

# Sample RDT report

## Reliability Demonstration Test



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# 1 Reliability Demonstration Test

## 1.1 Executive Summary

A reliability demonstration test was conducted to verify the product meets its product specification of a mean time between failures (MTBF) of 200,000 hours. The test was conducted over a 3-month period at Percept Technology labs starting in June 2001. The product specification requires the product to be operated continuously performing data transfers. In order to design a test to verify this specification, a mathematical model based on statistical analysis was used. Since the product performance during the test was unknown, a chart, which showed the required total test time based on the performance of the product, was created. A further requirement of the test plan was to ensure that test results would predict overall product performance with a minimum of a 90% confidence.

The model required the total test time to be well in excess of the specification to ensure this level of confidence was met. The chart of the model provided three regions accept, continue testing, discontinue testing; by plotting the product performance vs. total test time an analysis of the test results could be updated as the test progressed. Also, if the product had a performance issue a decision on continuation of the testing could easily be made. The product executed the entire test plan without a performance issue and completed the test in the minimum required total test time of 8 weeks.

The test model chosen required the accumulation of a significant number of product usage hours. In this case, an equivalent of well over 500,000 hours of continuous data transfer operation was witnessed without incident. An accumulation of this magnitude is not time or cost effective without the use of an acceleration factor. Significant research and mathematical analysis has been expended to fully document the alteration of electronic components due to elevated temperatures.

The Arrhenius model has been used for over a century to document the acceleration of degradation due to temperature. The semiconductor industry has sponsored basic research to document the parameters of the Arrhenius model and has issued the results to the public domain for use in testing and product reliability demonstrations. This combination of a large test quantity, a small acceleration factor, and a substantial test period has provided a robust reliability demonstration of the product.

The reliability demonstration test parameters were chosen based on the mathematical model. But, they also provide some insight into the performance capabilities of the product due to the arduous nature of the test. The constant usage stress encountered under the test conditions is not likely to be found in normal customer operations. The utilization of constant stress, as required by the product specification, is also intended to provide some degree of confidence in the ability of the product to withstand less than continuous usage under room temperature conditions for much longer periods of time.

## 2 Test Definition and Configuration

### 2.1 Test definition

The reliability demonstration test is based on the Probability Ratio Sequential Test (PRST) chart above. Using an acceleration factor of 4, a product quantity of 100, and a confidence level of 90%, the PRST calculations show a minimum of 8 weeks of testing.

The chart, Figure 1, shows the bounds for a 90% confidence level. The left most line represents the point of test failure. Data in this region would indicate that the failure rate would be too high to allow the product to meet the design specification. The line on the right side represents the minimum points, with a 90% confidence, that would produce results which can be shown to be representative of failure rates less than that required by the product specification. The estimation of the distribution of the failures of the product was calculated using an exponential chi-squared distribution as described in MIL-HDBK-781-A. The lines intersect the x-axis at the minimum values of total test time.

The PRST chart is a conversion of the MTBF formula into a test length format. The MTBF formula, based on a chi-squared distribution is:

$$MTBF = \frac{2T}{X^2[\alpha, (2f + 2)]}$$

where:

T = total test time

$\alpha$  = significance level

f = number of failures

$X^2$  = chi squared statistic

Specifically, for this test, the following values were used.

