# Reliability Considerations in Enterprise SSD


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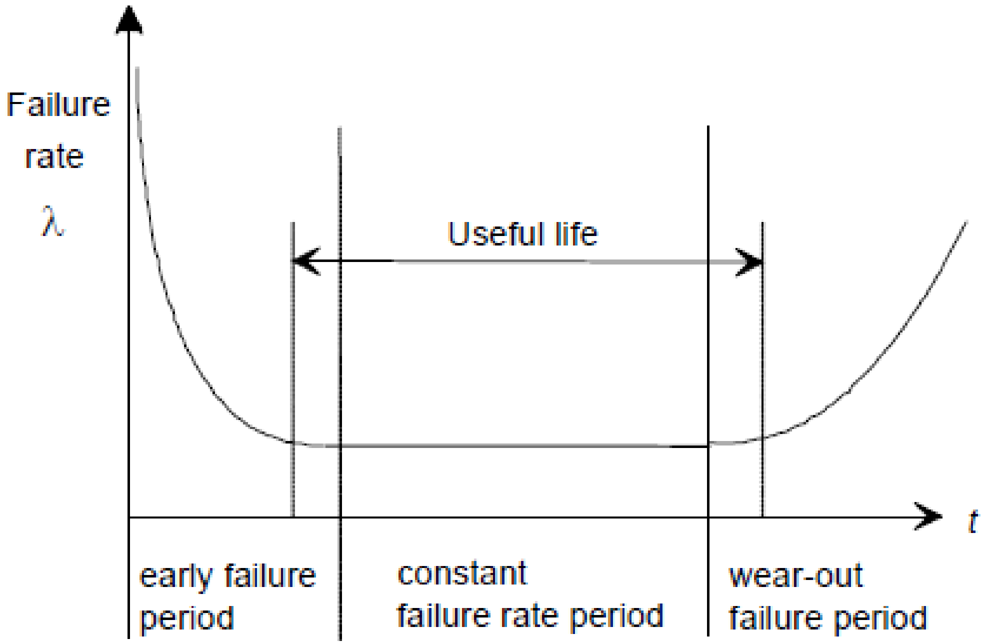
# First, Some Definitions

- Reliability
  - "the probability that a piece of equipment operating under specified conditions shall perform satisfactorily for a given period of time" -EPSMA
- Failure Rate ($\lambda$)
  - "Number of units failing per time"
  - If constant and random then Reliability is: $R(t) = e^{-\lambda t}$
- MTBF
  - Mean Time Between Failure
  - $MTBF = 1/\lambda$
- FIT Rate
  - Failures per billion hours of operation
  - FITs add linearly: FIT of system = sum of component FITs

# The Bath Tub Curve

- Reliability analysis is concerned with steady state region



# What Does MTBF Really Mean?

- Reliability: $R(t) = e^{-\lambda t} = e^{-t/MTBF}$

- When $t = MTBF$, then $R(MTBF) = e^{-1} \cong 0.37$
  - For a large number of units, only 37% of their operating times will exceed the MTBF
  - For a single unit, the probability that it will work up to its MTBF is only 0.37

- MTBF is NOT the expected service life

# Enterprise SSD Target MTBF

- Historical Target MTBF is 2,000,000 Hrs
- 2,000,000 hrs = 500 FITs
- Embedded is 4,000,000 hrs or 250 FITs
- This is the maximum composite failure rate for ALL components in the SSD.

