ECE 510 Midterm – 13 Feb 2013

Questions (short answer)

1. What does QRE stand for?

   A: Quality and Reliability Engineer

2. Name 3 job activities a QRE might perform.

   A: qualify a product, advocate for the customer, etc.

3. Would 100 DPM at the end of an expected life of 5 years be a typical goal for a semiconductor component sold into a consumer market? Give at least one reason why or why not.

   A: No. Too low, too expensive for a wearout mechanism.

4. What was the fail mechanism and the associated stress that caused the failure and crash of the De Havilland Comet aircraft in the 1950's?

   A: Mechanism: metal fatigue or crack propagation. Stress: cabin pressurization or high-altitude flight.

5. Name two fail mechanisms for commercial semiconductor devices and one associated stress for each.

   A: Examples: oxide wearout (TDDB) and voltage or temperature, electromigration and current, BTI and temperature, package corrosion and humidity, and so on.

6. Histograms and CDF plots are both useful ways of looking at data. Name one disadvantage of a histogram and the corresponding advantage of a CDF plot.

   A: histograms require binning of data and don't show each data point, whereas CDF plots show each data point.

7. Consider the CDF plot for a set of N data points with values x_i. Each data point is plotted. Give the x (horizontal) and y (vertical) position of point i. That is, what goes on the x and y axes of a CDF plot?

   A: x-axis just uses the data value x_i and y-axis uses (rank–0.3)/(N+0.4) (or betainv), which is the median rank of the data point.

8. Describe the distinction between a sample statistic and a population parameter.

A: A statistic is calculated from a sample, the population parameter is unknown, the statistic is used to estimate the parameter.

Problems

Please show your work or describe your thinking for each problem; usually a single sentence is all that is needed.

1. If 0.7% of a population of parts are faulty when shipped from a factory, what is the DPM of the population? Is this a measure of quality or reliability?

A: 7000 DPM. Quality.

2. If 0.7% of a population of parts fails in its first 10,000 hours of operation, what is the FIT rate for the population? Is this a measure of quality or reliability?

A: =0.07%/1000hr*10^4=700 FIT. Reliability.

3. Say that you did a Monte Carlo simulation of some sort that used N=10,000 randomly generated data points. If your boss tells you that she wants 10x greater Monte Carlo accuracy (that is, 1/10 of the random Monte Carlo uncertainty than your current simulation), what sample size would you need to use?

A: 1,000,000 units since uncertainty goes as 1/sqrt(n).

4. Say that a fail mechanism has a hazard function $h(t) = 1$ FIT (that is, constant at 1 FIT). (a) What is the corresponding fail function $F(t)$? Give the value of any parameters in $F(t)$, including units. (b) What is the MTTF? (c) What is the probability of failure in 10 years of use?

(a) $H(t) = \int_0^t 1\ \text{FIT} = t\ \text{hr} * 1\frac{\text{fails}}{10^9\text{hr}} = \frac{t}{10^9}$ with t in hours, $F(t) = 1 - \exp(-H(t)) = 1 - \exp\left(-\frac{t}{10^9}\right)$ so $F(t) = 1 - \exp(-\lambda t)$ where $\lambda = 10^{-9}\ \text{hr}^{-1}$.

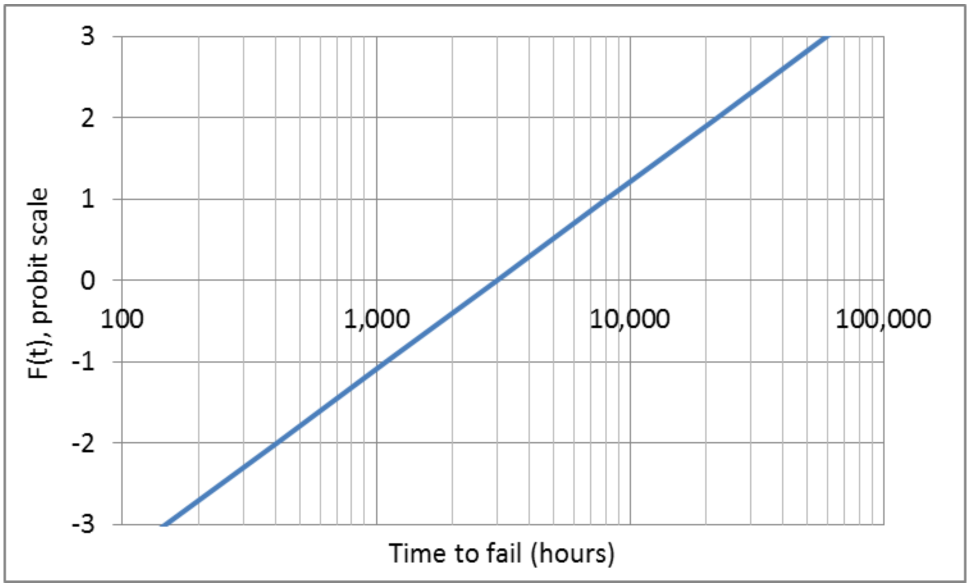
(b) $\text{MTTF} = \frac{1}{\lambda} = 10^9$ hr.

(c) $\text{F(15,000 hr)} = (1 - \exp(-10^{-9}\ \text{hr}^{-1} * 10 * 365 * 24\ \text{hr})) * 10^6 = 87.6\ \text{DPM}$.

5. How many samples do we need to verify that a population has a MTTF of 100,000 hours or more at 90% confidence, given that we can run the test for 1000 hours and no fails are allowed?