MTBF = 200,000 hours

Confidence level = .9 = 1 -  $\alpha$  ; thus =>  $\alpha$  = .1

Degrees of Freedom, used in looking up the chi squared value, is 2f + 2

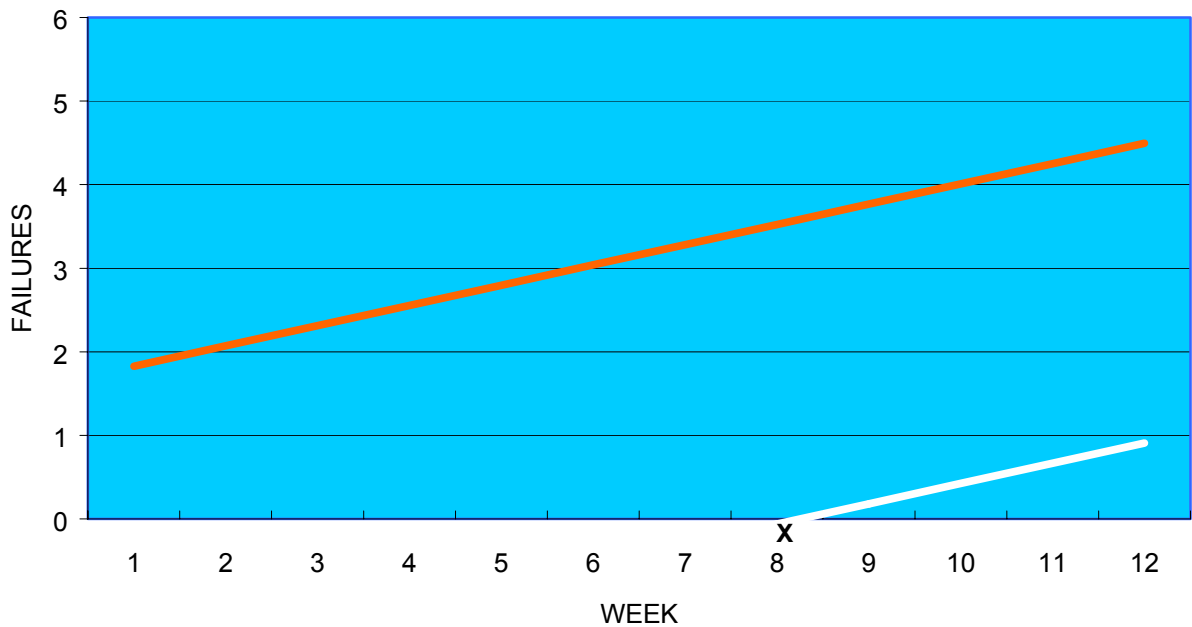
f = number of failures; thus, D.F. for f = 1 is 4

Table 1: The chi squared table for a significance level of .1

D.F.	$\chi^2$
1	2.706
2	4.605
3	6.251
4	7.779
5	9.236
6	10.646

Using the formula above and substituting in numbers of failures, (f), the chart below was calculated.

Figure 1: PRST test duration chart



The calculations use inputs of test units and product life. The x-axis intercept point, for the two lines shown on the chart, was calculated for the specific test parameters and thus was specific to this test design of 400 units and a MTBF of 200,000 hours. Two lines are shown on the chart to document the failure, continue testing, and accept regions.

Testing was done on 100 units using a temperature based acceleration factor. The Arrhenius method of modeling the affects of temperature has been used historically on electronic components to mathematically quantify the effects of temperature. The additional stress of temperature has been utilized in this testing to create a larger sample size for the analysis. Specifically, temperature was elevated by 20°C and the sample size, used in the calculation of the chart above, was 400 units.

The appendix contains documentation of the use of the Arrhenius model to derive an acceleration factor of 4.

In summary, the data input to the chi-squared formula for life test analysis was 400 units with a required product life specification, MTBF, of 200,000 hours. The calculation produced the chart, Figure 1, above. The testing was completed with no failures and was documented as complete once the minimum time specification of 8 weeks was met.

## **2.2 Test Configuration**

The units were powered from external power supplies. Test routines were run from an external computer and test results monitored during all of the testing.

The test systems were maintained at ambient temperature conditions outside of the product test area.

## **2.3 Thermal Test Area**

A test area was designed to house the 100 products and maintain a temperature of 38 +/- 2 deg C. Supplemental heat was applied as needed. A temperature controller operating a ventilation fan maintained room temperature.

Picture 1: Test control consoles outside thermal test area



## 2.4 Test Racks

The products were tested on wire racks with fans installed to maintain airflow. Fan performance data was used to ensure the product specification of 2 cubic feet per minute was met for all products during testing.

## 2.5 Write \ Read Test Hardware

The write and read testing utilized the Percept Technology RDT system, which runs on Intel Celeron workstations with processor speeds of at least 600 MHz. Each workstation has 256 MB of RAM and ran the Windows NT 4.0 operating system.

The Advansys 3940 SCSI card was used as the primary host bus adapter. The host pc contained 3 PCI slots. Each slot was filled with a 3940 card. Each HBA card drove 3 products. In total, each test pc contained 3 HBA cards with 3 products attached for a max of 9 products per pc.

