbance.

Test Condition:

Perform the test with minimum V_{in} and maximum V_{in}

Perform the test with maximum load

Test setup:

Set AC source output with specified V_{in} voltage

Set AC source line disturbance to -100%, time interval to specified value

Set E-load to specified load

Enable PS_ON

Enable AC source output and E-load

Verify PCD turn off during input disturbance and turn on after AC input resumes by monitor all DC output and POK

Repeat test with all test conditions

Disable AC source output, E-loads and PS_ON

Application Note:

When AC input disturbance time is not defined by the specification, factory needs to conduct experiment to pick up the minimum value that can get PCD turn-off from the following time intervals: 25ms, 40ms, 60ms, 90ms, 130ms, 1.3s, 2.0s.

- **AC Line Drop Off**

This test is to verify that when AC drop off time is shorter than hold up time, all DC output will keep in regulation.

Test Condition:

Perform the test with minimum V_{in} and maximum V_{in}

Perform the test with maximum load

Test setup:

Set AC source output with specified V_{in} voltage

Set AC source line disturbance to -100%, time interval to specified value

Set E-load to specified load

Enable PS_ON

Enable AC source output and E-load

Verify all DC output keep in regulation during AC disturbance

Repeat test with all test conditions

Disable AC source output, E-loads and PS_ON

- **PFC – Power Factor Correction Test (only for PCD having PFC)**

In case PCD has PFC circuitry, this test is to verify the PFC meets the specification.

Test Condition:

Perform the test for minimum and maximum V_{in} with specified frequency

Perform the test at 20%, 50% and 90% loads.

Test setup:

Set AC source output with specified V_{in} voltage

Set E-load to specified load

Enable PS_ON

Enable AC source output and E-loads

Verify the PCD PF meets specification by AC analyzer or equivalent

Repeat test with all conditions

Disable AC source output, E-loads and PS_ON

- **Regulation Test**

The power supply DC output must keep in regulation range at output connectors when load condition is within range covered by the specification.

Test Condition:

Perform the test for minimum and maximum V_{in} with specified frequency

Perform the test for all load conditions defined by the specification

Test setup:

Set AC source output with specified V_{in} voltage

Set E-load of each output rail according the specification

Enable PS_ON

Enable AC source output and E-loads

Verify PCD all output regulation voltage at PCD output connector end meet the specification

Repeat test with all test conditions

Disable AC source output, E-loads and PS_ON

- **Ripple Test**

Ripple level of each DC output terminal with all working conditions must not exceed limit described in the specification.

Test Condition:

Perform the test for minimum and maximum V_{in} with specified frequency

Perform the test with minimum and maximum load

Test Setup:

Set AC source output with specified V_{in} voltage

Set E-load of each output rail according the specification

Enable PS_ON

Enable AC source output and E-loads

Verify ripple of all PCD output channel by O-scope or equivalent with BW set to 20MHz while monitoring the DC output voltage meet the specification.

Repeat test with all conditions

Disable AC source output, E-loads and PS_ON

Application Note:

The PCD outputs will be bypassed with one 0.1uF multilayer (type X7R) and one 10uF (low ESR) capacitors. Outputs will be tested per the setup in Figure A-C-1.

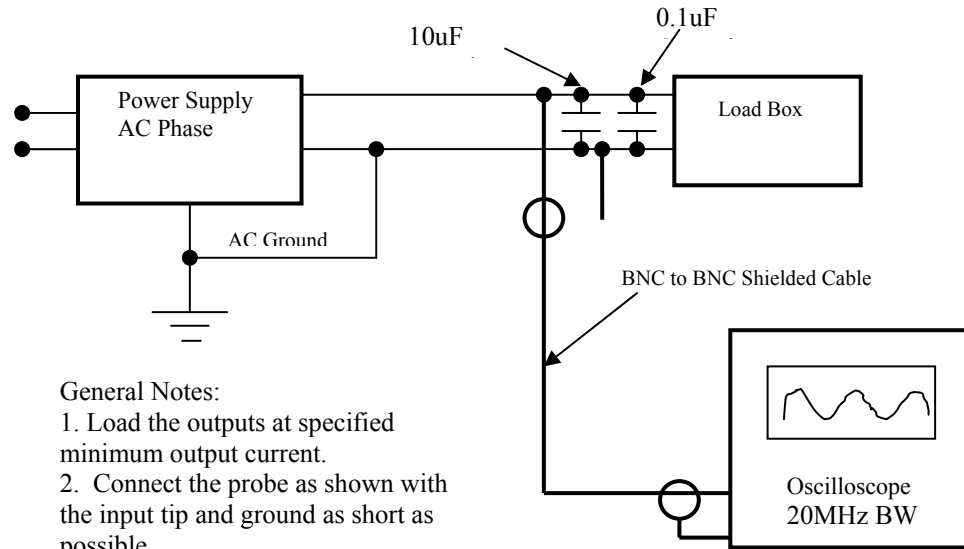


Figure A-C-1 Ripple Test Setup for DC Output Measurements

Transient Load Test

Transient load test is to verify the PCD outputs can still be in regulation when applying transient load to each DC output terminal. Output voltage undulation must not exceed the spec.

Test Condition:

Perform the test for minimum and maximum V_{in} with specified frequency

Test setup:

Set AC source output with specified voltage

Set up transient load (Starting Load, Load Step, current slew rate, Frequency and duty cycle per specification) for one of the output channel while keeping the load in spec for all other channels.

Enable PS_ON

Enable AC source output and E-loads

Verify the overshoot and undershoot of channel which transient load added meets spec while monitoring all other output channel voltage in regulation spec.

Repeat test with all conditions

Disable AC source output, E-loads and PS_ON

Application Note:

Set the transient load to 1kHz with 50% duty cycle except where the specification calls for other values.

- **Over current Protection**

This test is to verify the function of over current protection circuit

Test Condition:

Perform the test for minimum and maximum V_{in} with specified frequency

Test Setup:

Set AC source output with specified V_{in} voltage

Set one DC output rail to maximum load and other DC output set to 50% load

Enable PS_ON

Enable AC source output and E-load

Verify PCD turn on by monitor DC output and POK

Increase current of full load channel to the value that 1% lower than low limit of OCP with 10A/s slew rate

Verify PCD not in over current protection mode by monitoring all DC output and P-OK signal

Increase load of full load channel to the upper limit of OCP with 10A/s slew rate

Verify PCD in over current protection mode by monitoring all DC output and P-OK signal

Repeat the test for all specified DC output channels with all test conditions

Disable AC source output, E-loads and PS_ON

- **Short Circuit Protection**

To verify the short circuit on any DC output terminal will trigger the short circuit protection function.

