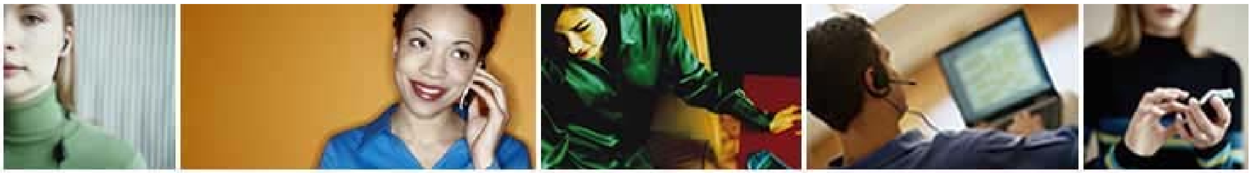


DragonWave APX/SDU Products

Failure Rate and MTBF Prediction

Author: Billy Wilson
Date: Dec 2, 2008

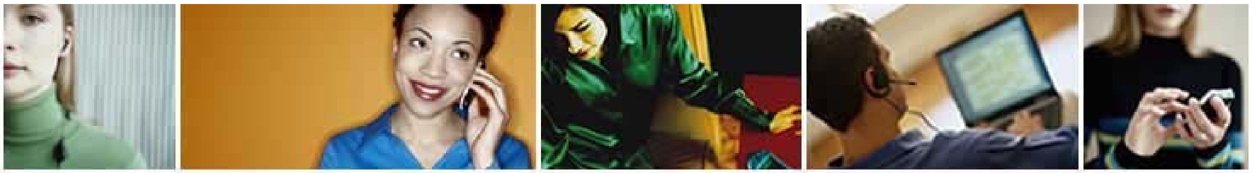
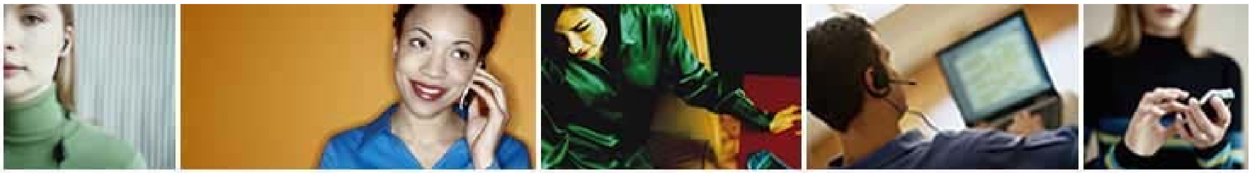


Table of Contents



1 Introduction

1.1 Project Definition

This document provides details of failure rate prediction work performed by DragonWave, Inc. It includes the scope of the work, the assumptions, and a results summary along with detailed results information.

This project involves performing a failure rate prediction based on the bill of materials (BOM) generated on December 2006 for the APX 104E and APX 108E, January 2008 for SDU DS-3, SDU-16 and SDU-155.

The prediction is performed in accordance with Telcordia standard SR-332 Issue 2 based on supplied component temperatures and stresses. Other environmental factors have been determined based on information supplied by DragonWave design and mechanical teams.

The following configuration architecture is considered:

- **All Indoor (IDU)**: Switch indoors.

The rack mounted Switch is operated indoor with a constant operating temperature.

1.2 Acronyms

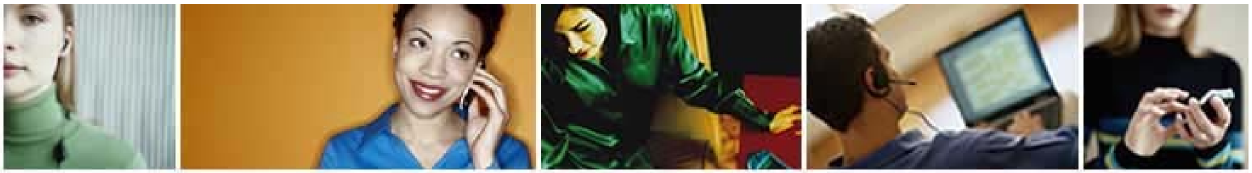
BOM	Bill of Materials
FITs	Failures per 109 hours
IDU	Indoor Unit
MRP	Material Resources Planning
MTBF	Mean Time Between Failures
APX	AirPair Extender
SDU	Service Delivery Unit

