ELE 491
Senior Design Project Proposal

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ELE 491
Senior Design Project Proposal

Class 12 – Reliability

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Reliability
Overview

- Reliability
  - How long will a system operate without failure
  - Which failures are material
  - Which failures are recoverable
  - What is an acceptable failure rate
    - Safety
    - Cost
    - Brand value

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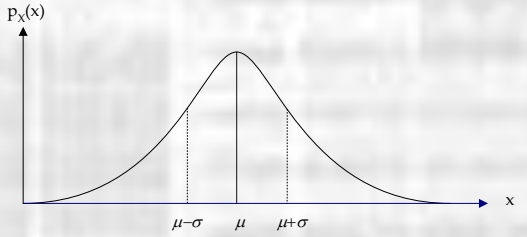
Reliability

Probability Review

- Probability

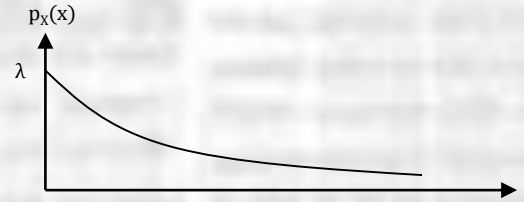
$$P(a \le X \le b) = \int_a^b p_X(x)dx$$

- Density Functions
  - Normal: $p_X(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$



  - Uniform: $p_X(x) = \frac{1}{b-a}, \quad a \le x \le b$

  - Exponential: $p_X(x) = \lambda e^{-\lambda x}, \ \lambda > 0$



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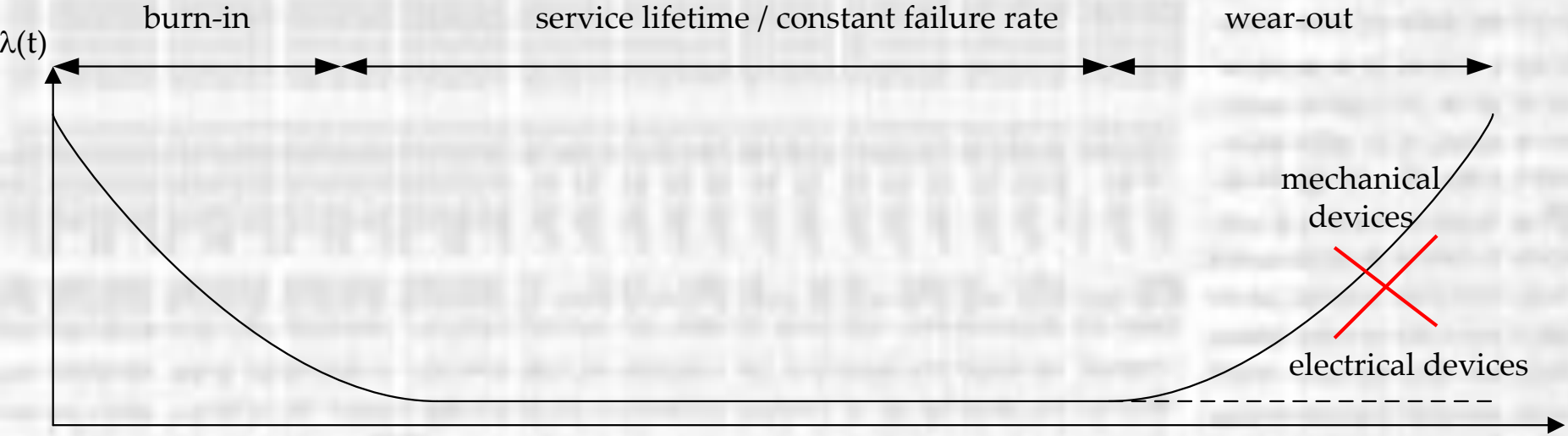
Reliability

Definitions

- Failure Rate
  - λ(t)
  - Expected number of failures per unit time
  - Determined by testing large numbers of devices at different time intervals
  - Units: failures/hr, failures/day, …



Reliability

Definitions

- Reliability
  - R(t)
  - Probability that a device is still functioning at time t

$$R(t) = \exp\{-\int_0^t \lambda(\tau) d\tau\}$$

  - For the region where λ(t) is constant

$$R(t) = exp(-\lambda t)$$

  - Units: none (probability)

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Reliability
Definitions

- Mean Time to Failure
  - MTTF
  - Mean time it takes for a device to fail
  - For λ(t) constant
    $$MTTF = 1/\lambda$$
  - Units: hours, day, …

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Reliability

System Reliability

- Series Systems
  - Systems where all components in the system must perform properly for the system to perform properly
    - Signal processing chain
    - Four channel A/D where all four channels are used
  - Failures of blocks/components are assumed to be independent events
  - System Reliability: $R_S(t) = R_1(t)R_2(t)R_3(t)\ldots R_n(t)$
  - System Failure Rate: $\lambda_S = \sum_{i=1}^{n} \lambda_i$
  - $MTTF_S = 1/\lambda_S$

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Reliability

System Reliability

- Parallel Systems
  - Systems where some components in the system may fail but the system can perform properly
    - RAID
    - Four channel A/D where two channels are used
  - Failures of blocks/components are assumed to be independent events
  - System failure requires all redundant components to fail
  - System Reliability: $R_S(t) = 1 - \prod_{i=1}^{n}[1 - R_i(t)]$

$$R_S(t) = 1 - [1 - R_i(t)]^n$$

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Reliability

FMEA

- Failure Modes and Effects Analysis
  - Qualitative measure of component reliability impact on the overall system
  - Failure Modes
    - Errors, defects or failures
    - Real or imagined
  - Effects Analysis
    - Consequences of errors, defects, failures
    - Incorrect operation, unpredictable operation, failure to operate
    - Over time, under certain conditions, randomly
    - $$$, time, reputation, lost sales, legal action
    - Can include everything from benign effects to life threatening effects

