## Equivalence Methods for Shock Testing

By Tom Irvine Email: tomirvine@aol.com

June 12, 2012

## **Introduction**

Shock fatigue analysis of electronic components is difficult for the reasons given in Reference 1. The leading concerns are the unknown fatigue exponent and nonlinear effects.

Now consider a component which must withstand thousands of field shocks. Assume that a shock response spectrum (SRS) level has been derived to cover these events. Call this the maximum expected level. It could be derived as a maximum envelope of measured events, or it could be taken as the P95/50 level using the factors in References 2 and 3.

Further conservatism is needed for establishing a qualification level, such as the P99/90 level recommended in Reference 3, Appendix B. Some thought should be given as to whether the underlying distribution is lognormal for this approach.

Next the component must be subjected to qualification shock testing in order to verify that it can withstand the field environment.

The purpose of this paper is to give a method by which a higher level may be substituted for the qualification level to allow a fewer number of shocks in the test lab.

## **Scaling Equation**

The following equation is taken from Steinberg, Reference 4, section 8.25, page 238. It is intended for sine and random vibration. Assume that it can also be used for shock testing.

$$T_{1}G_{1}^{b} = T_{2}G_{2}^{b}$$
(1)

Each G value is in terms of GRMS. Assume that G could also be the peak G SRS level.

Each T value represents test time. Assume that T represents the number of hits for shock testing.

Furthermore, the exponent b is taken as 6.4 for PCB-component lead wires. This number is derived in Reference 3, section 7.3, page 177. It represents generic metal. It is used in Reference 2 for both sine and random vibration.

## Recommendation

Selection of the fatigue exponent requires a great deal of engineering judgment. A smaller fatigue exponent is more conservative for the problem at hand.

Assume that b=6.4 as discussed previously. The numbers of field shock events covered by a single test shock are given for four amplitude increase cases in Table 1, as calculated using equation (1).

Table 1. Number of Field Shocks Covered by One Test Shock, b=6.4				
Level Increase	3 dB	6 dB	9 dB	12 dB
Amplitude Multiplier	$\sqrt{2}$	2	$2\sqrt{2}$	4
Number of Field Shocks	9.1	83	759	6918

The level increase is with respect to the qualification level.

## Cautionary Notes

Again, caution must be exercised, particularly with the fatigue exponent.

In addition, this approach did not consider any endurance limit, or other effects which would cause the fatigue exponent to vary with the number of shock events.

Extensive "test-to-failure" testing would be required to identify an appropriate fatigue exponent for a given component. See Reference 1 for a rough example.

There are numerous potential sources of nonlinearities including damping. Damping tends to increase as the base input level increases for shock events, due to joint slippage, etc.

Furthermore, the potential failure mode at, say, a 12 dB increase for one test shock may be different than that for 6918 field shocks at a lower level.

As an example, there could be a loss-of-clearance failure due to excessive relative displacement with the 12 dB increase that would not occur in the field.

# **References**

- 1. T. Irvine, Low-Cycle Shock Fatigue of Electronic Components, Revision B, Vibrationdata, 2011.
- 2. T. Irvine, Normal Tolerance Factors for Upper Tolerance Limits, Vibrationdata, 2010.
- 3. T. Irvine, Uncertainty Margins in Aerospace Vibroacoustic Levels, Revision E, Vibrationdata, 2010.
- 4. Dave Steinberg, Vibration Analysis for Electronic Equipment, Second Edition, Wiley-Interscience, New York, 1988.