XP Power

XPerts in Power - Module 23
Reliability

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Module Content

- Terminology
- Factors Affecting Reliability
- Estimating The Failure Rate
- Prototype Testing
- Manufacturing Methods
- Systems Reliability
- Comparing Reliability

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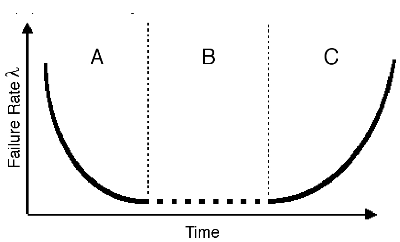
Failure Rate (λ)



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Reliability ($R_{(t)}$)

The probability that a piece of equipment operating under specified conditions shall perform satisfactorily for a given period of time.

Mean Time Between Failures (MTBF)
Mean Time To Failure (MTTF)

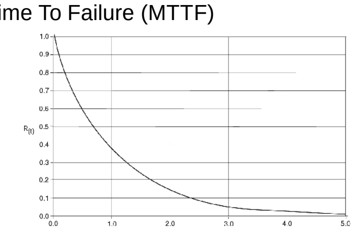
$$m = \frac{1}{\lambda}$$

$$R_{(t)} = e^{-\lambda t} = e^{-t/m}$$

$$m = \frac{t}{\log_n\left(\frac{1}{R_{(t)}}\right)}$$

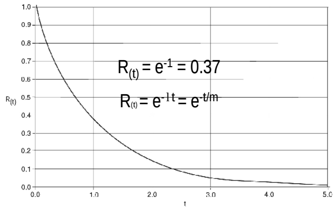
Where R(t) = reliability
e = exponential (2.718)
λ = failure rate
m = mtbf
t = time

Mean Time Between Failures (MTBF)
Mean Time To Failure (MTTF)



Reliability $R_{(t)}$ Plotted Against (λt) for a Unit with a constant failure Rate λ

Mean Time Between Failures (MTBF)
Mean Time To Failure (MTTF)



$R_{(t)} = e^{-1} = 0.37$

$R_{(t)} = e^{-1t} = e^{-t/m}$

Reliability $R_{(t)}$ Plotted Against (λt) for a Unit with a constant failure Rate λ

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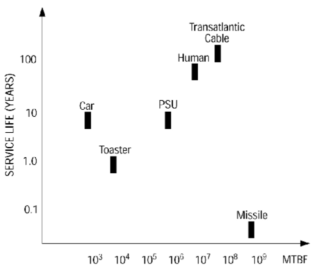
Service Life (Mission Life)



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Design Factors

- •Complexity
- •Stress
- •Generic

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Design Factors

- Complexity
- Stress
- Generic

What isn't there, can't fail

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Design Factors

- Complexity
- Stress
- Generic

For every 10° rise in temperature component lifetime will halve

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Design Factors

- Complexity
- Stress
- Generic

What price Reliability?

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Estimating the Failure Rate

- During design, it is predicted
- During manufacture, it is assessed
- During the service life, it is observed

- MIL-HDBK-217 - US NAVY
- HRD5 - British Telecom
- Bellcore - Bell Telephone

Prediction

Parts Stress Method:

Work out ALL the stresses for EACH component, then calculate the Failure Rate for EACH component

Cct.ref 6.3	l_b	p_T	p_A	p_R	p_S	p_Q	p_E	l_p
Q1	0.00074	3.9	1.5	5.5	0.73	8	1	0.13904
Q2	0.00074	5.2	1.5	2.3	0.54	8	1	0.05735
Q3	0.00074	1.3	1.5	0.77	0.39	8	1	0.00347
Q4	0.00074	1.3	0.7	0.77	0.39	5.5	1	0.00111
… etc.						subtotal		0.20097

Parts Count Method:

An average Failure Rate is given for each KIND of component

Component class	Quantity	l_p	subtotal
Power Transistor	4	0.0057	0.0228
Capacitor, ceramic			
Capacitor, tantalum			

Assessment

$$l = \frac{c^2_{(2r+2),(1-f)}}{2tN}$$

where l = demonstrated failure rate with a one-sided higher confidence limit of f *(phi)*

t = test time.

