Application Note

Reliability MTBF Assessment for the VRG8601/2 Rad Hard Dual Adjustable Positive & Negative Voltage Regulator

SUMMARY

The VRG8601/2 series feature an adjustable output from ±1.2V to +37V & -27V while delivering 1.5Amps to the load and includes current limiting, output short circuit protection, and thermal shutdown capability. The VGR8601/2 is a hybrid microcircuit containing a positive and negative regulator chip (RH117 & RH137). Each regulator requires two (2) external resistors to set the output voltage. A description of the entire product performance can be found in the standard product data sheet at http://ams.aeroflex.com/productfiles/datasheets/power/8601-04datasheets.pdf.

Life test data has been obtained for the VRG8601/2 following an accelerated burn-in temperature test conditioning with an accumulated test time of 4,201,716 hours. At present the life test data demonstrates a Mean Time Between Failure (MTBF) of 1.076 x 10^9 hours at the 95% Confidence Limit (CL), i.e. only a 5% risk of the MTBF being a lower value.

FIT: Failure-in-Time is also a measure of failures over time and is derived by multiplying Failures/10^6 x 10^{+3}.

Qualification details are stored at Aeroflex and can be reviewed at customer request.

INTRODUCTION

Reliability is defined as a measure of probablility of success and is given by the following exponential equation:

$$R = e^{-\lambda(t)}$$

However, $\lambda(t)$ by definition is a measure of the unit failure rate and relates more to the Reliability function and MTBF. Therefore the VRG8601/2 probability of success for any given mission can be calculated given the mission time (t).

ACCELERATED STRESS TESTING

Because certain devices undergo extensive pre-production screening and testing, temperature-accelerated stresses are needed to observe some failure pattern within a reasonable time period.

The relationship between stress and time to failure for a given product is determined by the activation energy and the Chi-Square failure distribution. Activation energies (E_a) are determined from extensive accelerated stress testing which is usually performed at the time a failure mechanism occurs. In many instances the device reliability is estimated by using an approximation of a composite of activation energy values, however, if no failures are recorded within the life test of the unit under test, then an activation of 1.0eV is assumed as a default and is the one considered for this report. Some common failure mechanisms are listed in Table I as a reference.

TIME-TEMPERATURE RELATIONSHIP (ARRHENIUS EQUATION)

For many physical and chemical processes that lead to failure due to accelerated temperatures stressing, the acceleration factor (A_f) is the measure that describes this characteristic and is shown by the following equation below. The acceleration factor is a constant used in the reliability prediction process to express the enhanced effect of temperature on a device's failure rate. It is often used to show the difference or acceleration effect between a failure rate at two temperatures, i.e. the failure rate of a device operating at 125°C is approximately 5x greater that at 25°C.

Acceleration factor is given by the following equation:

$$A_f = e^{\frac{E_a}{K}\left[\frac{1}{T + Ta} - \frac{1}{T + Ts}\right]}$$

E_a = Activation Energy (eV) T_A = Operating ambient temperature

E_a = Activation Energy (eV) T_S = Stress ambient temperature

K = Boltzman constant T = 273^0 Kelvin

= 8.63×10^{-5} eV/°K

CHI-SQUARE SOLUTION DEFINITION

The FIT calculation including a Confidence Level is determined from the Chi-Square solution below:

$$Failure\ In\ Time\ (FIT) = \frac{ChiSquare}{2 \times T_{tt} \times N \times A_f} \times 10^9$$

T_{tt} = Total test time

N = # of units in test

A_f = Acceleration factor

The Chi-Square value is based on a particular type of statistical distribution (Chi-Square probability table reference: "Handbook of probability and statistics with tables by Burlington & May"). The application of a confidence interval therefore is a measure of how "confident" we are that the sample in question approximates that of the population. In this test the Confidence Limit is based on a time-truncated test with no failures noted.

