Estimating Reliability of Telecommunication and Electronic Devices

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Reliability

- Reliability is defined as the probability that a device will perform its required function under stated conditions for a specific period of time

Reliability Parameters…

- MTBF

  Mean Time Between Failures (MTBF), as the name suggests, is the average time between failure of hardware modules.

  It is the average time a manufacturer estimates before a failure occurs in a hardware module.

Reliability Parameters...

- MTBF for hardware modules can be obtained from the vendor for off-the-shelf hardware modules.
- MTBF for in house developed hardware modules is calculated by the hardware team developing the board.
- MTBF for software can be determined by simply multiplying the defect rate with **KLOCs** executed per second.

Reliability Parameters…

- FITS (Failures in Time)

  FITS is a more intuitive way of representing MTBF.

  FITS is nothing but the total number of failures of the module in a billion hours (i.e. 1000,000,000 hours).

Reliability Parameters...

- A correct understanding of MTBF is important.
- A power supply with an MTBF of 40,000 hours does not mean that the power supply should last for an average of 40,000 hours.
- An MTBF of 40,000 hours, or 1 year for 1 module, becomes 40,000/2 for two modules and 40,000/4 for four modules.

Reliability Parameters...

- MTTR

  Mean Time To Repair (MTTR), is the time taken to repair a failed hardware module.

  In an operational system, repair generally means replacing the hardware module.

  Thus hardware MTTR could be viewed as mean time to replace a failed hardware module.

Estimating the Hardware MTTR …

- It should be a goal of system designers to allow for a high MTTR value and still achieve the system reliability goals.

- You can see from the table (Next Slide) that a low MTTR requirement means high operational cost for the system.

Estimating the Hardware MTTR

Where are hardware spares kept?	How is site manned?	Estimated MTTR
Onsite	24 hours a day	30 minutes
Onsite	Operator is on call 24 hours a day	2 hours
Onsite	Regular working hours on week days as well as weekends and holidays	14 hours
Onsite	Regular working hours on week days only	3 days
Offsite. Shipped by courier when fault condition is encountered.	Operator paged by system when a fault is detected.	1 week
Offsite. Maintained in an operator controlled warehouse	System is remotely located. Operator needs to be flown in to replace the hardware.	2 week

Total Outage Duration

- **Critical time as further failures can occur during recovery**
- **Total Outage duration (MTTR) =**

Time to Detect	**(need good monitoring)**
+ Time to Diagnose	**(need good docs/ops, best practices)**
+ Time to Decide	**(need good org/leader, best practices)**
+ Time to Act	**(need good execution!)**

Estimating the Software MTTR …

- MTTR for a software module can be computed as the time taken to reboot after a software fault is detected.
- Thus software MTTR could be viewed as the mean time to reboot after a software fault has been detected.
- The goal of system designers should be to keep the software MTTR as low as possible

Availability…

- Availability of the module is the percentage of time when system is operational.

- Availability is typically specified in nines notation. For example 3-nines availability corresponds to 99.9% availability. A 5-nines availability corresponds to 99.999% availability

Availability…

Availability of a hardware/software module can be obtained by the formula given below

$$A = \frac{MTBF}{MTBF + MTTR}$$

MTBF or MTTF = Mean Time Between (To) Failure
MTTR = Mean Time To Repair

Availability is typically specified in nines notation. For example 3-nines availability corresponds to 99.9% availability. A 5-nines availability corresponds to 99.999% availability.