Test Condition:

Perform this test with any voltage within normal V_{in} range

Perform this test at minimum load

Test setup:

Set AC source output with specified V_{in} voltage

Set E-load according the specification

Enable PS_ON

Enable AC source output and E-load

Short one of the output (except V_{sb}) channels by an impedance less than 0.1Ω

Verify all other output of PCD latch off except V_{sb}

Remove short

Reset PCD by AC input or PS-ON

Repeat test for all output channels except V_{sb}

Short V_{sb} channel by impedance less than 0.1Ω

Verify PCD all other output channels shut down

Remove short on V_{sb}

Verify V_{sb} resume

Disable AC source output, E-loads and PS_ON

Application Note:

If OCP and UVP circuits are separate, verify that OCP functions during a short before the UVP circuit activates.

An OCP circuit must meet any delay spec required to prevent false triggering during load transients.

OCP must meet any I^2t spec for maximum power dissipation during short.

- **Over-Voltage Protection**

This test is to verify the function of over voltage protection circuit

Application Note:

Conduct OVP test at finish good level is preferred, the test need verify PCD not trigger OVP mode at LSL and must trigger OVP at USL. In case product design not allow OVP test at finish good level, board level OVP test is mandatory.

- **Under-Voltage Protection**

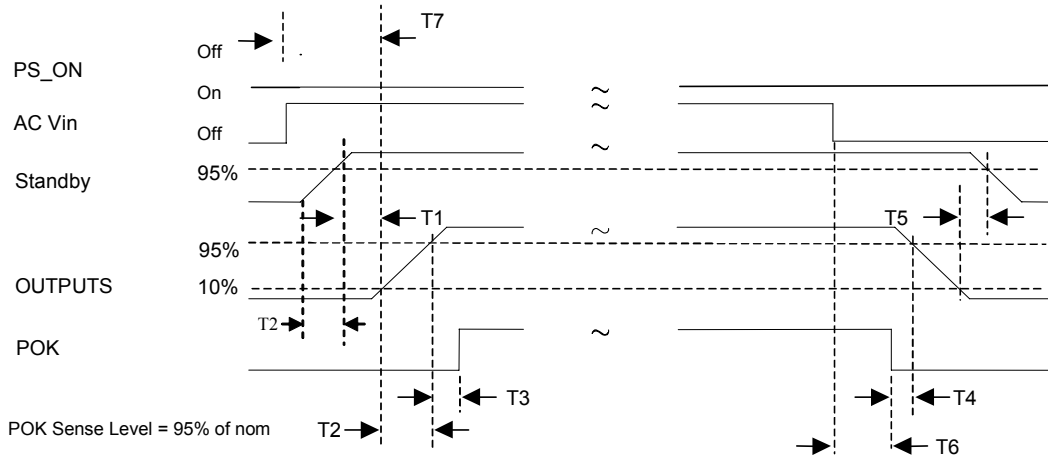
This test is to verify the function of under voltage protection circuit

Application Note:

Conduct UVP test at finish good level is preferred, the test need verify PCD not trigger UVP mode at USL and must trigger UVP at LSL. In case product design not allow UVP test at finish good level, board level UVP test is acceptable.

- **Power Time Test**

This test is to verify the logic sequence and timing between each electrical event during PCD power-up and power-down stage. Following diagram is a guide of timing definition only. Refer to the specification for actual timing requirement.



Above is an example of turn-on timing signals. And below is an example of turn-off timing signals.

Test Condition:

- Perform test with minimum and maximum Vin
- Perform test with minimum and maximum load

Test Setup:

- Set AC source output to specified Vin
- Set E-loads according the specification
- Enable PS_ON
- Enable AC source output and E-load
- Verify T1, T2, T3, T7 meet specifications
- Disable AC source output
- Verify T4, T5, T6 meet specifications
- Disable PS-ON
- Enable AC source output
- Enable PS_ON
- Verify T2, T3, T9 meet specifications
- Disable PS_ON
- Verify T4, T8 meet specifications
- Repeat test for all test conditions
- Disable AC source output, E-loads and PS_ON

- **Current sharing**

This test is to verify the redundant power supply current sharing accuracy meets the specification

Test Condition:

- Perform the test for normal Vin with specified frequency
- Perform the test with specific load

Test Setup:

Connect a known good PCD to PDB (power distribution board) which can parallel multiple PCD accurately

Set AC source output with specified Vin voltage for the known good PCD and PCD

Set E-load of PDB according the specification

Enable PS_ON

Enable AC source output and E-loads

Connect PCD output to PDB

Verify the PCD output current meet spec

On/Off AC input of known good PCD and PCD for 2 times each

Monitor DC output PG has not glitch

Set E-load of PDB to transient mode per spec

Verify both known good PCD and PCD must not go into protection mode

Repeat test with all conditions

Disable AC source output, E-loads and PS_ON

- **Remote Sense Test**

The test is to verify that the remote sense can be able to compensate for a specified drop to on wiring harness

Test Condition:

Perform this test with any voltage within normal Vin range

Perform the test with maximum load

Test Setup:

Set AC source output to nominal Vin

Set E-loads to maximum which is full load of PCD but not exceed total power supply watts

Put a resistor in series of DC output. The resistor needs make a voltage drop lower than the specified voltage that sense line can compensate.

Float the PCD sense line

Enable AC source output and E-load

Verify the PCD DC output meets regulation specifications

Connect PCD sense line to load terminal

Verify PCD DC output meets regulation specifications

Repeat the test for each output rail which has sense line

Disable AC source output, E-loads and PS_ON

Application Note:

In case of E-load has sense line it may be required to float the load sense during this test. Please refer to instrument manual case by case.

- **PS_ON Threshold Test**

This test is to verify the threshold of enable and disable signals while measuring the draw current from system.

Test Condition:

Perform this test with any voltage within normal Vin range

Perform the test with maximum load

Test setup:

Set AC source output to nominal input voltage per spec.

Set E-load according the specification

Enable AC source output and E-load

Set PS_ON to a voltage that 10mV lower than turn on threshold

Verify PCD is turned on by monitoring P-OK signal and all outputs while draw current does not exceed the specification

Set PS_ON to the voltage that 10mV higher than turn off threshold

Verify PCD is turn off by monitor P-OK signal and all outputs while draw current does not exceed the specification

Disable AC source output, E-loads and PS_ON

- **Fan Speed Test**

This test is to verify fan RPM or flow meet product spec. When possible, both hi/low speed need to be verified.