N = number of units on test.

r = number of failures.

$c^2_{(2r+2),(1-f)}$ = value of the c^2 distribution with probability **(1-f)** of not being exceeded in random sampling where **(2r + 2)** is the number of degrees of freedom.

r	*f = 0.6*	*f = 0.9*
0	93×10^3	230×10^3
1	200×10^3	390×10^3
2	310×10^3	530×10^3
3	420×10^3	670×10^3
4	530×10^3	790×10^3
5	630×10^3	910×10^3
6	730×10^3	1040×10^3
7	830×10^3	1160×10^3
8	930×10^3	1300×10^3
9	1040×10^3	1410×10^3
10	1140×10^3	1530×10^3

Let us consider the case when we have 50 units on test and one fails after 4 months (2920 hours):

t = 2920, N = 50, r = 1

From the table, we can say with 60% confidence that the failure rate will be less than

$$\frac{200{,}000}{50 \times 2920} = 1.37\%/1000 \text{ hrs}$$

Alternatively, we can say with 90% confidence that the failure rate will be less than

$$\frac{390{,}000}{50 \times 2920} = 2.67\%/1000 \text{ hrs}$$

Prototype Testing

- HALT - Highly Accelerated Life Test
- HASS - Highly Accelerated Stress Screening

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Manufacturing Methods

- Suppliers
- Manual Assembly Methods
- Tweaking of settings and parameters

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System Reliability

- More Reliable Components
- Redundancy

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System Reliability

$(R+Q)^T = [(R^T + TR^{(T-1)}Q + (T(T-1)/2!)\, R^{(T-2)}Q^2 + (T(T-1)(T-2)/3!)R^{(T-3)}Q^3 + \ldots + Q^T]$

Where T = Total number of units
R = Probability of success
Q = Probability of failure = (1-R)

The 1st term is the probability that 0 units will fail
The 2nd term is the probability that 1 unit will fail
The 3rd term is the probability that 2 units will fail
The 4th term is the probability that 3 units will fail
The 5th term is the probability that 4 units will fail
…and so on

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System Reliability

$(R+Q)^T = [(R^T + TR^{(T-1)}Q + (T(T-1)/2!)\, R^{(T-2)}Q^2 + (T(T-1)(T-2)/3!)R^{(T-3)}Q^3 + \ldots + Q^T]$

0 Failures : 0.8^4 =0.4096
1 Failure : $4 \times 0.8^3 \times 0.2$ =0.4096
2 Failures : $(4 \times 3/2) \times 0.8^2 \times 0.2^2$ =0.1536
3 Failures : $(4 \times 3 \times 2/3 \times 2) \times 0.8^1 \times 0.2^3$ =0.0256
4 Failures : 0.2^4 =0.0016

1 unit required to support the load
0.4096 + 0.4096 + 0.1536 + 0.0256 = 0.9984

2 units required to support the load
0.4096 + 0.4096 + 0.1536 = 0.9278

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Comparing Reliabilities

- The database must be stated and must be identical
- The database must be used consistently and exclusively
- The external stresses and environment must be stated and identical
- The units must be FFF interchangeable in the application

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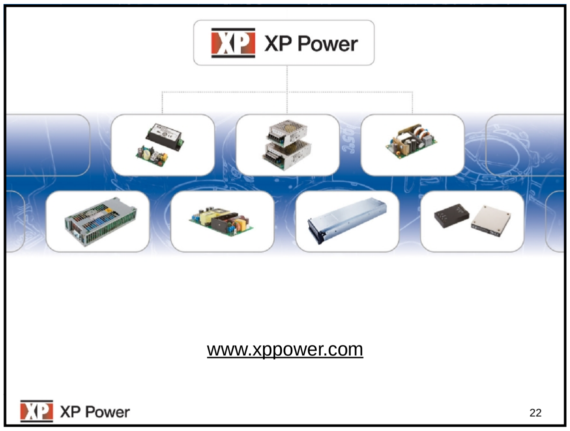
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