Application Note

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Reliability MTBF Assessment for the ACT5028 16 Bit Monolithic Tracking RAD HARD Resolver-To-Digital Converter with the Arrhenius Solution

ABSTRACT

The ACT5028 converter is a Type II tracking resolver to digital converter fabricated in a single CMOS monolithic chip. It is implemented using precision analog circuitry and digital logic. For flexibility, the converter bandwidth, dynamics and velocity scaling are externally set with passive components. Life test data has been obtained for the RDC following an accelerated burn-in temperature test conditioning with an accumulated test time of 21,000 hours. At present the life test data demonstrates a Mean Time Between Failure (MTBF) of 6,500,000 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}.

INTRODUCTION

Reliability is usually given as a measure of probablility of success, 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 RDC 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, failure-accelerated stresses are needed to observe some failure pattern within a reasonable time period. Also noted in the absence of any failure is the time-truncated test to evaluate accelerated stress testing.

The relationship between stress and time to failure for a given product is determined by the activation energy and the ChiSquare failure distribution used to describe a failure mechanism and is also a key component in the Arrhenius algorithm. Activation energies (E_a) are determined from extensive accelerated stress testing, usually done at the time the failure mechanism occurs. In many instances the device reliability is estimated by using an approximation of a composite of activation energy values. Studies of infant mortality data over a period of time indicate a low activation energy for failure mechanism, while recent data indicates a value of 0.55eV is most appropriate for establishing time-temperature trade-off in screening for infant mortality failures. An activation energy of 0.7eV is generally assumed as an average activation energy for times beyond the early stages of infant mortality failures and is the conservative value considered for this evaluation, reference Table I.

TIME-TEMPERATURE RELATIONSHIP * (ARRHENIUS EQUATION)

For many physical and chemical processes that lead to failure due to accelerated temperatures stressing, the acceleration factor is described by the following equation. 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 likely to be 5x greater that at 25°C.

Acceleration factor (A_f) 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)

K = Boltzman constant

= $8.63\text{x}10^{-5}$eV/°K

T_A = Operating ambient temperature

T_S = Stress ambient temperature

T = 273^0 Kelvin

Because of the small random sample chosen to determine its reliability a statistical analysis with associated confidence limits is then necessary to express the MTBF.

This number expresses the confidence level that the actual failure rate of the lot will be equal to or lower than the predicted failure rate. The failure rate calculation, including a confidence level, is determined per the ChiSquare Solution below:

CHISQUARE SOLUTION

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

T_{tt} = Total test time

N = # of units in test

A_f = Acceleration factor

The ChiSquare value is based on a particular type of statistical distribution. 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.

* http://weibull.com/AccelTestWeb/arrhenius_relationship_introduction.htm

Therefore:

The Arrhenius solutions below was based on a Single tail time truncated test at the 95% and 90% CL with $E_A = 0.7$.

ChiSquare degrees of freedom as measured by (2n+2); [1-.95] 5%Risk, Consumer Risk → '0' failures.

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

Lot sampling included the following:

5 units in Group C2 testing for 1320 hrs/unit

6 units Lot Acceptance Testing (LAT) (Room-Hot-Cold) at 1240 hrs/unit

22 units Lot Acceptance Testing (LAT) (Room-Hot-Cold) at 320 hrs/unit

Total Test Time = 21,080 hrs

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

$A_f = 933.486$

95% Confidence level

Single Tail time-truncated test as measured by ChiSquare (2n+2) = 1 - CL = 1-.95 → 5%Risk, Consumer Risk '0' failures, DF = 2.

$$FIT = \left[\frac{chisq}{2 \times (T_{tt} \times A_f)}\right] \times 10^9$$

ChiSq = 5.991

FIT = 152.2

MTBF = 6.569 x 10^6 hrs

90% Confidence Level

ChiSq = 4.605

FIT = 117.01

MTBF = 8.546 x 10^6 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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