1.3 References

[1] Reliability Prediction Procedure for Electronic Equipment, SR-332, Issue 2, Sept 2006, Telcordia Technologies
[2] ETSI Standard, ETS 300 019-1-4: Equipment Engineering (EE); Environmental conditions and environmental test for telecommunications equipment.

2 Prediction Methodology

This failure rate prediction is performed according to Telcordia Standard, SR-332, “Reliability Prediction Procedure for Electronic Equipment.” SR-332 was originally



created based on the procedures in MIL-STD-217, but accounting for the failure rates and environments typical in telecommunication applications rather than military. This section provides some details of SR-332 relevant to the current activity.

2.1 Prediction calculation vs. Actual field data

The results published in this report are prediction values only and are not based on actual field data. DragonWave has historically seen actual field data performance that is 2-3 times better than the predicted values that we calculated with the prediction methods shown here in this report.

2.2 Parts Count Method

The Parts Count Method from SR-332 is used which assumes that the failure rate of a product is equal to the sum of the failure rates of the individual components that make up the product and can be expressed as:

$$\lambda_{PC} = \pi_E \cdot \sum_{i=1}^{n} \lambda_{SS}$$

Where

n is the number of different components in the unit.

π_E is the environmental factor based on the general environment in which the unit is installed.

The steady state failure rates for components are determined using the Black Box Method from SR-332 where the steady-state failure rate for the i^{th} component is based on a generic failure rate for the component multiplied by factors accounting for the component's quality and it's application. The steady-state failure rate is calculated as:

$$\lambda_{SS_i} = \lambda_{G\,i} \cdot \pi_{Q_i} \cdot \pi_{S_i} \cdot \pi_{T_i}$$

Where

$\lambda_{G\,i}$ is the generic steady-state failure rate for the i^{th} component

π_{Q_i} is the Quality Factor for the i^{th} component

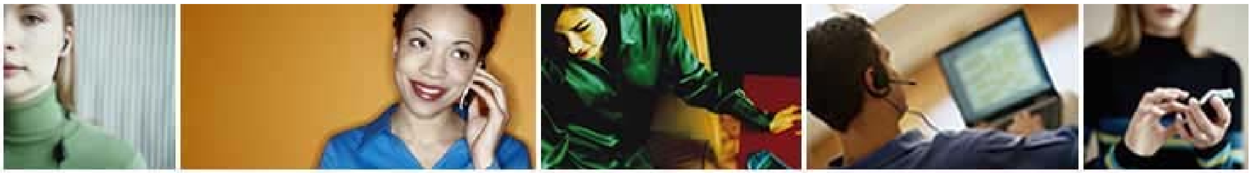
π_{S_i} is the electrical Stress Factor for the i^{th} component

π_{T_i} is the Temperature Factor for the i^{th} component

The generic failure rate and the various factors are discussed in the following sections.

2.3 Component Reliability

What Telcordia defines as the generic steady-state failure rate is the failure rate of a device of the typical quality used by most telecommunications providers and under



typical conditions in a telecommunications Central Office environment. This is a method of normalizing all components to a fixed set of conditions. As an example, it assumes operation at 40 °C with 50% of the maximum electrical load. Operation under other conditions is accounted for by the multiplying factors.

The generic steady-state failure rates are based to a large degree on field data in telecommunications environments, and so take into account factors such as the typical design and manufacturing quality of telecommunications equipment providers. For this reason, elements such as circuit boards and solder joints are not assigned failure rates, as their contribution is assumed to be reflected in the component failure rates.

