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

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2.0: EXECUTIVE SUMMARY

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2.1 INTRODUCTION

The purpose of this document is to define (1) guidelines for Navy and contractor program managers and (2) design and manufacturing fundamentals for power supply engineers, that will result in power supplies which meet or exceed the reliability requirements.

The information contained in Sections 3 and 4 applies primarily to low-voltage power supplies delivering up to 5 kilowatts and 300 VDC or less. Some topics, such as output power density have been tailored for power supplies below 1,500 watts and outputs of less than 28 VDC. The unique requirements of high-voltage power supplies, those whose output voltage exceeds 300 VDC, are addressed in Section 5. While these guidelines do not directly address other power conversion equipment, such as frequency changers, inverters, uninterruptible power supplies, or static switches, precepts contained herein, such as component deratings and environmental stress screening, can be applied. Consideration will have to be given to development schedules, volume and weight, to take into account the complexities of the other types of equipment.

Modern Navy system requirements dictate that most power supplies in new equipment be of the switching-mode type. For this reason, the switching-mode assumption is implicit throughout the document.

2.2 PROGRAM MANAGEMENT

Program management must address those aspects of power supply acquisition which are associated with (1) specifying the power supply requirements and (2) meeting the requirements, including reliability, within cost and schedule targets. This involves constraints external to design and manufacturing, including not only the available resources but also realistic technical requirements which acknowledge what can and cannot be done within both the current state-of-the-art and the military standards, specifications and policies.

Equally important is the selection of a design and manufacturing activity capable of implementing the guidelines in this document. Fundamental criteria in power supply source selection should be the proposed, perceived and demonstrated ability to comply with these guidelines.

DEVELOPMENT SCHEDULE AND COST

Traditionally, the specification and design of the power supply has been left until the host system has reached substantial design maturity. The development of a reliable custom power supply requires an average time of 18 months from specification release and design go-ahead to first mature production units, using standard design and construction techniques (military standard components, non-proprietary circuitry); 24 months is not unreasonable for new designs which involve invention. To reduce the schedule below 18 months imposes shortcuts which are likely to degrade reliability.

Among the most common of these shortcuts is postponement of environmental qualification and reliability testing until installation in the host system. By this time, redesign to improve reliability is unlikely due to cost and schedule constraints.

The idea that power supplies are simple leads to insufficient funding and buy-in by inexperienced and otherwise unqualified firms. The non-recurring development cost of a typical power supply is 5% to 10% of the total electronic system development cost, excluding software. Staffing may include some 6,600 man-hours in various technical disciplines to reach reliability maturity.

Budgets, specifications, program plans and proposals which violate the 18-month and/or 5% to 10% cost guidelines must be considered high risk. It is incumbent on the Navy and the contractor to question such power supply planning and design to ensure that the reliability of the program is not being compromised.

OUTPUT POWER DENSITY

Low-voltage power supplies on the order of 6 watts per cubic inch represent conventional technology where high reliability can be guaranteed using established design and construction techniques. These power supplies are of the switching-mode type; linear power supplies are limited to about ½ watt per cubic inch. Exceeding a ½ watt per cubic inch packaging density using linear techniques, or on the order of 6 watts per cubic inch using switching-mode techniques, can contribute to poor power supply reliability in the fleet when the higher density is achieved by current design practices rather than advanced circuit and packaging technology. Factors restraining higher power density are:

(1) Availability of approved components

(2) Isolation transformers

(3) Enhanced EMI requirements

(4) Holdup time requirements after prime power loss

(5) Cooling techniques.

Nevertheless, higher power density is, or will be, required in current and future systems. Techniques exist and are being improved upon to satisfy future system requirements.

Output power density requirements exceeding 6 watts per cubic inch should trigger an in-depth technical investigation and design review to ensure that reliability is not being compromised. Any reliability claims should be substantiated by test data taken in environments equal to or exceeding the anticipated system environment.

OUTPUT POWER DENSITY DEVELOPMENT

As electronics continues the quest for miniaturization, the space available for the power supply will continue to shrink, demanding ever higher output power density . Maintaining control of this necessary growth to ensure that reliability is not compromised in the process must be a major concern of program management. Factors that affect the increase in output power density are advanced design techniques and components.

Increasing switching frequencies from 20-40 kHz to 100-500 kHz or higher is presently the most significant technique used to increase power density. This reduces the size of the magnetics and filter capacitors. Higher power field effect transistors and newer devices are replacing conventional bipolar devices. Power hybrid microcircuits and monolithic integrated circuits for power supply functions are becoming available for military applications. Capacitor volume continues to be a burden; however, improved versions of both aluminum electrolytic and tantalum capacitors are becoming available. Packaging techniques have a direct bearing on increasing output power density. Examples include rectangular capacitors and both flexible and multi layer printed wiring boards.

Selection and conservative application of components in power supplies is critical to ensuring a highly reliable design. Maximum usage of military- qualified standard components is recommended. However, rapid advances in power supply design technology and availability of new, higher capability, high- reliability components have resulted in making some of the standards obsolete. Military qualification and standardization of new power supplies has not kept pace with switching-mode power supply design technology. Application of new technology to power supply design and production can result in meeting the power density requirements while in fact increasing the reliability.

Examples of qualifiable components for power supply applications include higher power Schottky diodes, bridge diode assemblies, highly integrated regulator circuits, analog optical isolators, metalized polypropylene capacitors, printed wiring board connectors, isolated-case power transistors and power field effect transistors. Until such are qualified as military standard, their use requires the exercise of existing government procedures for nonstandard component approval. The use of nonstandard components in switching-mode power supplies should not be prohibited, provided there are at least two independent sources.