*Picture 2: Test system startup*



## **2.6 Conditions monitored during RDT**

- Product and Host Bus and Command Protocol
- Read Errors
- Write Errors
- Mechanical failure
- Media Failure

## 3 Test Process

### 3.1 Reliability Test System Pre-Qualification

**Objective:** The system qualification is used to certify the hardware used in the reliability demonstration test.

**Date Tested:** June, 2001

**Test Engineer:** Michael Suzuki, Percept Technology

**Method:** Each PC based test system was tested with nine known good products to verify the proper connection of hardware and installation of software. Each test port must be capable of operating a product for one full write and read. Measurements of the voltage at each power connector were taken. Each product to be used in testing was assigned a serial number and tested to verify the product met manufacturing error rate specifications.

**Exit Criteria:** Voltages at 12 VDC and 5 VDC +/- .1 VDC. Product combinations meet error rate specification. A total of 100 qualified test ports and products verified.

**Test Results:** The test system was certified for use on June 21, 2001

### 3.2 Product Qualification

**Objective:** The product qualification was used to certify products used in the reliability demonstration test were free of infant mortality defects. This test was required due to the manufacturing process being in the early stages of development.

**Date Tested:** June 22-24, 2001

**Test Engineer:** Michael Suzuki

**Method:** The RDT product population of 100 products was run using the RDT system at ambient temperature for 72 hours.

**Exit Criteria:** A total of 100 products complete the test.

**Test Results:** All 100 products were certified for RDT.

### 3.3 Reliability Demonstration Test

**Objective:** The reliability demonstration test was used to validate the product's performance capability, using an acceleration factor, over time.

**Date Tested:** June 25 to August 20, 2001

**Test Engineer:** Michael Suzuki, Glenn Davis

**Method:** Utilizing the test system, all 100 products were operated continuously for the duration of the test. Daily status checks, without intervention, were performed to document the results. Weekly, the test was stopped to perform a cleaning operation. The write and read error rates were recorded for the previous week. The product was power cycled to clear the memory registers. Ten load cycles weekly or a total of 80 load cycles were performed.

**Documentation:**

A database was used to record the motion hours, serial number, and test slot assigned to each RDT product at the beginning of the test.

The room temperature was automatically recorded using a thermal couple hourly. It was monitored hourly until room temperature stability was achieved. It was reviewed twice daily subsequently.

Test logs were taken to record the weekly operations. They included: statistics from write and read testing, the power cycle of the product and verification of the supply voltages.

Any change of product, test slot, or incident, which requires restarting the test, was logged.

**Exit Criteria:** The test was complete after the accept region of the PRST graph is reached.

**Test Results:** Testing was completed after 8 weeks of operation without any failures. The RDT confirmed the MTBF specification of 200,000 hours.

## 4 Appendix

### 4.1 Arrhenius model calculation of the Acceleration Factor

The Arrhenius model, is defined by the equation

$$L(V) = C e^{\frac{\beta}{V}}$$

where:

$L(V)$  = quantifiable life measure

$C$  = model parameter

$\beta$  = model parameter

$V$  = stress level (absolute temperature)

For this test, the result required is the acceleration factor, which is

$$A_f = \frac{L_{use}}{L_{accel}}$$

Where  $L_{use}$  and  $L_{accel}$  are the Arrhenius calculations of the life duration at the given test temperatures. Thus, substituting terms to solve for  $A_f$ , the result is:

$$A_f = \frac{L_{use}}{L_{accel}} = \frac{C e^{\frac{\beta}{V_u}}}{C e^{\frac{\beta}{V_a}}} = e^{\left(\frac{\beta}{V_y} - \frac{\beta}{V_a}\right)}$$

For a given test condition, where  $V_{accel}$  is defined as the absolute temperature of the test case, the acceleration factor can be determined if the parameter  $\beta$  is known.

$$\beta = \frac{E_a}{K} = \frac{\text{activation energy}}{\text{Boltzman's constant}} = \frac{\text{activation energy}}{8.617385 \times 10^{-5} \text{ eV K}^{-1}}$$

The activation energy for integrated circuits has been established by the industry and published data is available. The following data was used:

Table 2: Activation energy of integrated circuits

<b>Failure mode</b>	<b><math>E_a</math> Activation energy</b>
Oxide Breakdown	0.3 - 0.5 eV
Corrosion	0.3 - 0.6 eV
Electro-migration	0.45 - 1.0 eV
Ionic Migration	0.6 - 1.4 eV
Assembly Defects	0.5 - 0.7 eV

The value of  $E_a$  selected from the data was 0.55. The acceleration factor calculated was 4.02 or 4.