Stating a failure rate prediction implies a certain mathematical level of confidence. The Telcordia steady-state failure rates are based on a 60% upper confidence level. This implies that there is at least a 60% chance that the actual failure rates will be less than the prediction.

2.4 Environmental Factor

The Environmental Factor takes into account the conditions into which the equipment is deployed. For this reason, a single value for the environmental factor applies to the entire calculation. Harsher environments have higher multiplying factors. Details can be found in Telcordia, SR-332, Table 9-5. Briefly, the environments are:

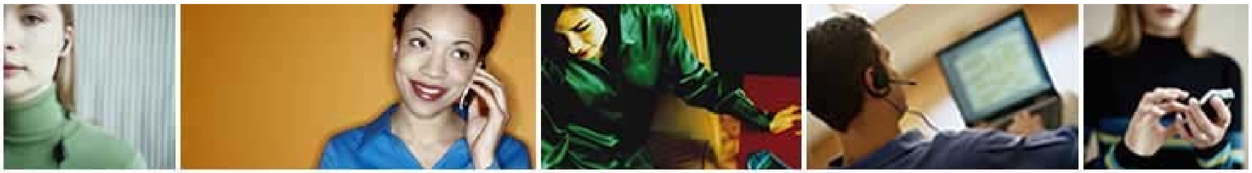
Ground, Fixed, Controlled
Nearly zero environmental stress - typical of Central Office or environmentally controlled shelters, vaults, or customer premise areas.

Ground, Fixed, Uncontrolled
Some environmental stress – typical of man-holes, poles, customer premise areas subject to shock, vibration or environmental variation.

Ground Mobile
Conditions more severe than Ground, Fixed, typically due to shock and vibration – typical of mobile phones, portable operating equipment, test equipment.

Airborne, Commercial
Conditions more severe than Ground, Fixed, typically due to pressure, temperature, shock and vibration - typical of the passenger compartment of commercial aircraft.

Space-based, Commercial
Low earth orbit with conditions as for Airborne, Commercial, but with no maintenance – typical of commercial communications satellites.



2.5 Quality Factor

The Quality Factor, represented by π_Q, reflects the quality of each component being used in a product. One of four levels (0, I, II and III) are assigned based on the quality of the component supplier and the procedures in place to ensure the quality of components received. Note that different component types in a design may have different quality levels. Telcordia, SR-332, Table 9-4 should be consulted for details. Following are a few key elements of each level:

Quality Level 0
Commercial-grade or re-worked components with no qualification or lot-to-lot control. Steps must be taken to ensure they are compatible with the application.

Quality Level I
Commercial-grade components without thorough qualification or lot-to-lot control. Steps must be taken to ensure they are compatible with the application and with manufacturing processes. An effective feedback and corrective action system must be in place for manufacturing and in the field.

Quality Level II
Requirements of Quality Level I, plus

- purchase specifications must identify important component characteristics.
- components and their manufacturers must be qualified and identified on approved parts/manufacturers lists.
- lot-to-lot controls with adequate AQL/DPM levels must be in place by equipment manufacturer of device supplier.

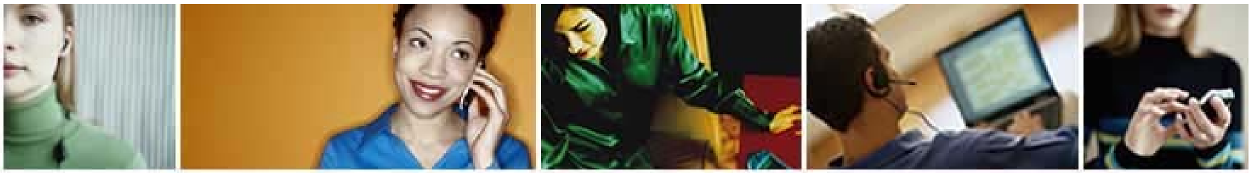
Quality Level III
Requirements of Quality Level II, plus

- periodic re-qualification of device families
- 100% screening (may be reduced to an audit if warranted)
- continuous improvement programs in place at device and equipment manufacturers

The usual expectation is that most telecommunications equipment providers should be operating at Quality Level II – a fact which is reflected in the multiplying factor for that level being 1.0. Other Quality Levels have higher or lower multipliers as appropriate.