- **LED indicator**

To verify the function of LED indicator. Please refer to PCD spec for test requirement.

- **Capacitive Loading**

To verify power supply can be able to power up and operate normally with the capacitance defined in the PCD specification.

Test Condition:

Perform this test with any voltage within normal Vin range

Perform the test with maximum load

Test setup:

Add capacitive load to PCD output according the specification

Set AC source output to nominal input voltage per spec

Set E-loads to maximum which is full load of PCD but not exceed total power supply watts

Enable PS_ON

Enable AC source output and E-load

Verify PCD turn on by monitor P-OK signal and all outputs

Disable AC source output, E-loads and PS_ON

- **DC Output Monotonic Start up:**

This test is to verify all DC output ramp up monotonically during turn on phase

Test Condition:

Perform this test with any voltage within normal Vin range

Perform the test with maximum load

Test Setup:

Set AC source output to nominal voltage

Set E-loads to maximum which is full load of PCD but not exceed total power supply watts

Enable PS_ON

Enable AC source output and E-load

Verify PCD all DC output voltage ramp up monotonically with O-scope or differentiator

Disable AC source output, E-loads and PS_ON

- **I²C Device Validation**

This test is to verify the functionality of I2C. Please refer to PCD product spec to for test requirement.

- **POK Sink Current test**

This test is to verify the PCD can hold POK lower than 0.4Vdc when POK sink max. current defined by PCD product spec

- **Vin Good Sink Current test (Server PSU only)**

This test is to verify the PCD can hold Vin_Good lower than 0.4Vdc when Vin Good sink max. current defined by PCD product spec.

- **PS On Draw Current test**
This test is to verify the PCD PS_On will not source more than max. current defined by PCD product spec when PS_On is 0.8V
- **PS Kill Draw Current test (Server PSU only)**
This test is to verify the PCD PS_Kill will not source more than max. current defined by PCD product spec. when PS_Kill is 0.8V
- **Vin Good Logic Timing Test (Server PSU only)**
This test is to verify VIN_GOOD must be in the correct state (high or low) within 20mS of the Standby output going into regulation.
- **Fan Fault Logic Timing Test (Server PSU only)**
This test is to verify the –FAN_FAULT signal must be driven low before or at the same time that POK is driven low.
- **OTP Logic Timing Test (Server PSU only)**
This test is to verify the OTP signal must be driven low before or at the same time that POK is driven low.
- **OTP Test**
This test is to verify the function of OTP. Trigger OTP circuit by simulate over temperature condition is acceptable. A typical example of over temperature simulation is to parallel a pre-defined resistor to NTC resistor.
- **Restart After Shutdown**
This test is to verify in case PCD go into latch mode, cycling the stage of PSON from On to Off to On can reset the PCD. Set the pulse width of PS_On according minimum cycle time defined by product spec.
- **No Load Power On Test**
This test is to verify PCD can power up without any load. Refer to PCD product spec for output voltage regulation.
- **5V, 3.3V Sequencing Test**
This test is to verify the 5V output rail stays higher than 3.3V during PCD turn on phase. 5V max. load and 3.3V min. load is the worst test condition.
- **Vibration Test**
Vibration test is intended to detect the weak soldering, solder ball, intermittent connection etc. See Environmental Test requirement.
- **Cable Test**
This test is to verify the correctness of output cable. Connection of each individual functional pin(s) of output connector is required.

Appendix D Stress Testing

Stress Testing (HALT/ HASS/STRIFE)

Performing HALT (Functional Test and Equipment):

HALT testing is normally performed in a HALT Environmental chamber, a chamber that can simultaneously provide temperature control and vibration to the device under test. It must be possible to apply incremental increases (and decreases) in temperature and vibration to levels in excess of those specified for normal product operation. During testing, it is essential to exercise product operation and ensure functionality. Test setups should be optimized to maximize functional test coverage. The test setup should also allow for remote operation of the test and product from outside of the environmental chamber.

Considerations (Stress Application Ordering):

The ordering in which stresses are applied is governed by their likelihood of precipitating catastrophic failures. The following order is recommended:

- Decreasing temperature
- Increasing temperature
- Increasing vibration
- Minimum Sample Size - Multiple samples (at least 2 units) of mixed component suppliers should be subjected to the step stress process to determine the correlation of operation or destruct limits inherent to the design. Large deviations in operational limits (stress failure level) between samples should be investigated if possible to reduce the underlying manufacturing process variation.

Stress Step Increment Size

Stresses are increased in an incremental or stepwise fashion. The size of each step is determined based upon the accuracy required for failure point definition and the time available for testing. It is usual to vary step sizes as appropriate, in particular, reducing step size as failure point is reached allows a fine definition without compromising test duration.

Functionality Restrictions

It is sometimes the case that specific designs incorporate circuitry that changes functionality dependant upon stress level. In particular, there is often protection circuitry such as current protection, over temperature etc that will limit functionality at the stresses applied during HALT. In such cases it is necessary to test the product twice. Firstly, the product is tested with the circuitry enabled to ensure correct operation up to and beyond its trigger point. Then, the product is tested with the circuitry disabled to quantify failure modes and headroom.

Time to Failure

One complex aspect of HALT testing is the time to failure. At stresses above normal operation it is often the case that the product will fail eventually if left in the overstressed environment. For HALT however, it is immediate failures that are of interest. A thermal stress level should be set and the product monitored until it achieves this stress level. Once achieved for thermal test, the functional test should be executed straight away and any failures noted. For the vibration stepped stress process, fatigue damage is accumulated rapidly and the duration of the dwell time for each vibration step and for each sample should be adhered to for equal comparisons of fatigue strength limits between samples. Once achieved, the functional test should be executed straight away and any failures noted.

Testing Beyond the Failure Point

The HALT test should not stop when a failure is encountered. If possible, the failure mode should be analyzed and fixed to allow the test to continue beyond the stress level at which the failure occurred. If a fix is not possible then testing should allow for and accommodate the known failure mode during further testing. Only if a fix is not possible, and functionality of the product is degraded to the point where functionality is not testable should testing cease early. In general, HALT stresses will be increased until the Target stress or a Physical limit is reached.