# A Few More Definitions:

- Soft Failure
  - Recoverable failure (bits/bytes/blocks, even chips)
  - Data can be recovered using ECC or other redundancy
  - Applies to NAND and DRAM; focus of controller IP
- Hard Failure
  - Complete data loss
- Redundancy
  - The addition of capacity to enable failure recovery
  - Can be additional bits such as ECC
  - Can be reserve capacity
  - Can be RAID , remote backup, …

# A Few Words on Redundancy

- With enough redundancy reliability can be ~infinite
- Redundancy ALWAYS adds cost
- Redundancy ALWAYS adds latency and/or requires more processing horsepower
- The amount of redundancy required is proportional to the expected failure rates

# Components Subject to Failure

- NAND, DRAM
- Flash Controller, RAID Controller, PCIe Switch, Terminations, Buffers, etc
- Passives
- Power Sub-System
  - DC-DC Converters
  - Linear Regulators
  - Inductors, passives
  - Power Fail (switches, Bulk Caps, Battery,…)

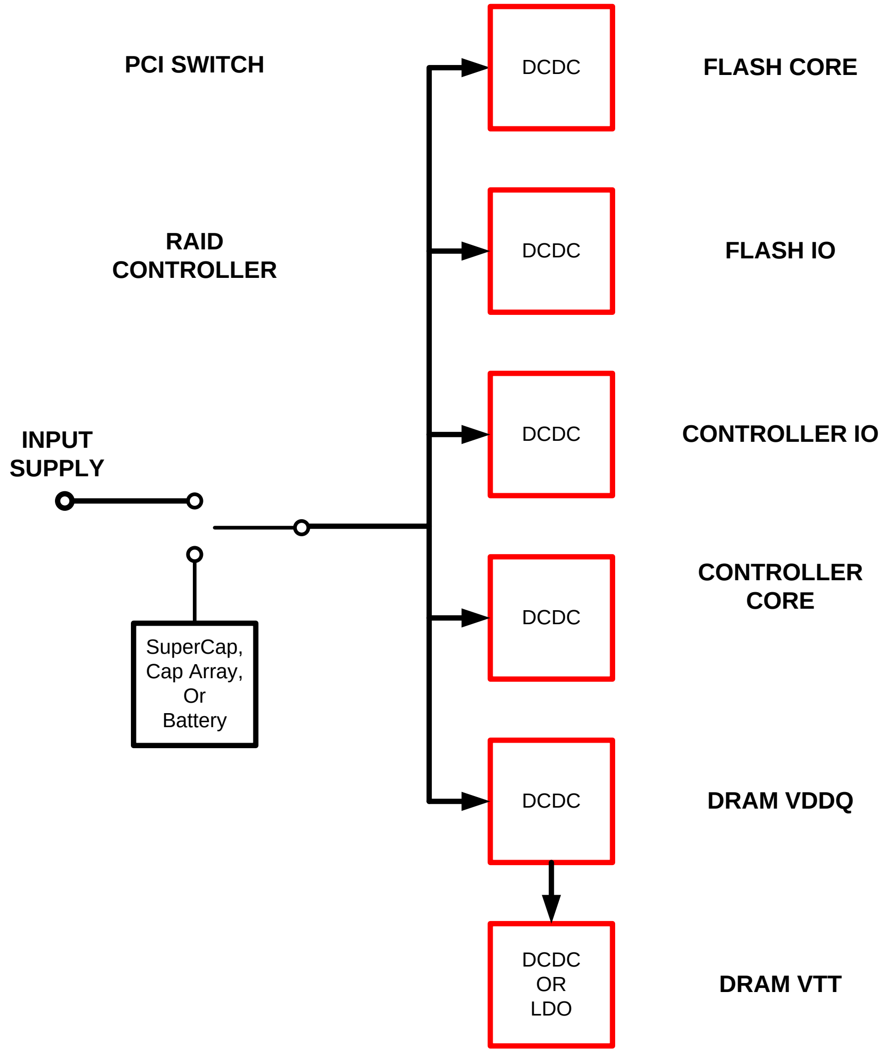
# Power Subsystem

"Power is a fundamental need but it can also be the biggest threat to the reliability and operation of any system".