2.6 Stress Factor - Electrical

The Electrical Stress Factor is based on the percentage of a component's maximum electrical rating under which it operates. The generic steady-state failure rates are normalized to an electrical stress factor of 50%, corresponding to a multiplier of 1.0.



The type of electrical stress which is relevant (power, voltage, current) depends on the type of component. For instance, capacitor electrical stress is dependent on voltage, whereas diode electrical stress is typically based on the applied current.

Electrical stress affects the failure rate of different components to differing degrees depending on the type of component – though they all follow an exponential curve. The following Figure 1 graph shows how electrical stress affects the failure rate of a few different components:

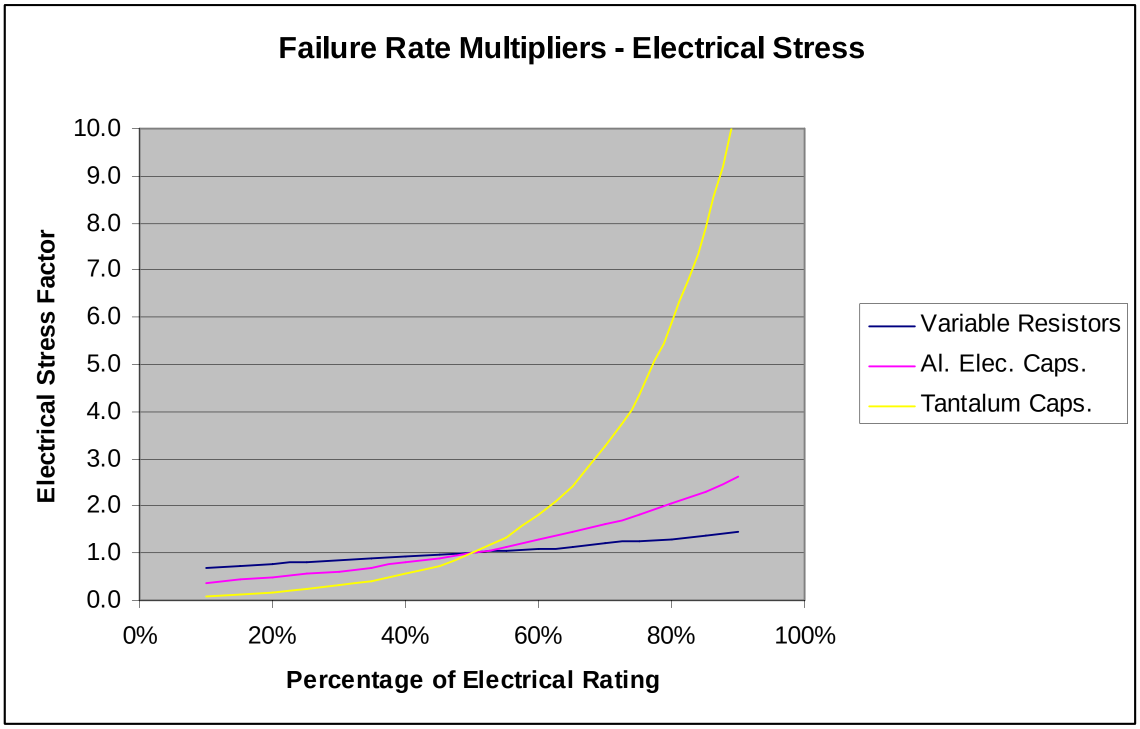
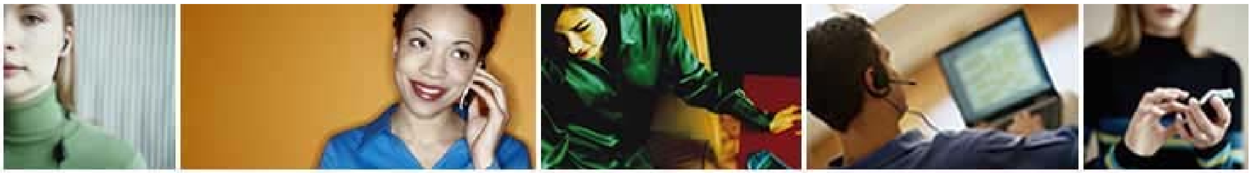


