Application Note AN-1078

An Examination of Changes Imposed by Revised Hybrid Models When Calculating MTBF Values using MIL-HDBK 217F, Notice 1 & 2

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1. **Resistors:** Originally included in MIL-HDBK-217E, the mechanism for calculating the failure rate of hybrid thick-film substrate resistors has been eliminated from MIL-HDBK-217F. Since these resistors are an integral part of the hybrid substrate and are generally more reliable than the Established Reliability types used in non-hybrid circuits, they are considered to have a negligible effect on the overall failure rate and therefore, AA considers their exclusion justified. The hybrid model of 217F recommends that resistors not be included except when a hybrid is principally composed of passive components. As applied to DC/DC converters, AA concurs with this assessment. Including resistive elements in the calculation of MTBF has negligible effect on the calculated value.

2. **Capacitors:** The hybrid model presented in MIL-HDBK-217F assumes a

quality factor (π_Q) of 1.0 for each component and then applies an overall π_Q of 0.25 to a class K hybrid. In the ART, the majority of ceramic chip capacitors incorporated are CDR types procured with a reliability level of 'S'. The π_Q given by MIL-HDBK-217F for CDR capacitors is 0.03, a value 1/8.3 times the π_Q of 0.25 allowed for use in a hybrid. AA believes that no justification exists for penalizing the failure rate of such capacitors by boosting① the quality factor by 8.3 times solely because they are used in a hybrid. Where noted in the attached table, a correction factor of 0.03/0.25 = 0.12 has been applied to the failure rate of all CDR type capacitors in order to override this penalty.

In the original data sheet for the ART2815T, MTBF was calculated using MIL-HDBK-217F Notice 1. Extensive revisions were made in 217F Notice 2 to simplify the capacitor failure rate calculation. These revisions tripled the failure rate of CDR type capacitors. This change alone reduces the ART MTBF by 30% when comparing Notice 1 and Notice 2 versions of 217F.

3. **Magnetics:** All magnetic components used in AA DC/DC converters are constructed from materials rated for 200°C or higher. Derating per MIL-STD-975 limits the operating temperature to 150°C. The power transformer for the ART2815T has a measured hot spot temperature less than 33°C above the case temperature (when measured with a case temperature of approximately 100°C). All other inductive devices have a temperature rise of from 5° to 15°C above case. There are no known incidents of a field failure caused by a magnetic component in the ART type DC/DC converters. According to Seymour Morris of ROME Laboratory, the hybrid model created for 217F was not designed to include magnetic/inductive components and suggests that they not be included unless the circuit consists largely of passive components. Consequently, the ART data sheet MTBF was calculated per 217F Notice 1 ignoring the contribution of the magnetic elements. AA now believes that all magnetic components should be included in the calculation but should not be burdened with the additional function factor π_F. Where noted in the attached table, a correction factor of $1/\pi_F$ has been applied to the failure rate of the inductive components to yield an effective π_F = 1.0.

① An increase in quality factor (π_Q) represents a decrease in MTBF.

4. **Function Factor, π_F**: The data used for creation of the 217F, Notice 1 hybrid model which led to the function factor (π_F) of 21 for power hybrids was collected largely from one hybrid manufacturer and consists mostly of process related failures involving seal, substrate attach, die attach and aluminum/gold intermetallic bonds. For AA DC/DC converter products which utilize qualified materials and processes (including industrial and military products representing tens of thousands of units shipped), there has been no known incident of any of these types of failures in the field. This includes the ART type converters and numerous other DC/DC products termed class H+ (class H compliant with class K screening). AA believes that classification as power hybrids imposing a function factor of 21 forces a high penalty on DC/DC converters not justified by experience. Since DC/DC converters are principally linear control circuits with few power components, the MTBF chould be calculated using a function factor of 5.8 (linear). For comparison purposes, a calculation globally applying p_F = 21 and another applying a π_F = 21 to the power devices and π_F = 5.8 applied to the balance of the circuit is presented in options 4 & 5.

Table I.
Comparison of Failure Rate Calculations for ART2815T

Option #	Conditions, Assumptions & Exceptions (Env. = SF, T_C = 45°C, V_{IN} = 28V)	Failure Rate (per 10^6 Hours)	MTBF (Hours)
1	MIL-HDBK-217E Seal Perimeter = 8.75" Area = 1.742 $in.^2$ Bimetal interconnects = 155 Resistors = 62	0.191775	5,214,439
2	MIL-HDBK-217F Notice 2 π_F = 1.0 for Magnetics π_F = 5.8 all other devices π_Q = 0.03 for CDR capacitors	0.189660	5,272,594
3	MIL-HDBK-217F Notice 2 π_F = 5.8 all devices (incl. Mags.) π_Q = 0.03 for CDR capacitors	0.353735	2,826,973
4	MIL-HDBK-217F Notice 2 π_F = 1.0 for Magnetics π_F = 21 for Power Semiconductors π_F = 5.8 all other devices π_Q = 0.03 for CDR capacitors	0.355031	2,816,651
5	MIL-HDBK-217F Notice 2 π_F = 21 all devices (incl. Magnetics.) π_Q = 0.03 for CDR capacitors	1.28077	780,783

Conclusions: A comparison of MTBF values calculated using MIL-HDBK-217E and MIL-HDBK-217F Notice 2 shows a dramatic decrease in the calculated value. A detailed investigation of the model created for 217F Notice 2 provides substantial cause to question the assigned value of certain p factors and their application in the model. Calculated failure rates and justifications are presented for several altered factors. AA reliability engineers believe that one of the first four conditions selected from Table I above more reasonably represents an accurate model for calculation of MTBF for power DC/DC converters. For consistency of Rev F with Rev E calculations, Option 2 presents the most similar results.

AA welcomes any comments, questions or suggestions. Details supporting any of the calculations listed above are available on request.