CHI-SQUARE PROBABILITY TABLE VALUE

Chi-Square solution for the VRG8601/2:

n = "0" failures

Degrees of freedom = (2n+2), ∴ Degrees of freedom = 2

Confidence limit = 95% (5% consumer risk)

∴ ChiSq = 5.991

ACCELERATION FACTOR VALUE

The Arrhenius reliability solution for the VRG8601/2 hybrid voltage regulator below is based on a Single tail-time truncated test at the 95% CL with E_A = 1.0 and "0" failures.

Ambient temperature was measured at +25°C and stress level temperature was set to 125°C.

$$A_f = e^{\frac{E_a}{K}\left[\frac{1}{T + Ta} - \frac{1}{T + Ts}\right]}$$

Ta = 25°C *Ts = 125°C* *T (Kelvin) = 273°K*

K (Boltzman Constant) = 8.6171 x 10^{-5} *Ea (Activation Energy) = 1.0*

$$\mathbf{A_f = 17756.73}$$

TEST DEVICE HOURS

RH117 – Sample size = 1702 @ 1300 hours per device, 0 Failures

RH137 – Sample size = 1639 @ 1200 hours per device, 0 Failures

per Linear Technology Table titled "Reliability Data RadHard Devices " dated 6/18/04, Form: 00-03-6209B. R301 Rev 11.

HYBRID MICROCIRCUIT SOLUTION BASED ON MIL-HDBK-217

MIL-HDBK-217 Hybrid equation below:

$$\lambda_P = [\sum N_C \bullet \lambda_C] \bullet (1+.2\pi E) \bullet \pi F \bullet \pi Q \bullet \pi L$$

RH117

$$\lambda_1 = \left[\frac{Chi-Square}{2 \times (T_{TT1} \times A_f)}\right] \times 10^9$$

$$T_{TT1} = 2.19558 \times 10^6 = \text{Total Test Time}$$

$$\boldsymbol{\lambda_1 = FIT_1 = 0.076835}$$

RH137

$$\lambda_2 = \left[\frac{Chi-Square}{2 \times (T_{TT2} \times A_f)}\right] \times 10^9$$

$$T_{TT2} = 2.006 \times 10^6 = \text{Total Test Time}$$

$$\boldsymbol{\lambda_2 = FIT_2 = 0.08409}$$

HYBRID MICROCIRCUIT SPACE ENVIRONMENT

Learning Factor	πL	1
Space Environment	πE	.5
Quality	πQ	.25
Circuit Function	πF	21

$$\lambda_P = \left[\frac{(\lambda_1 + \lambda_2) \bullet (1+.2\pi E) \bullet \pi F \bullet \pi Q \bullet \pi L}{10^9}\right]$$

$$\boldsymbol{\lambda_P = .929 \times 10^{-9}}$$

$$\boldsymbol{\frac{1}{\lambda_P} = MTBF = 1.076 \times 10^9 hrs}$$

Table I – Typical Failure Mechanisms

Failure Mechanism	Activation Energy	Screening and Testing	Control
Oxide Defects	0.3 – 0.5 Ev	High Temperature Operating Life (HTOL) and voltage stress	Statistical Process Control of oxide parameters, defect density control and voltage stress testing
Silicon Defects (Bulk)	0.3 – 0.5 Ev	HTOL and voltage stress	Vendor statistical Quality Control and Statistical Process Control on thermal process
Corrosion	0.45 Ev	Highly Accelerated Stress Testing (HAST	Passivation dopant control, hermetic mold compounds and product handling
Assembly Defects	0.5 – 0.7 Ev	Temperature cycling, temp/ mechanical shock and environmental stressing	Vendor statistical Quality Control and Statistical Process Control of assembly process
Electromigration Al line Contact/Via	 0.6 Ev 0.9 Ev	Test vehicle characterizations at highly elevated temperatures	Design process groundrules to match measured data, statistical contol of metals,photoresist and passivation
No failure	1.0 Ev	Non occurrence of a failure during life testing.	Default
Unknown failure	0.7 Ev	Unknown failure mechanism during the manufacturing process	

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