-BitMicro DataSentinal Whitepaper

# Power Fail Architecture

- Prevents data loss in buffer memory in the event of an upstream power loss
- Use energy storage device, (battery, SuperCap, or capacitor array) to provide power for orderly shut-down



# Power Fail Comments

- MTBF of caps or battery can be very poor.
  - Significant vulnerability.
- It is difficult to assess health of energy storage elements.
  - Must design to worst case.
- Cannot mitigate against down stream supply failure.
  - Catastrophic data loss

# Power Converter Reliability Prediction

- Assess using standard methodologies
  - MIL Handbook 217-F
  - Telcordia SR 332
- FIT rate of the converter is the sum of the FIT rates of the components

# DCDC Converter Component FITs

| ITEM | FIT RATE | COMMENT |
|---|---|---|
| Controller | 1-4 | |
| MOSFETs | 1-4 | |
| Tantalum Capacitors | 5-10 | Temp, Bias, Ripple Dependent |
| Aluminum Electrolytic | 20-300 | Temp, Bias, Ripple Dependent |
| Ceramic Capacitors | 0.1 | Typical value for X5R, X7R |
| Chip Resistors | 0.1 | |
| Inductor | 38 | |

# Example DCDC Converter MTBF

| ITEM | FIT RATE | # | TOTAL FITs | MTBF |
|---|---|---|---|---|
| Controller | 2 | 1 | 2 | |
| Tantalum Capacitors | 7.5 | 2 | 15 | |
| Ceramic Capacitors | 0.1 | 6 | 0.6 | |
| Chip Resistors | 0.1 | 4 | 0.4 | |
| Inductor | 38 | 1 | 38 | |
| **TOTAL** | | | **56** | **2,038 yrs** |

- FIT rate for just one single converter is ~56
- Recall that target for entire drive is 500

# Supply Related FITs for SATA Drive

| Supply Rail | FIT RATE | MTBF |
|---|---|---|
| Controller Core | 56 | |
| Controller IO | 56 | |
| Controller Memory | 56 | |
| FLASH Core | 56 | |
| FLASH IO | 56 | |
| DDR VDDQ | 56 | |
| DDR VTT | 56 | |
| **TOTAL** | **392** | **291 yrs** |

# Typical FIT Rate by Drive Type

| Drive Type | Number of Rails | Supply Related FIT Rate |
|---|---|---|
| **mSATA** | 3 | 168 |
| **SATA** | 7 | 392 |
| **SAS** | 9 | 504 |
| **PCIe** | 12 | 672 |

- Failure rates exceed target or leave no headroom

# Supply FIT Mitigation

- Limited traditional options:
  - Consolidate supply rails where possible
  - Try to eliminate Electrolytic and Tant Caps

- Leverage new converter technologies
  - PowerSoC or other module approach

# PowerSoC FIT/MTBF

| ITEM | FIT RATE | # | TOTAL FITs | MTBF |
|---|---|---|---|---|
| PowerSoC | 3.2 | 1 | 3.2 | |
| Tantalum Capacitors | 7.5 | 0 | 0 | |
| Ceramic Capacitors | 0.1 | 6 | 0.6 | |
| Chip Resistors | 0.1 | 4 | 0.4 | |
| Inductor | 38 | 0 | 0 | |
| **TOTAL** | | | **4.2** | **27,200yrs** |

- Contrast to discrete DCDC with 56 FITs

# FIT Rate Comparison

| Drive Type | Discrete DCDC | PowerSoC |
|---|---|---|
| **mSATA** | 168 | 12.6 |
| **SATA** | 392 | 29.4 |
| **SAS** | 504 | 37.8 |
| **PCIe** | 672 | 50.4 |

- PowerSoC provides > 10x improvement
- Increases FIT headroom for other components

# Summary

- Power conversion is a serious risk to Enterprise class Solid State Storage reliability.
- Power Fail circuits do not protect against down stream supply failures and represent significant reliability risks of their own.
- Discrete DCDC converters consume most or all of the target 500 FITs allowed for 2,000,000 hrs MTBF.
- PowerSoC offers a > 10x improvement in power supply related reliability for Enterprise SSD
- Enpirion is the inventor of, and leader, in PowerSoC
  - Visit us at: WWW.ENPIRION.COM