Recording Failures

For each failure identified during testing, the following information should be recorded

- Failure point
- Failure description
- Root cause of failure mode
- Type of failure (catastrophic or recoverable)
- Class of failure (generic or non-generic)

Documented report

For each HALT experiment conducted, a report should be generated. Each report should contain the following:

- Description of product and its stage of development.
- Specific goals for testing including target stress goals if defined
- Serial number(s) for product under test
- Test equipment list including serial numbers and software revision levels
- Functional test description and procedure
- Document any special arrangements or product alterations made for testing
- Table of failures encountered with attributes, listed in order of increasing stress
- Test conclusions including performance against stated target or prior product

HASS/HASA Testing Guidelines

▪ **Purpose**

This document is to serve as a general guideline and a reference for the power supply (DC-DC and AC-DC) suppliers to perform HASS/HASA testing as required by power supply users. Since it is only a general guideline, suppliers are required to generate their own testing profile based on their actual product performance and physical characteristics.

▪ **Pre-Work**

It is assumed that the supplier has performed HALT testing on the product during development process and has determined the Operation Limits and Destruct Limits of the product based on HALT testing results. If the supplier did not performed HALT for the product, a HALT must be run before designing the HASS/HASA testing profile. HALT should be performed on no less than 2 manufacturing samples in this case.

▪ **HASS/HASA Equipment**

HASS/HASA testing must be performed in industry standard HALT/HASS chambers. These chambers should have the capability of doing combined 6 degree-of-freedom random vibration plus rapid thermal cycling with transition rate greater than 30°C/min.

▪ **Fixture Design and Qualification**

HASS/HASA fixture should be designed and fabricated to support the product throughput testing and provide proper vibration transmissibility, thermal uniformity, and a balanced thermal rate of change.

▪ **Profile Design**

The HASS/HASA testing profile should be based on the HALT results, along with other product-related variables such as functional test duration, thermal long-term degradation effects, product-specific stresses, and production throughput test requirements. Stresses in a typical HASS include combinations of input voltage, output load, power cycling, random vibration, and rapid thermal cycling. A sample testing profile is as follows in Fig. A-D-1 which shows the thermal cycling and vibrations combination.

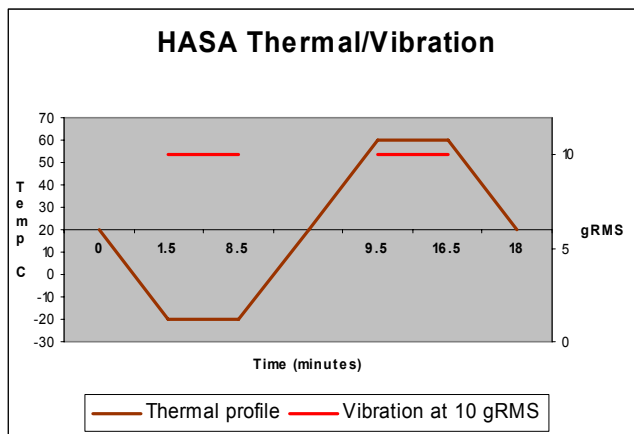


Fig. A-D-1 Example Showing HASA Thermal Plus Vibration Test Profile

- **Temperature Range for Thermal Cycling**

As a rule-of-thumb estimate, the initial temperature range could start at 80% of the UOL and LOL determined from HALT. For example, if the UOL is 100°C and LOL is -50°C from HALT results, then the initial HASS/HASA thermal cycling range could start with -40°C to 80°C, or a range of 120°C.

- **Vibration Level**

The vibration should be modulated throughout during HASS/HASA, beginning at 3 to 5 Grms (depending on product) and slowly ramped to the maximum level. This process should be repeated in reverse, from the maximum level to 3 to 5 Grms. As a rule-of-thumb, the initial maximum vibration level of HASS/HASA should be at 50% of the vibration destruct limit (DL) but not exceed its operation limit (OL) found during HALT.

- **Testing Duration**

The dwell time at each temperature extreme depends on the size and weight of the product to be tested and the time needed to run a functional test or diagnostic test profile. The minimum dwell time should be no less than 5 minutes. The dwell time began after the product reached its desired stable temperature. The minimum requirement for vibration is at least 5 minutes at the maximum vibration level plus slow ramped vibration modulation.

- **Cycle Times**

As a rule-of-thumb, the thermal cycling plus vibration should be running for 5 cycles as an initial testing profile. The cycle times shall be adjusted based on the actual products and the test effectiveness.

- **Other Stresses**

The product function test routine should be performed throughout the profile. This includes supplying a variable input voltage to the units and a variable load on the outputs. Power cycling should be performed at the thermal extremes.

- **Proof-of-Screen**

A proof-of-screen testing must be run before determining the final HASS/HASA testing profile for use in manufacturing. Proof-of-screen is a two-step process: 1) to determine if the initial profile is effective to detect manufacturing flaws, and 2) to prove that the profile has not removed too much of a product's useful life or will not damage a good part.

Since units gone through HASS/HASA will be customer shippable, the rule-of-thumb for the safety of HASS/HASA profile is that the test should not removed more than 10% of the total product useful life. To do this, a test needs to run *at least* 10 times of the initial profile, for example, to run 50 cycles (10x5 cycles) of the above testing profile. No failure after these many cycles will indicate the initial testing profile is not too strong to remove too much useful life, or the profile is relatively safe. If it fails, the process is repeated at lower stress levels to modify the initial testing profile.

To show if the initial testing profile is effective to detect manufacturing flaws, some "seeded" samples, such as samples with known defects or field returned NTF parts, should go through the testing profile to see if these known defects can be detected. This part of testing is voluntary not mandatory.

If the proof-of-screen test show that samples can stand at least 10 times of the initial or modified HASS/HASA test profile, the profile will be accepted as formal HASS/HASA testing profile to be used in manufacturing process.

- **HASA Testing Sample Size**

During initial production, HASS shall be performed on 100% of the production units. After the production process matured and most of the early failures and defects have been fixed, the power supply suppliers could consider to switch from 100% HASS to sampling HASA, with power supply users' approval. The HASA sample size should be large enough for the HASA testing to catch defect variations effectively when the defect level is increased from baseline defect level to an unacceptable defect level with desired confidence level or risk level.

The sample size of HASA depends on the following parameters: risk levels (manufacturer and customer risk levels, α and β), baseline defect rate (p , $q=1-p$), and defect level change to be detected (D). If the total population is big enough ($>1,000$), the following equation can be used to calculate the sample size needed. The $Z\alpha$ and $Z\beta$ are the standard Normal distribution values for α and β . The sample size needed is based on each lot, i.e., it is the sample size per manufacturing lot.

$$N = (Z\alpha + Z\beta)^2 \cdot p \cdot q / D^2$$

For example, if both manufacture’s and customers’ risk levels are $\alpha = \beta = 10\%$, or with confidence level of 90% ($1 - \alpha$ or $1 - \beta$), assume the baseline defect level is 0.1% (1000 PPM), and it is required that the HASA testing should be able to detect the variation when the defect rate changes from 0.1% to 1.0%, or the defect level change $D = 0.9\%$, the required HASA sample size can be calculated as 81 based on the above equation. The following table shows some more examples of required sample sizes for different defect levels. The actual sample size should be determined between the power supply supplier and the power supply users. The testing samples should be randomly selected from manufacturing process.