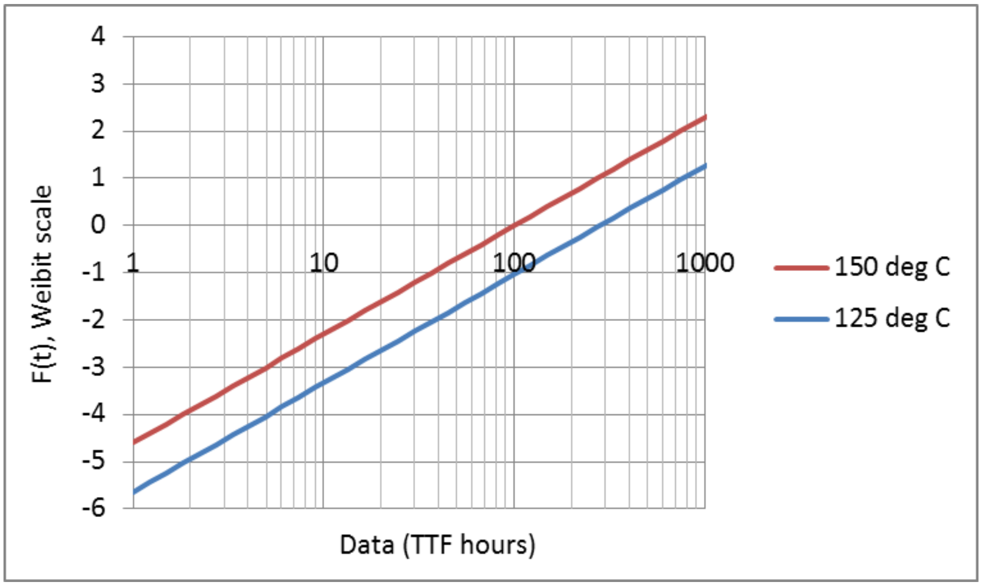
lambda target = 1/MTTF (*10^6) = 10 DPM
lambda UCL = CHIINV(1–90%, 2*(fails+1)) / (2*hours*SS) (*10^6)
adjust SS by trial and error and find that SS=231 to get UCL below 10 DPM
(230 is also OK because it gives a UCL closest to 10)

6. Consider the cumulative fail function F(t) shown in the graph below. Note that the time axis is on a log scale but is labeled in actual (non-log) time. (a) What functional form is this? (b) What are the values of the parameters for this function? Please include units on your parameter values. Your values should be correct to within 10% of the true values.



(a) Linear with probit and log time axes means lognormal.
(b) mu=ln(3000)=9 and sigma=ln(8000)–ln(3000)=1, both in units of ln hours.

7. Consider the two cumulative fail functions shown in the graph below for the same population of devices tested at two different temperatures. Note that the time axis is on a log scale but is labeled in actual (non-log) time. (a) Assuming a Weibull distribution, find the alpha (scale) and beta (shape) parameters for the 150 deg C line. (b) Is acceleration valid for this data set? Why or why not? (c) Find the acceleration factor from 125 deg C to 150 deg C. (d) Find the activation energy Ea in an Arrhenius acceleration model for this mechanism. Your values should be within 10% of the correct answer.



(a) beta = slope = $\frac{2.3-(-4.5)}{\ln(1000)-\ln(1)}$ = 0.98 ~ 1. alpha = exp(–intercept/slope) = exp(–(–4.5)/0.98) = 97 hr ~ 100 hr.

(b) Acceleration is valid because the two distributions are parallel.

(c) AF = 105/35 = 300/100 = 3. The inverse, 1/3, is also OK.

(d) From $AF = \exp\left(\frac{E_a}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right)$, solve for Ea to get $E_a = \frac{\ln(AF)*k}{\left(\frac{1}{T_1}-\frac{1}{T_2}\right)} = \frac{\ln(3)*0.00008617}{\left(\frac{1}{125+273}-\frac{1}{150+273}\right)} =$ 0.64 ~ 0.6

Spreadsheet problems

Show work and thought process on spreadsheet or here (or both).

1. Fit this distribution by eye. (a) Make a Weibit plot of the TTF data. (b) Construct a 2-Weibull F(t) model, plot the model on same graph as the data, and fit the model to the data "by eye" (using your judgment on best fit). (c) Is this an example of the bathtub curve, with an infant mortality mechanism and a wearout mechanism?

2. Determine the functional form of this distribution data. Make “exbit”, Weibit, probit (normal), and lognormal plots of the data and determine “by eye” which fit is the best.

3. A development group did an experiment and measured the TTF for all 10 units in their sample, and fit the data to a Weibull distribution with alpha=100 hours and beta=1.5. They have asked you to find the 90% two-sided confidence limits on their alpha and beta parameters. Use a Monte Carlo simulation method to find the UCL and LCL for each parameter separately (don’t consider any correlations).

To do this, simulate 100 data sets, one simulation per row, and determine the alpha and beta parameters for each. (That is, calculate the Weibit and ln(time) for each synthesized data row, and use the graphical (slope and intercept) method to find beta and alpha for each row.) Then use the resulting distribution of alphas and betas to find the confidence limits.

4. Fit the given Weibull readout data with voltage acceleration. The data below is from a 2-leg, 6-readout experiment, where leg1 was stressed at 1.2V and leg2 was stressed at 1.4V. Each leg had the same readout times; at each readout, the number of fails was measured. We want to fit the data with a Weibull model and an exponential voltage acceleration model. Use the method of maximum likelihood to find the best estimate for the Weibull and acceleration parameters. Then use the likelihood ratio method to find the 90% two-sided confidence limits (UCL and LCL) on the C parameter only.