Your Name:_______________________________

Quality and Reliability Engineering. Final Examination. March 18 2013

Instructions.

The duration of the exam is 2 hours. It will start at 5:05P and end at 7:00P.

If you can't finish all questions or problems, it's better to give complete answers to some, rather than partial answers to all.

The exam is "open book" and "on-line" so that you may refer to your textbook, and any of the course materials posted on line.

A page summarizing some key formulae that you may need is given on the last pages of the exam.

Under each question we provide space for you to write answers and explain what you are doing. We want you to show your working so that we can give partial credit if you don't get everything exactly right. We will provide extra sheets of paper if you need it. We'll staple extra sheets to what you hand in.

We provide an Excel "Exam Workbook" which may be downloaded from the course web site or downloaded from a memory stick in the classroom .

Feel free to use the workbook to do calculations for any of the questions or problems. If you do work on the spreadsheet, name the tab appropriately, and mention this in your written answers.

Some of the questions have data already entered on an appropriately named tab. This will also be indicated in the written questions. This will help you answer the question.

For convenience, the "Reliability Calculator" has been included in the Exam Workbook.

Rename the workbook, including your name, and email to Glenn (*cgshirl@cecs.pdx.edu*) at the end of the exam, or Glenn can collect it on a memory stick.

Q1. Product Qualification for Plastic Packages [11 Total]

Product qualification for plastic packages consists of a Preconditioning step followed by Environmental Stresses.

A. What is the purpose of Preconditioning? [1]

B. What are the steps in the Preconditioning flow, and what are they intended to simulate? [1]

C. What is the most important failure mechanism likely to occur in the Preconditioning step? [1]

D. What is the purpose of Environmental Stress? [1]

E. Why are Steam (aka Autoclave) and Thermal Shock (liquid-to-liquid) environmental stresses to be used with great caution, and possibly even be "not recommended"? [1]

F. What are the main precautions for HAST testing that must be considered in 1) the ramp up to stress condition, and 2) the ramp down from the stress condition. What can occur if these precautions are not observed? [1]

G. Why must units be tested within 24 hours of removal from a moisture stress (e.g. HAST)? [1]

H. Typical JEDEC-recommended sample sizes for Environmental Tests such as Bake, T/C, HAST are 3 lots of 77 units each (231 units total).

   a. Why are multiple lots recommended? [1]

   b. For one failure (1/231) what's the confidence that 1% fail fraction has been validated? [1]

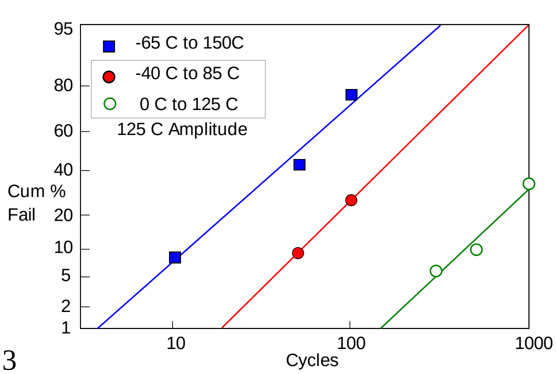
I. What's the difference between stress-based testing and knowledge-based testing in product qualification? Give a scenario in which stress-based testing would be preferred. [2]

Q2. Plastic Package Reliability [16 Total]