Sample Size <i>N</i>	α	β	<i>p</i>	<i>D</i>
81	10%	10%	0.10%	0.90%
410	10%	10%	0.10%	0.40%
33	10%	10%	0.10%	1.40%
136	10%	10%	0.30%	1.20%
401	10%	10%	0.30%	0.70%
68	10%	10%	0.30%	1.70%

Any failure found during HASS or HASA must be analyzed to its root cause and the root cause must be eliminated from the product or manufacturing process. The power supply users could ask the supplier to switch back to 100% HASS when failure occurs in HASA and before the problem is fixed.

▪ **Other Requirements for HASS/HASA**

- 1) The PCD of HASS/HASA must be turn-on during testing and functional test should be run at each temperature extreme.
- 2) The PCD must be continuous monitored during HASS/HASA.
- 3) Monitoring with very good coverage is essential to success for HASS/HASA. During HALT/HASS/HASA, more than one-half of the failures are intermittent failures and most failures are temperature and vibration dependent. If the product is not monitored during the test, these failures will skip the test without detection.
- 4) HASS/HASA is different than traditional quality test, such as AQL or LTPD testing. All failures during HASS/HASA must be analyzed to root causes. Corrective action is required.

Appendix E Life Testing – Reliability Demonstration Tests

Demonstrating reliability and MTBF at high confidence levels can require large sample sizes and long test times, even with moderate acceleration factors. The following table provides a guideline to reliability demonstration at 60% and 90% confidence levels. It assumes no acceleration factor. Temperature acceleration factors are shown in Table A-E-1 with nominal thermal acceleration effects.

Table A-E-1 Temperature Acceleration Factors

MTBF	Percent/1,000 Hours	Confidence Level	Sample Size	Time with 0 Failures
100,000 hrs	1%/1000 hrs	60%	30	3,054 hours
100,000 hrs	1%/1000 hrs	60%	60	1,527 hours
100,000 hrs	1%/1000 hrs	60%	90	1,018 hours
100,000 hrs	1%/1000 hrs	60%	120	754 hours
100,000 hrs	1%/1000 hrs	60%	180	509 hours
100,000 hrs	1%/1000 hrs	60%	240	382 hours
100,000 hrs	1%/1000 hrs	90%	30	7,676 hours
100,000 hrs	1%/1000 hrs	90%	60	3,838 hours
100,000 hrs	1%/1000 hrs	90%	90	2,559 hours
100,000 hrs	1%/1000 hrs	90%	120	1,919 hours
100,000 hrs	1%/1000 hrs	90%	180	1,280 hours
100,000 hrs	1%/1000 hrs	90%	240	960 hours

To determine test time for other MTBF values, multiply the tabulated time by (Required MTBF)/100,000. For example, for a required MTBF of 250,000 hours, multiply the times by 250,000/100,000 = 2.5. Note that this table cannot be applied to a test with observed failures. The table above assumes that failure modes expected in the devices under test yield approximately a constant failure rate. If a power conversion device under test has a significant infant mortality problem, it is most likely that failures will be observed in a short test (100's to 1,000's of hours), even if long-term failure rate is very low. If failures are observed you must use appropriate statistical software to estimate failure distribution and failure rate (and most likely, you must address root cause and corrective action before power conversion device under test has acceptable reliability performance).

Thermal Acceleration Factors are usually derived from the Arrhenius model. This model has a parameter, Activation Energy (Ea), that can vary from ~0.3eV for some failure mechanisms, such as corrosion and oxide breakdown, to over 1.0eV for specific types of ionic migration. Assembly defects are usually found to be in the 0.5 to 0.7eV range. Table A-E-2 assumes a value for Ea of 0.6 eV. The simplified Arrhenius relationship for testing is $A = e^{(11,605 \cdot E_a / (T_1 - 1/T_2))}$ where T1 is operating temperature in Kelvin and T2 is test temperature in Kelvin.

Table A-E-2 Acceleration Factor with Ea Assumed to be 0.6

Ambient Temperature	Test Temperature	Acceleration Factor
30°C	50°C	4.1
30°C	60°C	7.9
30°C	70°C	14.5
30°C	80°C	25.8
30°C	90°C	44.4
40°C	50°C	2.0
40°C	60°C	3.8
40°C	70°C	7.0
40°C	80°C	12.4
40°C	90°C	21.3

Acceleration factors in the range of 10:1 are reasonable for testing power conversion devices and can save substantial test time in a product development reliability program over testing at 'room' temperature. Note that reliability specifications should always be made at a specific operating temperature, and 30°C to 40°C is reasonable for most applications.

Appendix F Manufacturing Burn-In (Highly Accelerated Stress Test)

If required by the power conversion device user or conditions of manufacturing and observed early failures (typically during ramp up of a new product design) burn-in (or HASS) **shall** be performed on 100% of manufactured product. Failed devices **shall** be repaired and burned in again prior to shipment. All failures **shall** be documented and reported to the user during the life of the product. The Burn-In process is used to identify and eliminate Infant Failures in the product. It should be used to improve process and components so that in time, a 100% screen is no longer required.

During HASS all units shall be power-cycled and outputs **shall** be electronically monitored. Failures of any kind, including transient spec failures, **shall** be cause for analysis and repair. Conditions for reduction of burn-in time, or change from 100% HASS to sample HASA stress audits is to have prior written agreement with the user (AABUS).

