High Reliability Inverter Initiative

Status Update

October, 2004

Objectives (Additional to Standard)

QUALITATIVE

- **Reliable**
- **Long Life**
- **Rugged**

QUANTITATIVE

- **15 year warranty**
- **MTBF of 50 years or more**

Reliable/Long Life/Rugged

- Inherent Weaknesses
  - Defects
  - Aging (FITs)
  - Wearout
- External Forces
  - Temperature
  - Air density
  - Humidity
  - Ultra-Violet
  - Line and Array
    - Spikes
    - Surges
    - Sags
  - Shock/Vibration
- Internal Forces
  - Power→Temperature
  - dP/dt (thermal shock)
  - V, I
  - dI/dt, dV/dt
  - Aging Mechanisms

Examples

- μCracks
- Metal Migration
- Diffusion, Filamentation
- Crystallization

- Plasticizers
- Conductive Condensation
- Device Stress

- Fatigue due to Cycling
- Thermal Shock → Cracks

Focus of Initiative

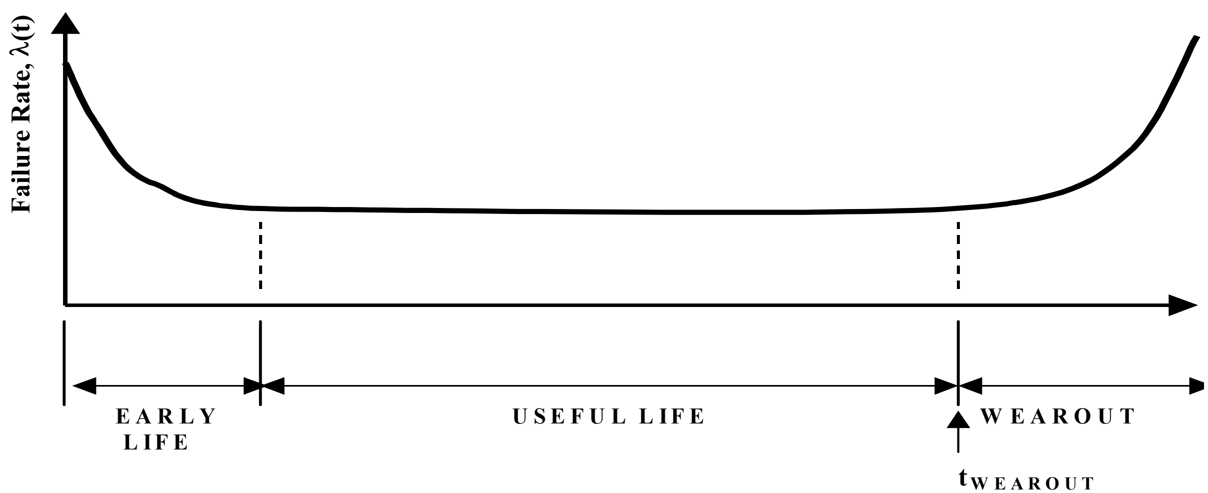
- Eliminate if Possible
  - Unreliable parts
  - Parts with pronounced Wearout
- Mitigate/Minimize Environmental Stress
- Minimize Dissipation, Maximize Heat Transfer
- Rugged Array and Grid Interface, Rugged Packaging
- Transition to Manufacturing critical (Design for Manufacturing, DFM)
  - Parts Qualification and Handling
  - Design Rules

FITs - Temperature is Critical

- Ambient Temperature
- ΔT (Power, R_{TH})
- Cycling
  - Cracking, crack propagation
  - Flexing, shear stress at interface (expansion mismatch)
  - Fatigue

$$MTBF = \frac{1 \times 10e9}{\sum_{i=1}^{n} q_i \times r_i}$$

r_i = Failure in Time (FIT)