Figure 1 – Electrical Stress

We see that electrical stress has a very large influence on the failure rate of tantalum capacitors and a fairly small influence on variable resistors. Generally, no component should be operated at over 90% of its maximum electrical stress, but the graph shows a further advantage can be achieved by drastically de-rating certain components to minimize the total failure rate.

2.7 Temperature Factor

Similar to electrical stress, increasing temperature causes an exponentially increasing failure rate in components. The rate of failure rate increase with temperature is dependent on the type of component.



It should be noted the Telcordia, SR-332 specifies the temperature as being measured ½ inch above the component, and so the thermal resistance of the air as well as air-flow comes into play. The component case temperature provides a more accurate view of the component operating conditions, but this can be related to the air temperature as specified by making a few simple assumptions.

The following Figure 2 graph shows the effect of temperature on a few different components. Note that in this case, the increasing temperature stress affects aluminum electrolytic capacitors much more than it does tantalum capacitors. This is reverse of the case with electrical stress, so each component type must be considered individually when accounting for stress in the design.

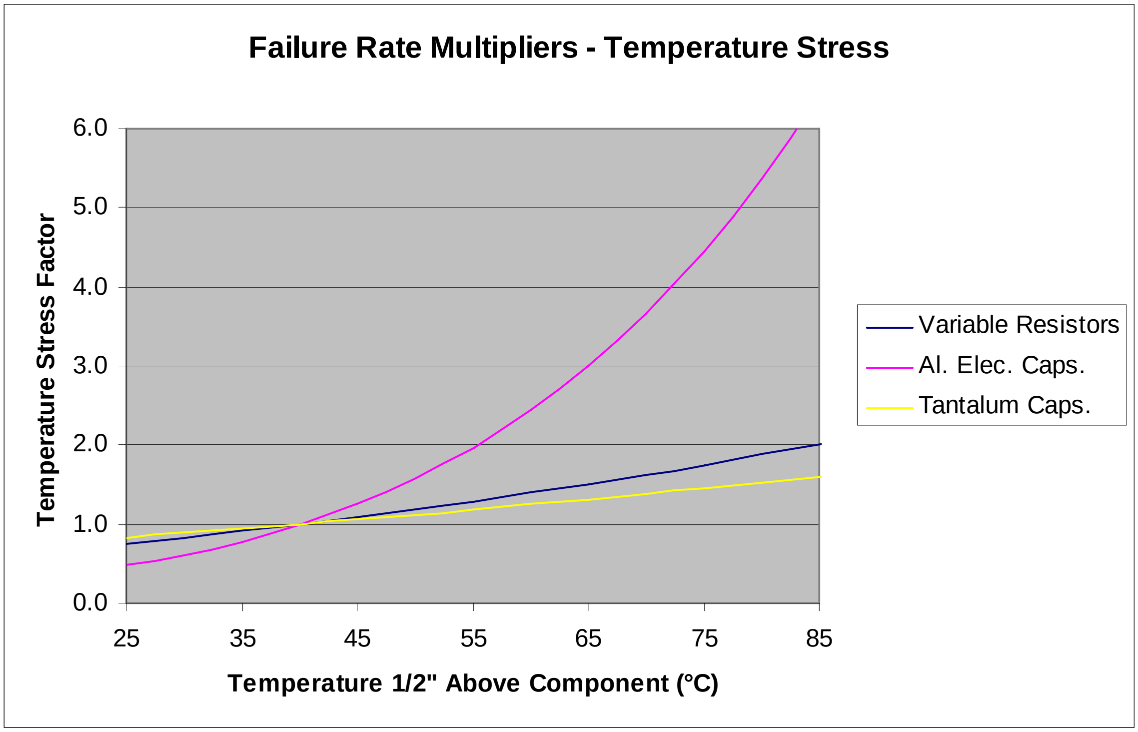
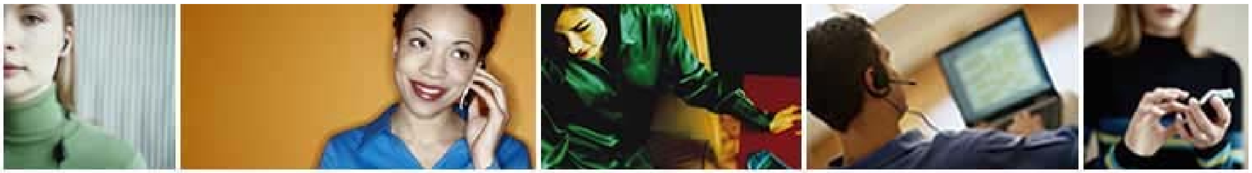