Conditions for burn-in **shall** include:

- a) Initially, minimum time **shall** be 24 hours. If quality goals are not being met, customer may request longer burn-in time.
- b) Input Voltage AC products: 110 Volts and 220 Volts (Lots can be split so that a partial lot is burned in at low line of 110-VAC and rest at 220-VAC)
- c) Input Voltage DC products: High specification limit of nominal DC input voltage
- d) Ambient Temperature Burn-In chamber: 50 C to 55 C
- e) Output Load (per output): $90 \pm 5\%$ of maximum rating for all outputs (Load can be Resistive or Electronic type)
- f) Input Power Cycling: For any given hour of Burn-In, if not defined elsewhere, the following profile outlined in Fig. A-F-1 shall be used:

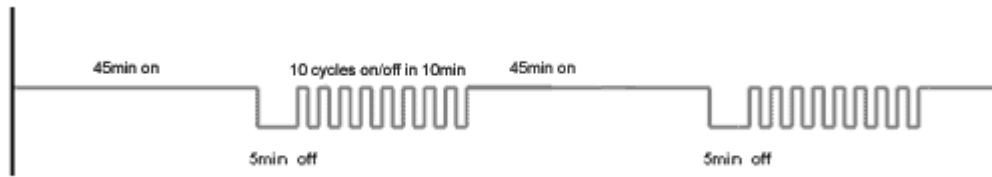


Figure A-F-1 Input Power Cycling Diagram

- g) Monitoring and Failure Reporting: Supplier **shall** have Real Time automated system to Monitor and be able to accurately capture any and all failures during the Burn In with time to failure, symptom and root cause and corrective action.

Appendix G

An Example of Quality System Requirements

Quality Program

The supplier shall implement and maintain a quality program that shall assure design and manufacture of products is consistent with the requirements of ISO 9001:2000 Quality management systems – Requirements and ISO 9004:2000 Quality Management Systems Guidelines for Performance Improvements. The Supplier shall assure that these requirements are implemented during the design phase and the manufacturing of product. The supplier shall notify the customer of any changes in its quality program prior to implementation.

Management Responsibility

The Supplier's executive management will develop a company-wide quality policy. This policy will be deployed and understood by all employees. A management review system will be implemented. The Quality policy and system will be reviewed at prescribed intervals to assess the continuing suitability and effectiveness of the quality system. This review will include the quality policy, internal audit results, product complaints/returns, process/product quality reports, and others as they apply. Executive management will appoint a management representative with the responsibility/authority to monitor compliance to the system, and to ensure corrective/preventive measures are implemented.

Organization

The supplier will have an organization that supports, implements and maintains the quality system at all levels.

Quality Policies, Procedures, and Work Instructions

The supplier shall establish and maintain a documented quality program as a means of ensuring that product and/or services comply with the requirements set forth in this standard. All work affecting the quality of products and/or services shall be documented in clear and concise policies, procedures, and work instructions. The supplier shall ensure that these documents are deployed, effectively implemented and understood within the company.

Quality Management Plan

The supplier shall submit a Quality Management Plan to the user's quality or procurement staff that describes the overall quality program used for the design, manufacture, test, and inspection of product. The Plan shall, at a minimum, describe the following:

- Identification of support team for Company (critical contacts)
- Product differences from previous models/parts
- Quality performance goals
- Site matching (if multiple Supplier sites are manufacturing the same part for Company use)
- Manufacturing processes
- Inspection/test strategies and processes
- Process control techniques
- First article requirements
- Internal change control procedures
- Procedures for handling discrepant material (identification, containment, root cause, corrective action)
- Failure analysis support for Company's line rejects (LRR) and field returns (IFIR)
- Engineering change requirements
- Record retention
- Continuous Improvement Program (CIP)

Internal Audit Program

The Supplier shall implement an effective internal audit program that provides for the following:

- Gap Analysis (Audit)
- System Audits
- Process/Product Audits

Only qualified auditors (trained) will conduct audits and will be independent from the area being audited. The audit program structure and requirements shall be provided to customers for review and approval. All audit results shall be maintained and made available to customers upon request.

Customer Audits

On a periodic basis, the customer may conduct audits/visits at the supplier's manufacturing locations. The supplier shall, at the customer's request, permit access to manufacturing operations involved in the production and/or inspection of products that the customer purchases, including access to sub-contractor facilities. Periodic audits will include quality inspection data and other data related to the product being produced, or process audits to verify compliance to the contractual requirements.

Under normal circumstances, the supplier shall be given advance notice of any customer visits.

Training

The supplier shall establish and maintain a program for the identification of training requirements for all personnel that affect the quality of a product during production and installation. Qualification to perform assigned tasks shall be based on individual education, training and/or experience as required. The supplier shall also assure that a system exists for the qualification, re-qualification, and disqualification of personnel. As a minimum, training for applicable personnel shall consist of quality system training, auditing techniques, Supplier Quality Engineering processes, assembly techniques, workmanship standards, and inspection requirements. Supervisors in the production area shall also have a working knowledge of quality systems and statistics. Records of all training shall be maintained and made available for Company SQE to review upon request.

Appendix H

Ongoing Reliability Testing (ORT)

A) Objective

To identify, before any customer, any variability in the production processes resulting in different levels of product performance. ORT shall be performed per an agreed upon plan on a calendar basis on product from each production site during the life of the product. Tests are a subset of DVT tests (to failure), aimed to map changes in the product performance margins for selected stressors as a result of variability in production processes of components and the final product. ORT, as with many other functional policies, is to be implemented by each company based on their individual business conditions.

Benefits include:

- Capture test escapes; potential optimization of Mfg Test Process
- Detect degradation in design margin and tolerances
- Uncover problems caused by component and/or workmanship issues
- Produce actionable data to Manufacturing and Engineering for continuous improvement
- Develop knowledge about failure mechanisms
- ORT is not:
 - i) A means to verify product design (i.e., it is not EDVT),
 - ii) A replacement for RDT (to demonstrate predicted MTBF) or
 - iii) A screen to catch trivial issues.

B) Scope

An ORT is very similar to the Reliability Demonstration Test (RDT) except that the RDT is usually performed once just prior to release of the product, whereas the ORT is an on-going test rotating in samples from the manufacturing line. ORT is a part of a comprehensive reliability test program. Such program should include power supply workmanship evaluation, RDT, Highly Accelerated Life Testing and other product quality activities. These “up-front,” or NPI activities together with production test process are necessary for successful ORT. ORT will commence immediately following the completion of pilot production.

C) Definitions

ATE:	Automated Test Equipment
AVL:	Approved Vendor List
AQL:	Average Quality Level. Refers to the quality level for inspection sampling plans described in Mil-Std-105 and ANSI/ASQC Z1.4
DPMO:	Defects per million opportunities (DPMO) is the average number of defects per unit observed during an average production run divided by the number of opportunities to make a defect on the product under study during that run normalized to one million.
FCS:	First Customer Shipment.
NPI Team:	The New Product Introduction team includes the following primary members who should be part of all defined technical and business decisions: Business Unit Power Manager, Assigned Power Engineer, Global Commodity Manager, component Engineer. Secondary members should be included on all correspondence and review distributions. They are: Compliance Engineer, Assigned Mechanical Engineer and Assigned Program Manager.
OOBA:	<i>Out of the Box Audit.</i>
QTP:	Qualification Test Plan -This document describes what testing will completed and critical requirements at each phase of development, test methods and other specific requirements for qualification of a custom power supplies.
RFQ:	Request for Quote - The process by which Global Commodity Management approved vendors competitively bid for the power supply development and production contract.
TTF:	Time to failure
TCOO:	Total Cost Of Ownership -A measurement of the total power supply cost to business unit which is used in RFQ process to select the power supply vendor. Included in TCOO is product cost, service cost, freight cost, design topology, etc. UUT: Unit Under Test - The actual power supply that is being tested. The UUT is defined by the test phase and serial number.