INPUT POWER SPECIFICATIONS

Program management needs to be aware of the tradeoffs involved in specifying input power so that system requirements can be met without placing an excessive burden upon the power supply or power supply design activity. There has been a trend towards requiring individual equipment to operate from a large variety of power sources. This has increased the complexity of the design approach, making the objectives of increased output power density and reliability more difficult while simultaneously dissipating investment monies and highly skilled manpower resources. Imposing the requirement to interface with various prime power inputs and provide multiple regulated output voltages reduce overall power density and can have a detrimental impact on reliability.

The tradeoffs for equipment for single-platform use are relatively simple. The shipboard choice indicated by a formal tradeoff study almost always results in the use of 60 Hz, 3-phase power at either 115 VAC or 440 VAC, the latter being stepped down in the system to 115 VAC or some DC voltage, such as 155 VDC; i.e., the voltage obtained from off-line rectification of 3-phase 115 VAC. The aircraft choice almost always results in 400 Hz, 3-phase, at 115/200 VAC with consideration given to future 270 VDC operation. If local off-line rectification is used, there is a need to ensure that the total contribution from the equipment meets the 3% harmonic current requirement for shipboard systems as found in MIL-STD-1399 SECTION 300.

See Appendix C for a detailed discussion.

Selecting the best multi-platform power supply architecture is a fairly complex task and beyond the scope of these guidelines, but the following ground rules minimize the burden on the power supply:

(1) Optimize for aircraft power since the size and weight of the power supply contribution to avionics usually has a greater impact on overall system performance than it does for ships. One of the required input voltages for multi-platform equipment would then be 400 Hz, 3-phase, 115/200 VAC with strong consideration given to operating from 270 VDC.

(2) Design to interface with 60 Hz, 3-phase, 440 VAC or 115 VAC shipboard power such that the system meets the 3% harmonic current requirement for shipboard systems.

(3) Eliminate or minimize the need to interface with input power having any other characteristics.

The preceding ground rules should be applied by a program manager to help minimize the burden placed upon power supplies by multiple input power requirements until other approaches are developed or become mature.

Noninterruptable power is not a requirement set forth by any military standard but is an equipment specification levied by the procuring agency. The two most commonly specified prime power interrupt times, through which the equipment is required to continue operating, are 10 to 300 microseconds and 20 to 150 milliseconds. At the present time, the requirement to operate through the lesser interrupt does not impact the power supply significantly.

STANDARDIZATION

Presently, nearly every power supply applied within a Navy system was or is being uniquely packaged. To a large extent, this is unnecessary and often occurs because the procuring activity is unaware of the design and manufacturing impact of even small differences between power supply specifications. Power supply standardization is an approach to achieving high reliability with an affordable expenditure of resources. Standardization can make available a family of high reliability power supply designs that would reduce the cost and expedite the acquisition of Navy electronic systems. By limiting the proliferation of unique power supplies, logistic support could also be significantly improved.

Standardization would (1) partition power supplies in a manner which allows for commonality among a majority of equipment applications; (2) provide a rigorous quality program to ensure interchangeability and reliability: (3) establish basic requirements compatible with the majority of Navy electronic system applications and environments; (4) reduce recurring development costs and ease the logistic support burden by extensive intersystem commonality of a limited number of power supplies; (5) provide established mechanical packaging having flexibility for growth; and (6) develop functional specifications to avoid dependence on specific technology.

DESIGN REVIEWS

Design reviews can be powerful tools for the procuring agency to (1) maintain visibility of the status and progress of the power supply development to meet the specified requirements and (2) initiate corrective action if warranted. However, in order for a design review to be effective, it must be timely, expertly staffed and have an effective agenda.

The best intentions of program managers, with regard to power supplies in their systems, are for naught if they are unable to evaluate and therefore manage the status of the system at a level of technical detail adequate to identify noncompliance to the design and manufacturing guidelines outlined in this publication.

Design reviews should be timed to the completion of major milestones of the power supply development. Rather than establishing firm dates for the design reviews at program start, some flexibility in scheduling should be provided such that the activities associated with the milestones are indeed completed. The Navy or prime contractor may take appropriate action if a significant schedule slippage is indicated.

The quality and effectiveness of the design review is directly dependent upon the technical qualifications of the review team members. Technical incompetence can lead to misunderstanding, irrelevant questions and issuance of unnecessary action items. The Navy program manager should enlist the assistance of a team of power supply electrical, thermal and structural specialists, to assist in the design review. A design review checklist can be a significant aid to the review team in ensuring that every important issue is addressed. Detailed sample checklists are included in this publication as a guide (Appendices A and B).

An agenda should be generated and agreed upon by the Navy and the contractor well in advance of the design review. The agenda should delineate the items to be covered and should include the format in which the information will be presented. Once the design review date is established and an agenda agreed upon, a design review package should be provided to the procuring activity prior to the review in order that the members of the review team may become familiar with the task ahead and the material to be discussed.

Three and sometimes four design reviews are key program management tools in the material acquisition cycle: the Preliminary Design Review (PDR), the Critical Design Review (CDR), the Production Readiness Review (PRR) and at Navy option, the Preproduction Reliability Design Review (PRDR).

Additional design reviews may be conducted to reduce design risk.

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