Figure 2 – Temperature Stress



3 Prediction Assumptions

3.1 Quality Level

Telcordia Quality Level II is assumed for all devices included on the BOM. As outlined in Section 9.3, this essentially dictates that there is a qualification program in place for the devices and for the device manufacturers along with lot-to-lot controls for the devices. Though a formal evaluation has not been done, DragonWave has demonstrated many of the elements of Quality Level II, and has stated its intent to comply with this level. As a result, Quality Level II will be used for all components in the prediction.

3.2 Environmental Factor

3.2.1 All Indoor (IDU)

The IDU Switch installation is used indoor (IDU) and an environment defined by Telcordia as “Ground, Fixed, Controlled”. Telcordia describes this environment as,

> “Nearly zero environmental stress - typical of Central Office or environmentally controlled shelters, vaults, or customer premise areas.”

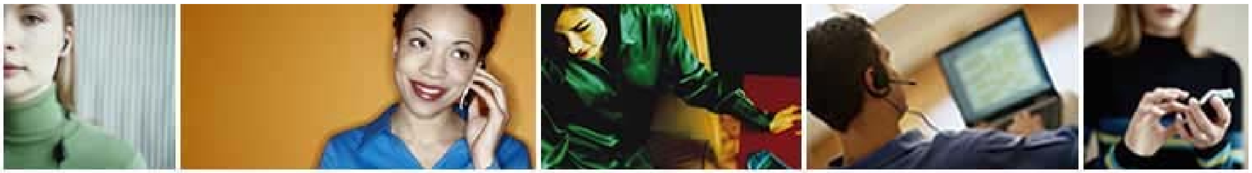
This implies an Environmental Factor of 1.0 as a multiplier for the failure rates of IDU Switch. Further detail on other Telcordia defined environments can be found in Section 9.4.

3.3 Operating Temperature & Temperature Stress

The prediction was performed and tabulated for a variety of ambient temperatures in accordance with an operating environment as specified in the ETSI standard, ETS 300 019-1-4. An average failure rate is also supplied based on typical varying temperature conditions.

