PART ELECTRICAL STRESS ANALYSIS

Practice:

Every part in an electrical design is subjected to a worst-case part stress analysis performed at the anticipated part temperature experienced during the assembly qualification test (typically 75°C). Every part must meet the project stress derating requirements or be accepted by a formal project waiver.

Benefit:

Part failure rates are proportional to their applied electrical and thermal stresses. By predicting the stress through analysis, and applying conservative stresses, the probability of mission success can be greatly enhanced.

Programs That Certified Usage:

Voyager, Magellan, Galileo.

Center to Contact for Information:

Jet Propulsion Laboratory (JPL).

Implementation Method:

Electrical circuits are analyzed to determine the maximum stress on each part when all applied voltages or currents are maximized and when all variations of other parts in the circuit are set to that combination of minimum and maximum values that produce worst-case maximum stress. This requires a new choice of "other" part combinations in the circuit each time the stress on a new part is determined. The stresses are aggravated by imposing maximum operating temperature when comparing the part stress to its required derating. The initial analysis usually is made without benefit of a detailed part level thermal analysis; therefore, a conservative temperature assumption is made. Highly stressed parts are identified for possible replacement with more robust parts or for possible circuit changes. The final design is confirmed by analysis, with part temperatures based on a part level thermal analysis, and with voltages and currents derived from either specification limits or the results of worst-case circuit analysis.

Technical Rationale:

Numerous life tests have been performed on electrical parts that establish the relationship of part life to applied stresses. There is a very strong dependence. The life expectancy typically can be doubled or tripled by operating at half the manufacturers full rated (100 percent) stresses, which typically are commensurate with a 10,000-hour life expectancy. Complex, multiple year missions must achieve

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very low part failure rates to achieve mission goals; therefore, operation at derated conditions is mandatory. Although typical reliability predictions are based on nominal stresses, circuit nonlinearities and part and voltage variations can cause large operating point variations. Therefore, it is essential that the conservative approach of using worst-case stresses be implemented as standard practice.

Although average temperatures during a mission may be nominal, typical qualification test philosophy results in test temperatures that stress the design to assure margin against possible flight contingencies (typically 75ºC). It is essential that negligible aging of the parts be introduced during protoflight testing to assure mission reserve life. For this reason, it is prudent to show that the deratings are met while operating in the worst qualification or protoflight test environment. Historical evidence has shown that significant (>40°C) temperature rises can exist between the thermal mounting surface of an assembly and the part body if good thermal design of the assembly is not rigorously pursued. For this reason, the results of a part level detailed thermal analysis must be an input to the part stress analysis.

In summary, the stress derating requirements of every part at worst-case circuit conditions and contingency temperatures must be met. This will ensure a design that will function with a high degree of confidence at these extremes. It also will force a conservative thermal design (small temperature rises), which will produce even greater mission life margins under the expected nominal flight conditions.

Impact of Nonpractice:

The failure to perform part stress analysis likely will result in several overstressed parts in the design. These will become the life limiting items of the design and produce unacceptably short-lived hardware. If the analysis is performed at nominal temperature and operating points, without derating, or without a detailed thermal analysis, there will be no margin for contingencies and the nominal life expectancy also will be degraded.

Related Practices:

1. *Part Junction Temperature*, Practice No. PD-ED-1204.