A. Mark each statement “true” or “false”: [1 each]

- If a package which has failed after moisture stress recovers when it is baked, it is OK and is not actually a failure.
- It is important to store plastic-packaged devices in sealed dry bags before they are solder-attached to printed circuit boards.
- The equilibrium concentration of moisture in molding compound depends only on the relative humidity of the surrounding air.
- Moisture-activated mechanisms in plastic-packaged devices are always more accelerated when the chip is in standby (dissipating negligible power) than when the chip is actively dissipating significant power because local die heating drives moisture away from the die.
- The molding compound of plastic packages provides a good moisture barrier, protecting the die from moisture.
- Passivation is designed to provide both mechanical and moisture protection to the die.
- The polyimide layer of passivation is a good moisture barrier.
- The nitride layer of passivation provides good mechanical protection of the die.
- Thin film cracking is driven by stresses imposed by the plastic molding compound on the surface of the die in plastic packages.
- Thin film cracking is maximum at the center of the die towards which all shear stress is directed.
- Thicker passivation reduces thin film cracking.
- Wide metal busses in die corners reduce thin film cracking.
- Popcorn damage occurs when plastic packages which have absorbed moisture are subjected to high temperatures during soldering to printed circuit boards.
- Small dies in thick packages are particularly susceptible to popcorn damage.

B. Consider the diagram showing temperature cycling failure data for a plastic packaged device. [2]



Why is the -40 C to 85 C amplitude stress about 9x more accelerated than the 0 C to 125 C stress even though the temperature amplitude (swing) is the same?

Q3. Acceleration [6 Total]

Two samples of a product were taken and were each stressed until 10% failed (Type II censoring). One group was stressed at 75 °C, and the other was stressed at 125 °C. The results are summarized in the table showing the cumulative fraction failing.

		Hours		
		216	472	1034
Temperature	75		1%	10%
	125	1%	10%	

A. What is the acceleration factor? [3]

B. What is the activation energy? [3]

Q4. Acceleration of Burn In [6 Total]

The guy in finance saw the burn in time formula in a spreadsheet and noticed that burn in time could be reduced by increasing the burn in voltage, V_{bi}. He figures he will get a Corporate Achievement Award for thinking of this. V_{bi} is currently 1.40 V. He recommends raising V_{bi} to 1.6 V because a technician reported that a part ran OK at this voltage.

A. If the voltage acceleration model is $AF = \exp\{-C\times(V_1-V_2)\}$ where $C = 14.3$ volts^{-1}, and the current burn in time is 1 hour, what burn in time improvement does he think he'll get? [3]

B. What is the finance guy missing? [3]

Q5. Yield Dependence of Burn In [5 Total]

A microprocessor in production is running with 80% yield at sort. Models of the burn in process say that this corresponds to 400 DPM at 30 days of use. One fine day, at the daily production meeting, good news is announced. Yield at sort has increased to 90% because of defect reduction projects.

A. Why would you expect infant mortality to improve? [2]

B. What should you expect the fraction failing at 30 days of use to be now? [3]

Q6. Designing a Stress Experiment [6 Total]

You were planning to run a life test using 2000 units, at a stress known to produce valid failures, out to 1000 hours. Because of schedule slips, your boss says she needs the results in 200 hours. You object, but she says, "No problem, I'll let you have another 8000 units so you can run more units at the planned stress."

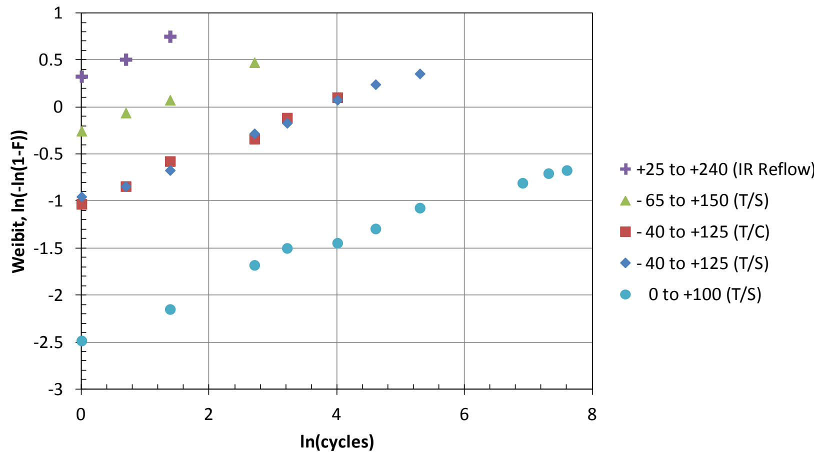
A. Why did your boss offer the specific number of 8000 units? [2]

B. Why did you object? What are the risks of your bosses' proposal? [2]

C. Propose an alternative. What are the risks of your alternative? [2]

Q7. III V Reliability [16 Total]

Bill Roesch showed experimental data for a device which had been subjected to various levels of temperature cycling (air to air) and temperature shock (liquid to liquid). The data is shown in the table, and is plotted in the graph. The graph plots the Weibit versus natural log of the number of cycles.