D) ORT Unit Requirements

ORT unit/system requirements, or sample sizes, are categorically and statistically determined based on the following factors:

- o FCS date
- o Risk factor (“high” or “low”)
- o Power supply complexity
- o Ship volumes
- o 0.65 to 1.0 Acceptable quality level (AQL) sampling plan

ORT Requirements “High Risk”

All power supplies are considered “High risk” for the first six months after FCS. After which time, power supplies must remain in the high risk category for the purposes of ORT sampling if ANY of the following conditions are true:

- o Any ORT failure in the previous 20 weeks
- o Manufacturing yields that are not meeting BU set targets

ORT Requirements “Low Risk”

After *FCS-plus-six-months*, power supplies may be considered “Low risk” for the purposes of ORT sampling only if ALL of the following conditions are true:

- o No (0) failures in ORT for the previous 20 weeks
- o Manufacturing yields are meeting or exceeding BU set targets.

Unit/System Requirement Calculation Methods

Table A-H-1 is derived from AQL Sampling Tables similar to those provided in **Mil-STD105E** and **ANSI/ASQC Z1.4-1993**. All sampling plans correspond to AQL levels 0.65 to 1.0 and either the “I” or “S-2” inspection level in these industry standards, and a reject threshold of 1 (c = 0).

Table A-H-1 Weekly Sample Size for ORT

Lot Size	High Risk	Low Risk
< 25	4	2
26-100	6	4
101-250	10	6
251-500	14	12
501-1200	20	16
1201-3200	24	18
>3200	26	20

High Risk: High Risk is used for FCS + 6 months and for “high risk products,” where high risk is defined as an ORT failure in the last 20 Weeks, or poor manufacturing yields.

Low Risk: Low Risk is used after FCS + 6 months and for “high risk products,” where low risk is defined as no ORT failure in the last 20 Weeks.

One week’s production, from which the sample is taken, is considered to be the “lot.”

E) Samples for ORT

One week's production, from which samples are taken as prescribed Section 4, is considered to be the "lot". Therefore, UUT need to be taken from production in such a way as to uniformly represent one week’s production. This way, the results from an ORT sample are associated with all product produced in the corresponding week.

For a standard two-week ORT (see Fig 1), samples are pulled daily until the sample size is complete in one week. UUT are tested and pulled out after the two week test period. At any one time (after the initial week) there are two ORT samples undergoing testing. Figure A-H-1 illustrates the distribution of sampling over 6 to 7 days followed by a two-week testing period.

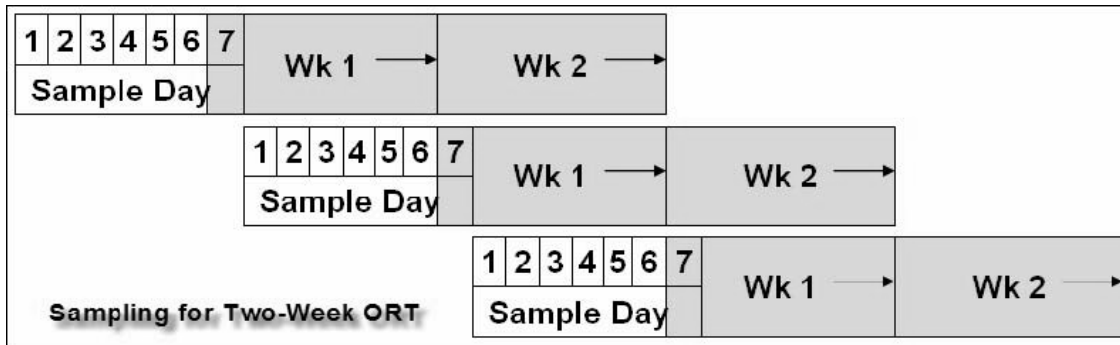


Figure A-H-1 Example Distribution of Sample Pulling Over a 6-Day Period

F) Test Methodology

Extended Burn-In

Line Voltage	Split population – half at 100 - 120VAC and half at 220 - 240VAC .
Burn In Temperature	55°C. Temperature of the Chamber should be maintained between 50°C and 55°C
Burn In Hours	336 Hrs (14 days)
Power Cycling (Ton -Toff)	45 min on / 5 min off /10 min Quick Power Cycling
Load	95% +/-5% of maximum power rating (all outputs)
Quick Power Cycle	10 min: 30 sec on / 30 sec off (10 cycles)
Output Voltage Detection	Monitor highest power output.

1) Operation Sequence

- Before "Burn In" test, turn on the power supply at full load condition, test using ATE tester before RDT and save the test data.
- During "Burn In" test to detect out failure in time, use electronic monitoring.
- After "Burn In" test, turn on the power supply at full load condition, test using ATE tester before RDT and save the test data.

2) Initial Time to Burn In 336 hours (14 days)

Note: If the user's quality goals are not being met, a longer Burn In time may be requested.

AC products Input Voltage: 100 - 120 Volts and 220 – 240 Volts (*Lots will be split 50% between the two input voltages*).

DC products Input Voltage: 48 volts or 54 volts DC.

3) Ambient Temperature at Burn In Is 55 C (may vary between 50 and 55 C)

The chamber used shall be capable of maintaining the specified chamber temperature and within the tolerance given. Forced air circulation may be used to maintain constant environmental conditions in the chamber. In order to limit radiation problems, the chamber walls, once temperature stability has been reached, must not differ in temperature by more than +/- 2 C of the set chamber temperature. This applies to all parts of the chamber walls and the assemblies.

Some form of mapping of temperature inside environmental chambers is required to ensure uniform test conditions. This mapping is an important part of the process to ensure the equipment meets required performance criteria.

Few basic steps need to be followed when mapping an environmental chamber.

Four data loggers placed near each corner plus one logger in the center. Mapping should be performed on all chambers where the user’s products are tested. Mapping study should be done for 24hours. Typically, data from the data logger is taken every hour for twenty four hours. Mapping study need to be repeated every quarter for all user’s products tested. All test data need to be documented in a format agreeable to the user and stored.

