QUICKLOGIC RELIABILITY MONITOR

INTRODUCTION

In order to guarantee that the high standards of reliability and quality required by QuickLogic, an ongoing Reliability Monitor Program has been established.

Individual product and package monitors are generally developed by identifying a process driver device (in most cases the same device used to qualify a process / product / package family). Once the process driver device is identified, the appropriate stress test programs are put in place to adequately monitor the ongoing process average of the specific family. This process average measurement is made by understanding the reliability and quality results of individual samples from production material. The latest production material is assembled and samples are pulled at the outgoing QA portion of the production flow, then randomly placed into specified reliability tests. These tests include early failure rate studies and dynamic long-term life test.

Monitor testing is completed on an ongoing quarterly cycle. Test results are subsequently made available in quarterly cycles. This report details all test results received for the previous quarter, outlining the reliability data associated with all process / package family types. With all of this data, an effective ongoing monitoring method is established which is capable of identifying reliability trends associated with all process/ product/ package families.

RELIABILITY DATA ANALYSIS

Reliability is the probability that a semiconductor device will perform its specified function in a given environment for a specified period. In other words, reliability is quality over time and environmental conditions. The most frequently used reliability measure for semiconductor devices is the failure rate (λ). The failure rate is obtained by dividing the number of failures observed by the product of the number of devices on test and the interval in hours, usually expressed as percent per thousand hours or failures per billion device hours (FITS). This is called a point estimate because it is obtained from observations on a portion (sample) of the population of devices. To project from the sample to the population in general, one must establish confidence intervals. The application of confidence intervals is a statement of how ''confident'' one is that the sample failure rate approximates that for the population. To obtain failure rates at different confidence levels, it is necessary to make use of specific probability distributions. The chi-square ($\chi 2$) distribution that relates observed and expected frequencies of an event is frequently used to establish confidence intervals. Chi-square values for 60% confidence intervals for up to 12 failures are shown in Table 1. The relationship between failure rate and the chi-square distribution is as follows:

$$\lambda = \frac{\chi 2\ (\alpha,\ d.\ f.)}{2t}$$

Where:
λ = failure rate
$\chi 2$ = chi-square function
α = (100 – confidence level) / 100
d.f. = degrees of freedom = 2r + 2
r = number of failures
t = device hours

Table 1. Chi–Square Distribution Function 60% Confidence Level

No of Fails	$\chi 2$ Quantity
0	1.833
1	4.045
2	6.211
3	8.351
4	10.473
5	12.584
6	14.685
7	16.780
8	18.868
9	20.951
10	23.031
11	25.106
12	27.179

The failure rate of semiconductor devices is inherently low. As a result, the industry uses a technique called accelerated testing to assess the reliability of semiconductors. During accelerated tests, elevated stresses are used to produce, in a short period, the same failure mechanisms as would be observed under normal use conditions. The objective of this testing is to identify these failure mechanisms and eliminate them as a cause of failure during the useful life of the product. Temperature, relative humidity, and voltage are the most frequently used stresses during accelerated testing. Their relationship to failure rates has been shown to follow an Eyring type of equation of the form:

$$\lambda = A \exp(\phi kT) * \exp(B/RH) * \exp(CE)$$

Where A, B, C, ϕ, and k are constants, more specifically B, C, and ϕ are numbers representing the apparent energy at which various failure mechanisms occur. These are called activation energies. ''T'' is the temperature, ''RH'' is the relative humidity, and ''E'' is the electric field. The most familiar form of this equation deals with the first exponential term that shows an Arrhenius type relationship of the failure rate versus the junction temperature of semiconductors. The junction temperature is related to the ambient temperature through the thermal resistance and power dissipation. Thus, we can test devices near their maximum junction temperatures, analyze the failures to assure that they are the types that are accelerated by temperature and then by applying known acceleration factors, estimate the failure rates for lower junction.

Known failure modes have various activation energies. QuickLogic uses a 0.7 eV activation energy to calculate the acceleration factor.

The semiconductor industry generally reports the failure rate at a 60% confidence level. Table 2 shows the QuickLogic reliability monitor results by quarter. As shown in Table 1, zero failures give a non zero $\chi 2$ value. The calculated failure rate with zero failures is a function of the number of devices and hours tested, with the larger samples result in a lower calculated failure rate.

Table 2 Quarterly Reliability Monitor Results

	Q1 '98	**Q2 '98**	**Q3 '98**
Units tested	250	100	200
Units failed	0	0	0
FIT at 60% confidence	32	80	40
FIT Goal	100	100	100
EQ Device-Hr	$2.8x10^7$	$1.1x10^7$	$2.2x10^7$