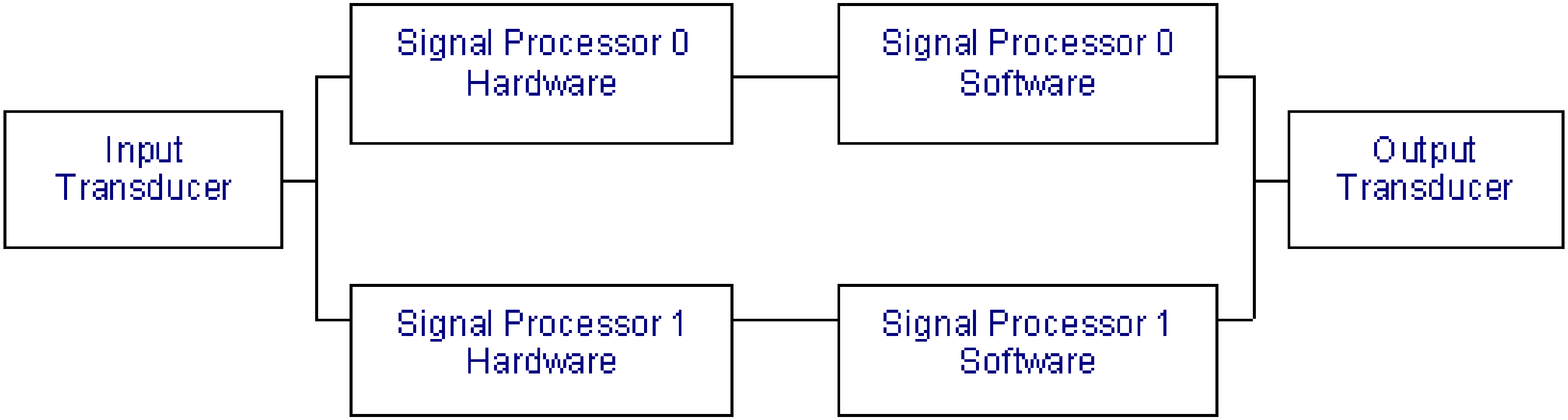
Availability…

Downtime

Downtime per year is a more intuitive way of understanding the availability. The table below compares the availability and the corresponding downtime.

Availability	Downtime
90% (1-nine)	36.5 days/year
99% (2-nines)	3.65 days/year
99.9% (3-nines)	8.76 hours/year
99.99% (4-nines)	52 minutes/year
99.999% (5-nines)	5 minutes/year
99.9999% (6-nines)	31 seconds/year !

Reliability Modeling of the System



- **The signal processor hardware and software have been modeled as two distinct entities. The software and the hardware are operating in series as the signal processor cannot function if the hardware or the software is not operational.**
- **The two signal processors (software + hardware) combine together to form the signal processing complex. Within the signal processing complex, the two signal processing complexes are placed in parallel as the system can function when one of the signal processors fails.**
- **The input transducer, the signal processing complex and the output transducer have been placed in series as failure of any of the three parts will lead to complete failure of the system.**

Calculating Availability of Individual Components

Component	MTBF	MTTR	Availability	Downtime
Input Transducer	100,000 hours	2 hours	99.998%	10.51 minutes/year
Signal Processor Hardware	10,000 hours	2 hours	99.98%	1.75 hours/year
Signal Processor Software	2190 hours	5 minute	99.9962%	20 minutes/ year
Output Transducer	100,000 hours	2 hours	99.998%	10.51 minutes/ year

Calculating System Availability

Component	Availability	Downtime
Signal Processing Complex (software + hardware)	99.9762%	2.08 hours/year
Combined availability of Signal Processing Complex 0 and 1 operating in parallel	99.99999%	3.15 seconds/year
Complete System	99.9960%	21.08 minutes/year

Reliability Predictions Methods…

- There are generally two categories:

(1) Predictions based on individual failure rates, and

(2) Demonstrated reliability based on operation of equipment over time.

- Prediction methods are based on component data from a variety of sources like failure analysis, life test data, and device physics.

Reliability Predictions Methods…

- MIL-HDBK-217
  - Generally associated with military systems
    - Models are very detailed
    - Provides for many environments
    - Provides multiple quality levels
- Bellcore (Telcordia)
  - Telecommunications Industry standard
    - Models patterned after MIL-HDBK-217, but simplified
    - Provides multiple quality levels
    - Can incorporate current laboratory test data
    - Can incorporate current field performance data
- Resources
  - Software packages cover both MIL-HDBK-217 and Bellcore models
    - RelCalc MTBF Reliability Prediction Software (T-Cubed)

Reliability Predictions Methods

- For some calculations (e.g. military application) MIL-HDBK-217 is used, which is considered to be the standard reliability prediction method.

- calculations using Telcordia Technical Reference TR-332 “Reliability Prediction Procedure for Electronic Equipment.”

Typical MIL-217 Failure Rate Model

A sample MIL-217 failure rate model for a simple semiconductor component is shown below. Many components, especially microcircuits, have significantly different and more complex models.

Failure rate = pib * piT * piA * piR * piS * piC * piQ * piE
Failures/million Hours

Where:

piT = Temperature factor
piA = Application factor (linear, switching, etc)
piR = Power rating factor
piS = Electrical (voltage) Stress factor
piC = Contact construction factor
piQ = Quality factor
piE = Operating environment factor

MTBF For Discrete LEDS and Photodiodes

- In the case of fiber optic data communication equipment, an area of primary concern is the MTBF values for the discrete Light Emitting Diodes (LEDs) and photodiodes used in the fiber optic transmitters and receivers.