The ETSI standard also requires operation at a low air pressure corresponding to an altitude of approximately 3000 m. At this lower pressure, the lower density of the air results in reduced cooling efficiency. This is particularly significant for long surfaces (1 m or more) and for those which use forced-air cooling. Fortunately, neither of these situations applies to either APX or SDU configurations. Further, air temperature is typically lower at higher altitudes – roughly on the order of 2 °C per 300 m. This reduction in temperature offsets the reduced cooling efficiency due to the lower air density. As a result, the effects of altitude are considered negligible for the current analysis.

For individual components, higher power components usually operate at higher temperatures. In these cases, the prediction for the corresponding components in the assembly should be adjusted accordingly to reflect the higher failure rate.



Correspondingly, any components operating at a lower temperature will have a lower failure rate. Depending on the components, variations of between 5 and 10 °C can readily be ignored.

Operating temperatures for the APX and SDU configurations were analyzed in cooperation with the DragonWave design and mechanical teams. The information available consisted of both thermal simulation results and actual measured data.

3.3.1 All Indoor (IDU)

The typical external ambient to internal ambient temperature rises of the APX 104E and APX 108E provided is 5°C, SDU-DS-3 provided is 6°C, SDU-16 is 6°C and SDU-155 is 7°C.

3.4 Electrical Stress

Electrical Stress applies to components such as resistors, capacitors, diodes, inductors, transistors, switches, and any component which has a voltage or current rating for which the applied load can vary widely. Higher or lower electrical stress levels would increase or decrease the failure rates accordingly. At no time should the stress levels exceed 90% of the maximum rating (see next section).

DragonWave typically operates passive components at 50% or less of their electrical ratings. This is consistent with the nominal Telcordia assumption and is used for components where stress was not determined through measurement or calculation.

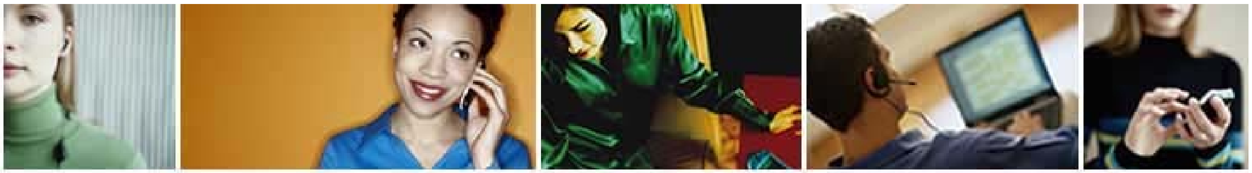
Capacitors are readily analyzed for their voltage stress level, and tantalum capacitors are particularly sensitive to electrical stress. On this basis, most tantalum and aluminum electrolytic capacitors were analyzed for electrical stress. The results were applied to the analysis and can be found in the prediction spreadsheet.

3.5 Thermal and Electrical Over-stress

The prediction assumes that all components are operating within their specifications. There should be prior design analysis to ensure no components are overstressed through the entire range of operation and storage. This is a critical assumption since, traditionally, most field failures are due to over-stressed or miss-applied components, or manufacturing quality problems.

3.6 Integrated Circuit Complexity

The failure rate of integrated circuits is partially dependent on the number of gates, transistors, or memory bits in the devices. The SR-332 prediction methodology reflects this fact. Unfortunately, aside from memory devices, these numbers are not typically stated in component data sheets. Since failure rates do not change rapidly with



gate/transistor count, estimates of these numbers can be used. Gate and transistor counts for this prediction have been estimated based on the available information in the data sheets, such as block diagrams, and on similar components. The assumed gate/transistor/bit counts are documented in the prediction spreadsheet.

4 Prediction Results

The tables provided in Telcordia, SR-332 list compensating factors for local ambient component temperatures down to 30 °C. This reflects the typical low end of operating temperatures for the products that furnished field data for the standard. The formulas provided do allow the calculation of failure rates for lower temperatures, but have not necessarily been verified in the lower ranges. The formulas are based on the activation energy for the dominant failure mechanism for a component, and so are dependent on that mechanism remaining dominant at the lower temperatures.