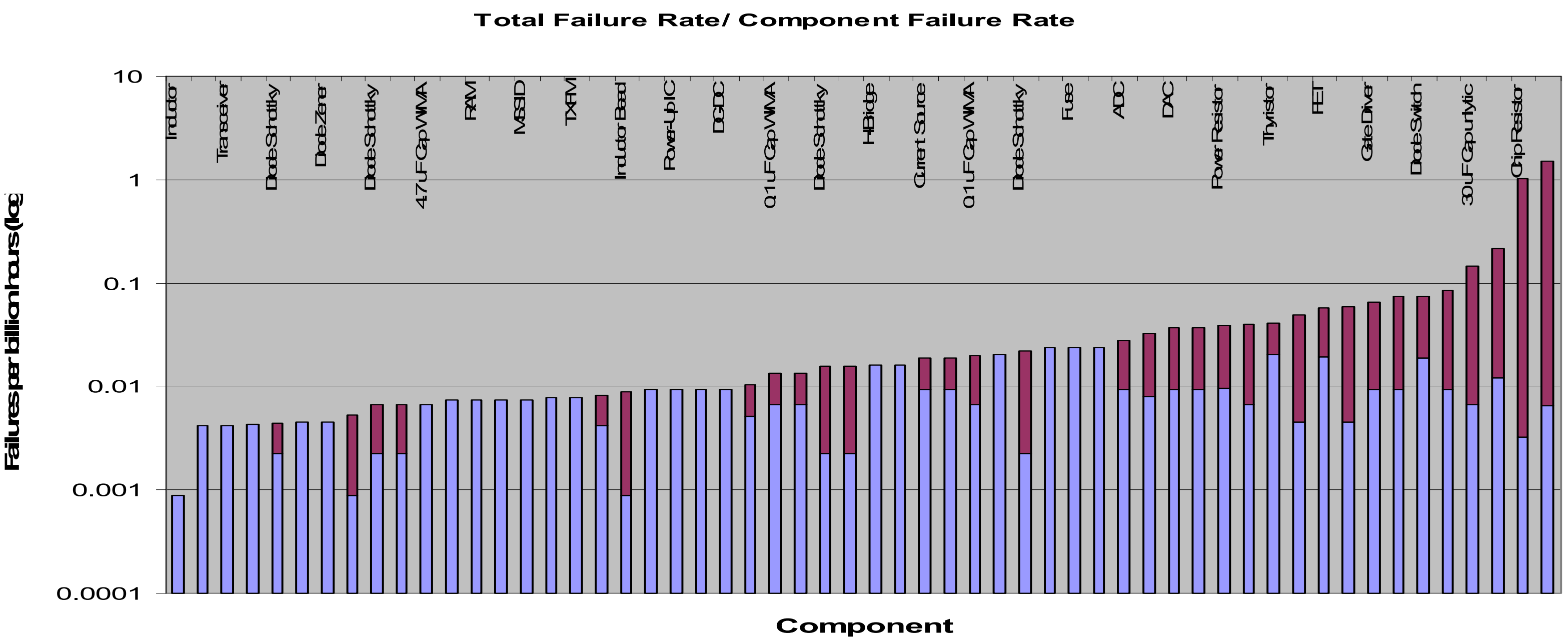
Squeeze Reliability into Design by Reducing FITs

- Reduce Stresses (derate) [Minimize Dissipation First]
- Reduce Component Count
- Eliminate Components
- Alternative Technology