Note: The graph and a table with data picked from the graph so it can be easily analyzed are provided in the "Q7_III_V_Rel" tab of the Exam Workbook.

A. Generally thermal shock must be used with caution, but in this experiment both thermal shock and cycle were used. How does the data show that is it OK to use thermal shock? [2]

B. What is an advantage of using thermal shock versus thermal cycle? [2]

C. What are the risks and disadvantages of using thermal shock? [2]

D. The lines in the plot for different cycle/shock are almost parallel. What does this tell you? [2]

E. By fitting trend lines, or by calculating slope and intercept of the Weibit/ln(t) plots, determine Alpha (or lnAlpha) and Beta for each of the 5 stresses. What is the acceleration from the 0 to 100°C case to each of the other cases? Recommendation: Use the Exam Workbook. [4]

F. Is this mechanism an example of a constant, increasing, or decreasing failure rate? Given the answer to this, is it possible to use temperature cycle to screen the population to improve reliability? [2]

G. What is primarily driving the mechanism? The amplitude of the temperature swing, the maximum temperature, or the minimum temperature? [2]

Q8. Defect Models [8 Total]

Silicon fabrication process produces bits which are 3 PPM defective. Suppose that design wants to make a 1Mb array (2^{20} bits = 1048576 bits) from the bits. Show your answers on the "Q8_DefectModels" tab of the Exam Workbook, where useful statistical functions are available.

A. Assuming no clustering of bits, what will be the yield of the 1Mb array if it must have no defective bits to be "good"? [2]

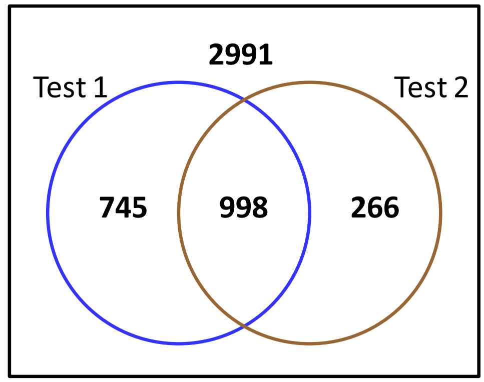
B. Assuming no clustering of bits, how many bad bits must be tolerated to get the yield above 90%. [3]

C. For the fault-tolerant array of the previous question, what is the effect of clustering on the yield? [3]

Q9. Test Coverage [11 Total]

Tests 1 and 2 in combination are able to screen all defective units so that none reach the customer. That is, with both tests the coverage is perfect ($c = 1$), and no defective units escape to the customer ($DL = 0$). However, for high volume manufacturing it is necessary to remove one of the tests, and allow some defective units to reach the customer. Continue-on-fail data for 5000 units was acquired with the following result:

Test 1	Test 2	Number of Units
Pass	Pass	2991
Fail	Fail	998
Pass	Fail	745
Fail	Pass	266
	Total	5000



A. Which test would you choose to retain if you had to use only one test? [2]

B. What is the coverage of Test 1 relative to the combination of Tests 1 and 2. [2]

C. What is the coverage of Test 2 relative to the combination of Tests 1 and 2. [2]

D. The yield at the time the continue-on-fail data shown above was acquired was 2991/5000 = 60%. To what level must the yield be improved to make it possible to remove one of the tests and still meet a customer-perceived fraction defective target of 1%? [5]

Q10. Fitting Readout Data with a T-Accelerated Weibull Model. [15 Total]

The "Q10_Fitting_Readout_Data" tab of the Exam Workbook gives data for an experiment in which 1000 units were stressed at 100 °C in "leg 1", and 1000 units were stressed at 150 °C in "leg 2". Each leg had the same readout times (1, 6, 48, 168, 500, and 1000 hours). At each readout the number of fails was recorded. On the Exam Workbook..