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Reliability

FMEA

- Failure Modes and Effects Analysis
  - Predictive
    - Intended to prevent problems before they occur
  - Subjective
    - Risk identification
    - Severity
    - Impact
  - Widespread
    - Products
    - Services
    - Manufacturing plants
    - Distribution systems
    - Networks
    - Military systems

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Reliability

FMEA

- FMEA Process
  - Identify and prioritize risks
    - Each component or subsystem should be examined
    - Possible failures are identified
    - RPN scoring process used to prioritize failure modes
  - Correct any possible failure modes above a given threshold
    - Create an action list for each item
    - Execute the corrections
  - Rerun the FMEA until no unacceptable failure modes exist

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Reliability

FMEA

- FMEA Process
  - RPN = Risk Priority Number
    - RPN = S x F x D
  - S = Severity of consequences of the failure
  - F = Frequency of the occurrence of the failure
  - D = Detectability of the failure
  - Create a scoring rubric for S, F, and D

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Reliability

FMEA

- Severity Scoring Rubric
  - This is an example – the rubric should be tied to the system, process or product

1. Minor user inconvenience – intermittent
2. User inconvenience – consistent
3. Failure to perform secondary function
4. Failure to perform primary function
5. Potential safety hazard – shock, fire, or failure to perform critical safety related function

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Reliability

FMEA

- Frequency Scoring Rubric
  - This is an example – the rubric should be tied to the system, process or product

1. Rare occurrence – late in product life
2. Moderate occurrence – late in product life (out of warranty)
3. Moderate occurrence – mid life (inside warranty)
4. Frequent occurrence – mid life (inside warranty)
   Moderate occurrence – pre-ship
5. Very Frequent occurrence – pre-ship

  - Occurrence can refer to # of devices or number of instances/device

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Reliability

FMEA

- Detectability Scoring Rubric
  - This is an example – the rubric should be tied to the system, process or product

1. Detected by other already required tests
2. Detected by simple additional test
3. Detected by special test and test equipment (not already required)
4. Detected by burn in
5. No known test for the defect

  - This example is geared toward a semiconductor device

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Reliability

FMEA

- FMEA Template

Project:	TEMPLATE
Team:	
FMEA Date (original):	
FMEA Date (current):	
FMEA Complete (Y/N):	N

Failure Mode and Effects Analysis

Design FMEA

Severity Rating Table	Frequency Rating Table	Detection Rating Table
5:	5:	5:
4:	4:	4:
3:	3:	3:
2:	2:	2:
1:	1:	1:

Block or Sub-system	Function(s)	Failure Mode	Effects of Failure	SEV	Causes of Failure	FREQ	Detection Technique	DET	RPN	Corrective Actions	Individual Responsible & Completion Data	Action Results: SEV	Action Results: FREQ	Action Results: DET	Action Results: RPN
									0						0
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Reliability

FMEA

- FMEA Simple Example

Project:	Example 1 Auto ABS System
Team:	
M Jackson	
H. Truman	
FMEA Date (original):	
11/11/2014	
FMEA Date (current):	
11/20/2014	
FMEA Complete (Y/N):	Y

Failure Mode and Effects Analysis

Design FMEA

Severity Rating Table	Frequency Rating Table	Detection Rating Table
5: Loss of life	5: Multiple times per trip	5: Post Failure w/o warning
4: Injury	4: Once per start	4: At failure with warning
3: Breakdown	3: Once / 20 starts	3: Pre-failure with warning
2: Limited functionality	2: Once / 50 starts or monthly	2: Dealer test
1: Annoyance	1: Occasionally or once / 200 starts	1: Factory Test

Block or Sub-system	Function(s)	Failure Mode	Effects of Failure	SEV	Causes of Failure	FREQ	Detection Technique	DET	RPN	Corrective Actions	Individual Responsible & Completion Data	SEV	FREQ	DET	RPN
												Action Results			
Detector	Wheel position	Intermittent signal	Limited wheel position accuracy	2	Missing sensors	1	Fixed data drop out	3	6	Detection loop to modify data	Joe Smith - 11/18/14	1	1	3	3
				2	Malfunctioning Sensors	3	Intermediate data drop out	5	30	Startup sensor check	Sally Sue - 11/18/14	2	3	3	18
				2	Poor connection	3	Intermediate data drop out	5	30	Startup sensor check	Sally Sue - 11/18/14	2	3	3	18
		No signal	No wheel position information	2	Missing sensors	1	Full data drop out	3	6	Startup sensor check	Sally Sue - 11/18/14	2	1	3	6
				2	Malfunctioning Sensors	2	Intermediate data drop out	5	20	Startup sensor check	Sally Sue - 11/18/14	2	2	3	12
				2	Poor connection	2	Intermediate data drop out	5	20	Startup sensor check	Sally Sue - 11/18/14	2	2	3	12
Controller	Braking control	Power Failure	No brake control signal	2	Fuse blown	1	Main controller detection	4	8						0
				2	System power failure	1	No system detection	5	10	Not necessary - no start					0
				2	Bad power connection	1	Main controller detection	4	8						0
		Incorrect Braking signal	No brake control signal	2	SW failure	2	Main controller detection	4	16						0
			Unintended braking	5	SW failure	2	No system detection	5	50	Mechanical pedal interlock	Jack Cho	5	1	3	15
															0
															0

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In Class Activity