Arrhenius

$k=A*\exp^{(-E_a/R*T)}$

E_a – Activation Energy

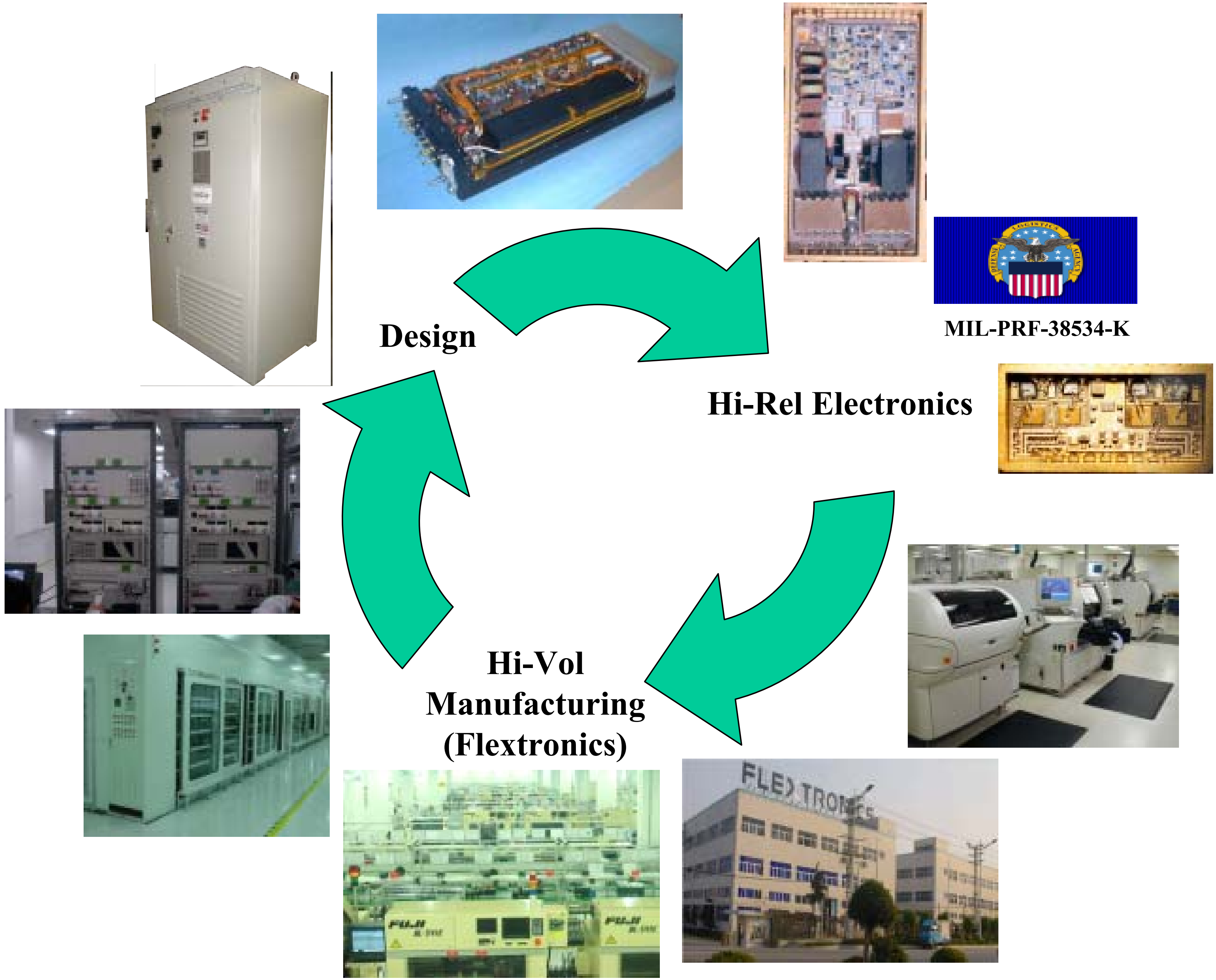


Typical Parts Derating

COMPONENT	APPLIED VOLTAGE	POWER	MAXIMUM TEMPERATURE
Film Resistors, Thermistors	80% rated	75% rated	125°C (150°C rated)
Metal Sense Resistors	N/A	75% rated	125°C (170°C rated)
Power Semiconductors	80% rated VGS, BVBEO	Observe temperature derating	125°C (Tj max; 150-175°C rated)
Signal Level Discretes	80% rated (if applicable)	75% Power, forward current, surge current	125°C (Tj max; 150-175°C rated)
Ceramic Capacitors	Continuous: 80% rated Peak: 100% rated	N/A	Self Heating <5°C, (125°C case temp rated)
Tantalum Capacitors	Continuous: 33% rated Peak/reverse: 50% rated	75% of rated ripple current	125°C max case; (170°C Tg)
PCB	Observe UL spacing for ISO barrier	N/A	120°C (135°C Tg); 125°C (170°C Tg)
Optocouplers	80% rated	75% rated forward current	110°C max case
Linear/Analog	80% rated	80% rated Pdiss	125°C (Tj max)
IC - Logic	80% rated	80% rated Pdiss	125°C (Tj max)
IC - ASIC/uP	80% rated	80% rated Pdiss	125°C (Tj max)
IC - CMOS	80% rated	80% rated Pdiss	125°C (Tj max)
IC - Bipolar	80% rated	80% rated Pdiss	125°C (Tj max)
Fuses	100% rated	80% rated current	75% I^2t rating

System Approach to Increasing Reliability/Service-Life

“Disciplines/Skills/Stages/Phases/…”	Impact of Weak Components	
	Ceramic Caps	**Electrolytic**
• **Power Circuit Topology**		*
• **Component Life/Reliability**	*	*
• **Control**		*
• **Hardware**	*	*
• **Software**		*
• **Packaging**	*	*
• **Thermal**	*	*
• **Passives (Magnetics/Capacitors)**	*	*
• **Design for Manufacturing**	*	
• **Transition to Manufacturing**	*	



Design
MIL-PRF-38534-K
Hi-Rel Electronics
Hi-Vol
Manufacturing
(Flextronics)

Project Status

Concept Design	Design Verification	Proof of Design	Proof of Manufacturing	Manufacturing Integration
• Generate electrical specification • Review Performance requirements • Design Simulation • Schematic • Qualify new components • Breadboard • Prelim thermal analysis Complete	• Full layout • Build engineering prototypes • Debug circuit • Component stress analysis • Stability analysis • Full electrical testing Complete • Worst-case electrical testing • Abnormal electrical testing • Specification review • Preliminary datasheet	• Build 10 units & electrically characterize • Verify electrical performance • Verify component stress analysis • Statistical variations • Thermal management analysis and imaging • HALT/HASS testing • Complete datasheet	• 25 unit Mfg. run • ATE testing • Yield analysis • Validate and finalize manufacturing processes • 1000 hour life test • Qualification testing (humidity, vibration, DMT, power thermal cycling, thermal and mechanical shock) • Certification (UL, FCC, …)	• Processes transfer • Full documentation release (SCD's, BOM, processes, procedures, etc.) • Release Qualification reports • Release final datasheet • Transfer units to Finished Goods

Phase II (Concept Design, Design Verification)

Phase III (Proof of Design, Proof of Manufacturing, Manufacturing Integration)

Future Directions

3—5 year horizon

- Active Devices
- Passive Devices
- Packaging

Higher E_a

SiC, GaN, …
Nanocrystalline, …
Diamond Like Film, …
Dielectrics, Dry Polymer, ...
High T plastics, …

- Improved Thermals
- Physical/Electrical Interfaces

- Control (Build on DeadBeat …)
- Fault Tolerance (Components, Circuits, Systems)
  - Paralleling for robustness and performance