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 VRG8601/2 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 probability 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:

\[ A_f = e^{\frac{E_a}{K} \left[ \frac{1}{T + T_a} - \frac{1}{T + T_s} \right]} \]

\( E_a = \text{Activation Energy (eV)} \quad T_A = \text{Operating ambient temperature} \)
\( E_a = \text{Activation Energy (eV)} \quad T_S = \text{Stress ambient temperature} \)
\( K = \text{Boltzman constant} \quad T = 273^0 \text{ Kelvin} \)
\( = 8.63 \times 10^{-5} \text{ eV/}^0\text{K} \)
CHI-SQUARE SOLUTION DEFINITION
The FIT calculation including a Confidence Level is determined from the Chi-Square solution below:

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

\( T_{tt} \) = 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 = \((2n+2)\), \( \therefore \) Degrees of freedom = 2

Confidence limit = 95% (5% consumer risk)

\( \therefore \) 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.

\[
A_f = e^{\frac{E_a}{K} \left[ \frac{1}{T_a + T_a} - \frac{1}{T_s + T_s} \right]}
\]

\( T_a = 25^\circ C \) \hspace{1cm} \( T_s = 125^\circ C \) \hspace{1cm} \( T (\text{Kelvin}) = 273^\circ K \)

\( K (\text{Boltzman Constant}) = 8.6171 \times 10^{-5} \) \hspace{1cm} \( E_a (\text{Activation Energy}) = 1.0 \)

\( A_f = 17756.73 \)

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:*

\[ \lambda_P = \left[ \sum N_C \cdot \lambda_C \right] \cdot (1 + .2 \pi E) \cdot \pi F \cdot \pi Q \cdot \pi L \]

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

\[ T_{TT1} = 2.19558 \times 10^6 \]

\[ \lambda_1 = \text{FIT}_1 = 0.076835 \]

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

\[ T_{TT2} = 2.006 \times 10^6 \]

\[ \lambda_2 = \text{FIT}_2 = 0.08409 \]

**HYBRID MICROCIRCUIT SPACE ENVIRONMENT**

Learning Factor \( \pi L \) 1
Space Environment \( \pi E \) .5
Quality \( \pi Q \) .25
Circuit Function \( \pi F \) 21

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

\[ \lambda_P = .929 \times 10^{-9} \]

\[ \frac{1}{\lambda_P} = \text{MTBF} = 1.076 \times 10^9 \text{hrs} \]
## Table I – Typical Failure Mechanisms

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