4) Output Load 95 ± 5 %

In case of multiple outputs, loading will be evenly distributed to achieve 95 % +/- 5 % of the total power rating of the power supply.

Load can be Resistive or Electronic type.

5) Input Power Cycling for Any Given Hour of Burn In (see Figure A-H-2)

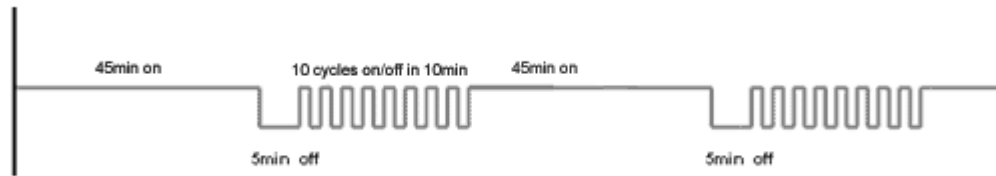


Figure A-H-2 Start of Next Hour

Note: The above parameters are a minimum requirement. If any deviation is necessary it must be entered on the supplier quality agreement and supplier should discuss it with the user.

Vibration test:

Test condition:

- A: Sinusoidal vibration(test for operation)
 - Frequency: 2-500Hz
 - Peak displacement: 2-8Hz -4mm
 - peak acceleration:8-200Hz -1g
 - peak acceleration:200-500Hz -2g
 - Sweeps rate:1 octave/min
 - Axes: 3(X,Y,Z)
- B: Random Vibration(test for operation)
 - Frequency range: 20 to 2000 Hz
 - Spectral Density: 0,018 g²/Hz
 - Average acceleration: 6 grms
 - Duration: 10 min each direction

Test quantity:

2 PCS for every month

Temperature & humidity cycle test:

Test condition:

- a. Vin:220V/50Hz
- b. Output Load: Full load.
- c. temperature & humidity:

step1	60 deg. C, 95% R.H.,	4 hours, power off
step2	60 deg. C, 90% R.H.,	4 hours, power on
step3	0 deg. C, * R.H	4 hours, power on

Remark : After step1, the unite shall run ON/OFF test for 5 times(each time for 1 minute)

Test quantity: 2 pieces for every month.

EMI test:

To ensure products are passing EMI specification and met customer requirement:

Conduction Emission Test Condition:

- a. Input voltage: 110Vac/50Hz, 220Vac /50 Hz.
- b. Output Load: Full load .
- c. Testing temp: 25°C or ambient temp
- d. EMI test requesting reference the EN55022 Class A ,
 FCC: frequency range 450 kHz – 30 kHz at 110 - 120 VAC@ 60 Hz.
 CISPR: frequency range 150 kHz – 30 kHz at 220 - 240 VAC@ 50 Hz.

Test quantity

Random sampling 2 units per model per month from production line.
 (products, which already pass ATE testing)

Operation / disposition

Compare golden sample data and test sample data, if in spec is pass, if over spec is fail.

Reliability Demonstration Test (RDT):

Sampling / Frequency Sampling 2 PSU from Inventory for testing and repeat with new power supplies every 6 months until end of production.

Test Condition

Line Voltage	Split population – half at 100 - 120VAC (nominal) and half at 220 - 240VAC (nominal).
Burn In Temperature	55°C. Temperature of the Chamber should be maintained between 50°C and 55°C
Burn In Hours	6 months
Power Cycling (Ton -Toff)	45 min on / 5 min off / 10 min Quick Power Cycling
Load	95% +/-5% of maximum power rating (all outputs)
Quick Power Cycle	10 min: 30 sec on / 30 sec off (10 cycles)
Output Voltage Detection	Monitor highest power output.

Test period: 6 Months

Operation Sequence

- Before RDT: Turn on the power supply at full load condition, test using ATE tester before RDT and save the test data.
- During RDT: To detect out failure in time, use electronic monitoring.
- After RDT: Turn on the power supply at full load condition, test using ATE tester before RDT and save the test data.

G) ORT Data Management and Reporting

The key to ORT monitoring and reporting is that specific information is captured and more importantly made available to the user. How this information is recorded and tracked is left to the discretion of the power supply supplier who owns the ORT reporting responsibility. The minimum required reporting elements are listed below:

Product ID or code name
 Sample Size Planned
 Number of UUT (sample size)
 Serial Numbers
 Production date each UUT is pulled
 Test Profile (temperature and routine)
 Start Date/Time
 End Date/Time
 Number of failures
 Failure Incident Date/Time
 UUT Status (Failure, Pass, In Progress)
 Failure Summary Corrective

Action Summary

- PCD output readings must be taken before ORT starts and after ORT is done to see if there were any drifts due to ORT testing.
- Supplier shall have Real Time automated system to Monitor and be able to accurately capture all catastrophic PCD failures during the ORT with time to failure data.
- All ORT failures must be analyzed for trends within same lot or between lots. Failures must be root caused and Corrective Actions reported on joint quality improvement program meetings or monthly user reports.

H) Review of Ongoing Reliability Test Procedure

For a mature product with demonstrated quality performance, field reliability performance per the user's SQA, the user will follow the following process to review the request for ORT:

- i) Include all Functional Failures experienced at OEM and any test station following ORT that should include final ATE, Hi Pot, QA audit and Burn-In.
- ii) In addition, any power supply being shipped to the user's contract manufacturer (CEM) should include the failures experienced at CEM's test process, which are functional in nature. Time to failure will also be additive.
- iii) OEM will then provide the above data to the appropriate user for their review and approval.
- iv) Traceability of power supplies that were part of ORT should be maintained, so that any power supplies EFA or RMA's that were returned can be verified whether power supplies went thru ORT testing.
- v) In any case, any change to ORT must be approved by the user after PCN submission by the supplier and prior to implementation.

I) Reverting to Initial ORT Procedure

Under following situations, the user may require that the procedure revert back to the initial ORT.

- o Major Design Change
- o OEM moving manufacturing location or starting an alternate location
- o Extended period of stoppage of production

Burn-in will automatically revert back to the initial ORT and the supplier will notify the user if any of the following events occur:

- o Any Out-of-Box Audit (OOBA) functional failure
- o The TTF of more than one BI failure during any given week exceeds three hours.
- o Final ATE failures due to component or material defect exceeds 1000 DPMO for any given week
- o A CEM rejection due to component or material defect exceeds 1000 DPMO for any given month.