4.1 Steady-State Failure Rate Predictions

Based on the analysis, the failure rate and corresponding MTBF for a number of steady state indoor ambient temperatures is given in the following table.

4.1.1 APX-104E

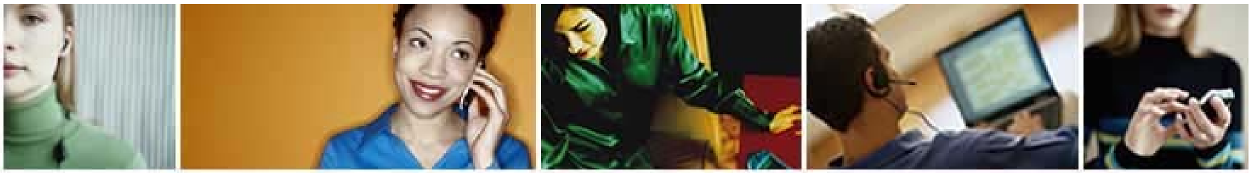
The reference tabulated data below is generated from APX 104E.

	IDU APX104E	
Ambient Temperature (°C)	Failure Rate (FITs)	MTBF (years)
23	3825	29.8

4.1.2 APX-108E

The reference tabulated data below is generated from APX 108E.

	IDU APX108E	
Ambient Temperature (°C)	Failure Rate (FITs)	MTBF (years)
23	5133	22.2



4.1.3 SDU-DS3

The reference tabulated data below is generated from SDU DS-3.

	IDU SDU-DS3	
Ambient Temperature (°C)	Failure Rate (FITs)	MTBF (years)
23	1349	84.5

4.1.4 SDU-16

The reference tabulated data below is generated from SDU-16.

	IDU SDU-16	
Ambient Temperature (°C)	Failure Rate (FITs)	MTBF (years)
23	1987	57.4

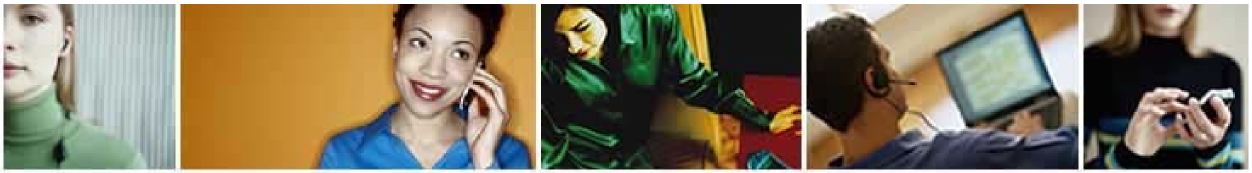
4.1.5 SDU-155

The reference tabulated data below is generated from SDU-155.

	IDU SDU-155	
Ambient Temperature (°C)	Failure Rate (FITs)	MTBF (years)
23	1737	65.7

4.2 Conclusions

It should be noted that a failure rate prediction is just that – a prediction. It is most useful for comparative purposes such as evaluating the effect of a change in design or for estimating the performance of a new product based on previous products using similar technologies. The actual failure rate is dependent on the performance of individual designers, the quality of the manufacturing process, the product shipping



environment and the actual customer application environment. The best absolute values for failure rate are determined from field performance.

The failure rate prediction results provided are based on specific temperature conditions. For customer applications with ambient conditions differing significantly from those used in the analysis, a custom analysis could be performed based on the relevant (customer-supplied) ambient temperature profile data.

4.3 History

Version	By	Date	Comments
1.0	Billy Wilson, CDS	Jan 4, 2007	Initial release.
1.1	Billy Wilson, CDS	December 2, 2008	Revised SDU-DS3, added SDU-16 and SDU-155

DragonWave Inc.
600-411 Legget Drive, Ottawa, Ontario, Canada, K2K 3C9
Tel: 613-599-9991   Fax: 613-599-4225
www.dragonwaveinc.com