A. Use MLE to find the best estimate for the Weibull parameters (one Weibull for both legs) and activation energy. [5]

B. Do two separate MLE Weibull fits, one for each leg. Determine if acceleration is valid for this data set. [5]

C. Do a Pearson's chi-squared test on the fit to leg 1 only (from part b) to see if the fit is good enough to accept. [5]

Useful Formulae

Defect Models

$\lambda = DA$	Average number of defects per die.
D	Defect density 1/cm^2
A	Die area cm^2
$Y = \exp(-\lambda)$	Fraction of defect-free dies, assuming no clustering ($\alpha \to \infty$).
$Y = \left(1 + \frac{\lambda}{\alpha}\right)^{-\alpha}$	Fraction of defect-free dies, assuming clustering.
$Y = \text{POISSON}\left(\lambda, k, \text{TRUE}\right)$	Fraction of dies with k or fewer defects, assuming no clustering ($\alpha \to \infty$).
$Y = 1 - \text{BETADIST}\left(\frac{\lambda}{\lambda + \alpha}, n+1, \alpha\right)$	Fraction of dies with k or fewer defects, assuming clustering.

Weibull Analysis

$W = \ln(-\ln(1-F))$ $\quad S = \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right]$ $\quad F = 1 - \exp\left[-\left(\frac{t}{\alpha}\right)^{\beta}\right]$

$$\ln(t) = \ln\alpha + \frac{W}{\beta}$$

$$W = \beta \times \left(\ln(t) - \ln\alpha\right) = -\beta\ln\alpha + \beta\ln(t)$$

AF of "stress" relative to "use" for Weibull

$$AF = \frac{\alpha_{use}}{\alpha_{stress}}$$

$$\ln AF = \ln\alpha_{use} - \ln\alpha_{stress}$$

$$AF = \exp\left(\ln\alpha_{use} - \ln\alpha_{stress}\right)$$

Test Coverage

If Test A fully covers B, then Test B coverage relative to Test A is

$$c = \frac{\ln Y_B}{\ln Y_A}$$

$DL = 1 - Y^{1-c}$ (Y is the yield if c = 0 (that is with no test)).

Thermal Acceleration

Arrhenius acceleration from T_1 to T_2:

$AF = \exp\left\{\left(\frac{E_a}{k}\right) \times \left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right\}$ where T_1 and T_2 are in Kelvins, or

$AF = \text{ARRHENIUS}(T_2, T_1, E_a)$ where T_1 and T_2 are in Celsius. (Available in Exam Workbook.)

Likelihood

Log likelihood for f_r fails between readout times t_{r-1} and t_r coming from a model with fail function $F(t)$ and survival function $S(t)$:

$$L = \sum_{r=1}^{R} f_r \cdot \ln\{F(t_r) - F(t_{r-1})\} + s_R \cdot \ln S(t_R)$$

Test if acceleration is valid, L_1 is for one model with acceleration, L_2 is for two separate models (no acc.):
p-value $= \mathrm{CHIDIST}(2 \cdot (L_2 - L_1), \mathrm{DoF})$ where DoF = {model 2 params} – {model 1 params}

Pearson's chi-square test:
p-value $= \mathrm{CHIDIST}\left(\sum_{i=1}^{N\ \text{bins}} \frac{(n_{i,\ \text{actual}} - n_{i,\ \text{expected}})^2}{n_{i,\ \text{expected}}}, \mathrm{DoF}\right)$ where DoF = bins – {model params} – 1