- The determination of the predicted MTBF for an LED or photodiode is a calculation using the part failure-rate model for optoelectronic devices as found in section 5.1.3.10 of MIL-HDBK-217E

MTBF For Discrete LEDS and Photodiodes

$$\lambda_P = \lambda_B \Pi_T \Pi_E \Pi_Q \quad \frac{failures}{10^6\ hours}$$

where:

$$\lambda_B = \text{ base failure-rate } \frac{failures}{10^6\ hours}$$

$$\Pi_T = \text{temperature factor}$$

$$\Pi_E = \text{environmental factor}$$

$$\Pi_Q = \text{quality factor}$$

The value for MTBF is then determined from:

$$MTBF = \frac{1}{\lambda_P}$$

MTBF For Discrete LEDS and Photodiodes

- The Value for MTBF is then determined from:

  $MTBF = 1/ \lambda_P$

Where:

$T_F = 8.01 \times 10^{12} \exp^{-(8111/TJ + 273)}$

$T_J = T_A + \theta_{JA} P_d$

T_A is the Ambient Temperature

P_d is the Power Dissipated by the Device

List of Constants

For LED

- B_F = Base Failure Rate = 6.5×10^{-4}
- θ_{JA} = Thermal Resistance = 150 $^{o}C/W$
- E_F = Environmental Factor = 1 (Normal)
- Q_F = Quality Factor = 0.5

For Photo Detector

- B_F = Base Failure Rate = 1.1×10^{-3}
- θ_{JA} = Thermal Resistance = 200 $^{o}C/W$
- E_F = Environmental Factor = 1 (Normal)
- Q_F = Quality Factor = 0.5

Practical Examples

- **Example 1:** Consider a standard hermetic (metal window can) LED, mounted in a receptacle (active device mount), operating at room temperature (25° C) in an office environment (G_B). The electrical operating parameters selected are I_F = 100 mA DC and V_F = 2.0 V_{DC}. Calculate the MTBF for this device under given conditions.

  (To be solved during the Session)

Practical Examples

- **Example 2:** The second example is a standard hermetic photodiode, mounted in a receptacle (active device mount), operating at room temperature (25° C) in an office environment (GB). The maximum power dissipation is given as 1 mW. Calculate the MTBF for this device under given conditions.

  (To be solved during the Session)

Quality Factors

Quality Factors
(from MIL-HDBK-217E, Table 5.1.3.10-4)

Quality Level	Π_Q	Description
JANTXV	0.001	Full testing as defined by MIL-S-19500 including Screening and Groups A, B, and C.
JANTX	0.02	Identical to JANTXV except does not include the 100% precap visual inspection contained in Screening.
JAN	0.1	Testing as defined by MIL-S-19500 including Groups A, B, and C, but not including Screening.
LOWER	0.5	Applies to all hermetic packaged LEDs and photodiodes.
PLASTIC	1.0	Applies to all devices encapsulated with organic materials.

Environmental Factors

ENVIRONMENTAL FACTORS
(from MIL-HDBK-217E, Table 5.1.3.10-1)

Environment	**Symbol**	Π_E
Ground, Benign	G_B	1
Ground, Missile Silo	G_{MS}	1.2
Ground, Fixed	G_F	2.4
Ground, Mobile	G_M	7.8
Space, Flight	S_F	1
Manpack	M_P	7.7
Naval, Sheltered	N_S	5.7
Naval, Unsheltered	N_U	11
Naval, Undersea, Unsheltered	N_{UU}	13
Naval, Submarine	N_{SB}	3.7
Naval, Hydrofoil	N_H	12

Environmental Factors

Airborne, Inhabited, Cargo	A_{IC}	2.5
Airborne, Inhabited, Trainer	A_{IT}	3.5
Airborne, Inhabited, Bomber	A_{IB}	5.5
Airborne, Inhabited, Attack	A_{IA}	3.5
Airborne, Inhabited, Fighter	A_{IF}	8
Airborne, Uninhabited, Cargo	A_{UC}	3
Airborne, Uninhabited, Trainer	A_{UT}	5.5
Airborne, Uninhabited, Bomber	A_{UB}	8
Airborne, Uninhabited, Attack	A_{UA}	5.5
Airborne, Uninhabited, Fighter	A_{UF}	10
Airborne, Rotary Winged	A_{RW}	17
Missile, Launch	M_L	26
Missile, Free Flight	M_{FF}	7.8
Missile, Flight, Air breathing	M_{FA}	11
Cannon, Launch	C_L	450
Undersea, Launch	U_{SL}	23

Ways to Improve Reliability

- **Reduce Part Count:** In general, reducing part count will increase reliability. You can use innovative design ideas, and more highly integrated functional parts, to reduce the number of parts without affecting circuit performance; part count reduction can also lead to lower cost and less board space required.
- **Part Selection:** The quality and reliability of the components you select for your product is very important; select suppliers that produce high quality, high reliability parts.

Ways to Improve Reliability

- **Derating:** Part failure rates generally decrease as applied stress levels decrease. Thus, derating, or operating the part at levels below it's ratings (for current, voltage, power dissipation, temperature, etc.) can increase reliability.
- **Burn-In:** Burn-in is operation in your factory, at elevated temperature, to accelerate the rate of failures; burn-in allows you to weed out failure prone devices in your factory, rather than in the field

Ways to Improve Reliability

- **Redundancy:** Product reliability may also be enhanced by using redundant design techniques.

Thank You