NAVSO P-3641: Navy Power Supply Reliability Design & Mfg Guidelines (NAVMAT P4855-1)

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4.2 DESIGN FOR RELIABILITY

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The design of highly reliable power supplies begins with:

(1) Verified circuit designs

(2) High reliability components

(3) Conservative derating practices

(4) Low junction/hot-spot temperatures

(5) Printed wiring boards and connectors instead of point-to-point and/or wiring harnesses.

CIRCUIT DESIGN CONSIDERATIONS

Peak Instantaneous Transients and Subtleties

The most predominant power supply failure modes are caused by peak instantaneous transients and subtle factors within and external to the power supply. Sneak circuits and built-in wear-out mechanisms must be considered in the design and packaging of the power supply system. Sneak circuits are addressed in Department of the Navy document NAVSO P-3634.

Hostile environments such as temperature, shock, vibration, altitude and humidity accelerate failure modes.

Training engineers, designing with margin, incorporating protective circuits, performing worst-case analysis and conducting comprehensive testing to prove the design are musts to achieve power supply reliability and performance longevity.

Use of MIL-HDBK-217

Many designers consider only static conditions and do not address transient conditions such as transistor load line variations and various peaks and surges as well as items such as capacitor core temperature.

Be cautious of a simple and inexpensive switching-mode power supply with a high predicted MTBF determined in accordance with MIL-HDBK-217. See Reference 30. The expected MTBF of power supplies designed and manufactured in accordance with the guidelines presented herein will exceed predictions per MIL-STD-756, Method 2005, using MIL-HDBK-217.

These predictions can be used to identify internal component reliability concerns and also identify the lower limit of expected MTBF performance. These predictions should not be used as a basis for setting contractual reliability requirements, but should focus on operational mission and system expectations.

Points to Consider

The following is a list of key points to consider when designing and evaluating a switching-mode power supply design:

(1) Incorporate voltage transient protection on the input power lines.

(2) Include a controllable soft-start circuit to relieve the component stresses during turn-on.

(3) Build an internal housekeeping power supply to isolate sensitive circuits from the hostile power line, improve human safety and allow control of the power-up and power-down cycles.
(4) Tailor the turn-on and turn-off load lines to minimize peak power in the semiconductors during power supply turn-on/turn-off intervals.

(5) Incorporate a crossover interlock circuit in the power stage that is connected across the power line so that two devices can never conduct simultaneously across the power line.

(6) Incorporate input EMI filtering having characteristics compatible with the negative resistance of the power supplies and variable input source impedances so that the combination is stable.

(7) Incorporate a fast-attack current limiting circuit to protect the power devices when the control logic "glitches" due to random noise or other abnormal circumstances.

(8) Design the power inductors, transformers and magnetics to keep them out of saturation during peak load and transient conditions.

(9) Sequence the turn-on/turn-off logic in an orderly and controllable manner.

(10) Analyze and measure worst-case peak currents, peak power, peak voltage and ripple currents in all devices and under all worst-case static and dynamic conditions. Compare the measured results with the rated limits of all components.

(11) Perform worst-case thermal and hot-spot analyses.

(12) Design printed wiring boards and packaging for the best heat transfer. Plan the circuit so that it will not be subject to common-mode and differential-mode noise. Circuit design engineers must be responsible for the electrical and printed wiring board layouts.

(13) Package magnetic devices and other heavy-current-carrying conductors with thermal interfaces adequate to meet hot-spot temperature requirements.

(14) Avoid ground loops and potential cross-talk and interaction by developing a grounding technique that is appropriate to the application.

(15) Analyze and measure loop stability to ensure that there is adequate phase and gain margin under all line, load, temperature and component tolerance variations.

RELIABILITY REQUIREMENTS FOR COMPONENTS

The ground rules for selecting components are:

(1) Microcircuits are in accordance with MIL-M-38510 Class B Standard Military Drawing (SMD) or are procured to Source Control Drawings, Specification Control Drawings and Selected Item Drawings that provide the same or a higher reliability level. Specification control drawings are preferred over source control drawings.

(2) Diodes and transistors are JANTX (or JANTXV) or are procured to Source Control Drawings, Specification Control Drawings and Selected Item Drawings that provide the same or a higher reliability level. Specification control drawings are preferred over source control drawings.

(3) Other discrete components are P-level or higher Established Reliability (ER) components or equivalent.

(4) Magnetic components should be equivalent to MIL-T-27 insulation Class S or better, with the addition of a 100% thermal-shock screen.

(5) Wet slug tantalum capacitors, except type CLR 79 per MIL-C-39006 /22 and /25, are not allowed in the design of militarized power supplies since they are prone to leak, resulting in corrosion and power supply failure.

There are special criteria for improving reliability for selected types of components. These are as follows:

(1) Aluminum Electrolytic Capacitors

These devices are susceptible to external contaminants during the assembly of the power supply, primarily by the cleaning agents. The failure mechanism is an internal short from chloride contamination that is a long- term, time and temperature process. Specifying epoxy end-seals minimizes or eliminates these external contaminants inside the capacitors.

(2) Power Semiconductors

Avoid the use of packages with electronically hot cases and use isolated cases where practical. Hot case devices require well thought out isolation techniques and additional assembly steps that are susceptible to error.

DESIGN DERATING

The failure rate increases as a function of the applied stresses imposed by the initial design decisions. Depending upon the specific component type, construction and materials used, these failure-prone stresses may include voltage, current, or power dissipation. However, predominant among all others is temperature (case hot-spot, junction temperature, ambient temperature). Derating is simply the practice of designing equipment using components whose allowable maximum application stresses are constrained to some percentage of the Absolute Maximum Rating (AMR), thus taking advantage of the lower failure rate which results.

Absolute Maximum Rating

AMRs on parameters are derived by component manufacturers as guidance for designers in determining whether their component applications are compatible with anticipated worst-case stress conditions in their equipment. An AMR is usually based on one of the following:

(1) The stress point beyond which device performance parameters are not specified or controlled.

(2) The stress limit beyond which permanent degradation of parameters may begin to occur.

Voltage and Power Derating

Operating voltages and power dissipation levels are derated, for particular applications, to ensure that the components will operate at the required reliability levels under specified environmental conditions. Voltage and power derating are separate and independent procedures. Voltage derating is done to reduce the possibility of electrical breakdown, whereas power derating is done to maintain the component material below a specified maximum temperature.

The first step in the process of derating is to establish the operating voltages and the second step is to adjust the power dissipation level. The voltage derating of passive components prevents voltage breakdown, flashover and corona effects at the atmospheric pressure (altitude) to which the components are exposed. These effects are dependent upon voltage gradients, configuration of terminals and the nature of the dielectric path. The operating voltage of active components, such as semiconductors, is dependent upon the breakdown characteristics of the semiconductor material.

After the operating voltages are established, the power dissipation level is determined. The degree of heat transfer from a heat-producing component and the immediate ambient temperature surrounding the component, will determine the surface temperature or junction temperature, core temperature and hot-spot temperatures at a particular power level. The junction temperature should not exceed +110ºC under worst-case conditions.

Table 4-1 defines the minimum derating criteria that are recommended for the design of power supplies. TE000-AB-GTP-010 and NAVAIR AS-4613 may in some instances require more stringent derating. Each application should be considered individually whenever design penalties result. The parameters of the values listed under "DERATED TO % RATING" are shown in "DERATING PARAMETER."

COMPONENT OPERATING TEMPERATURES

Lower operating temperature is synonymous with more reliable operation. The absolute value of operating temperature for all components in a power supply should be determined both analytically and empirically.