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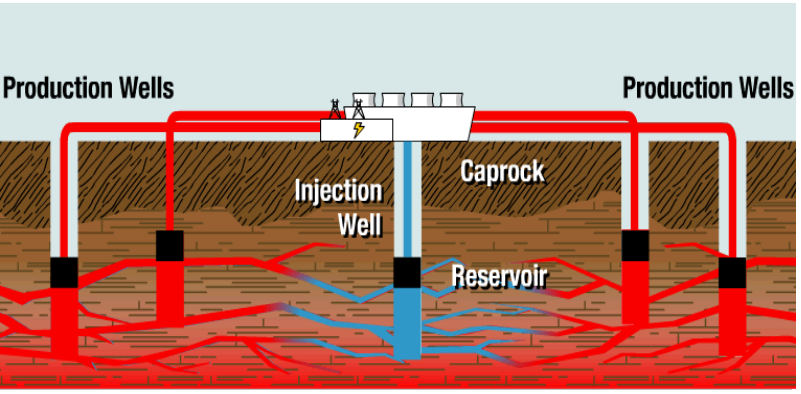

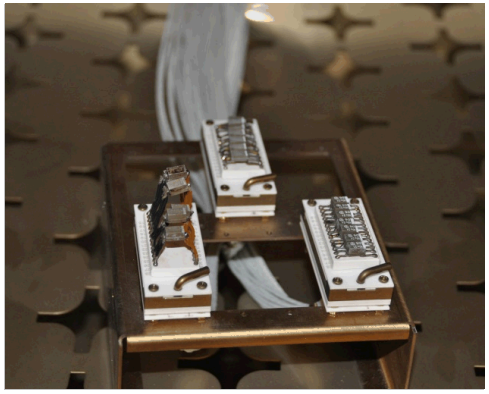

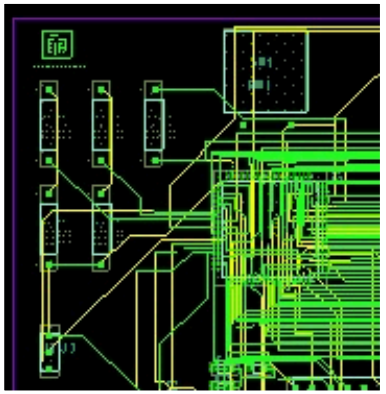

Evaluation of Commercial Flash Memory and Capacitors for Enhancement of Geothermal Tool Development

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U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Geothermal Environment

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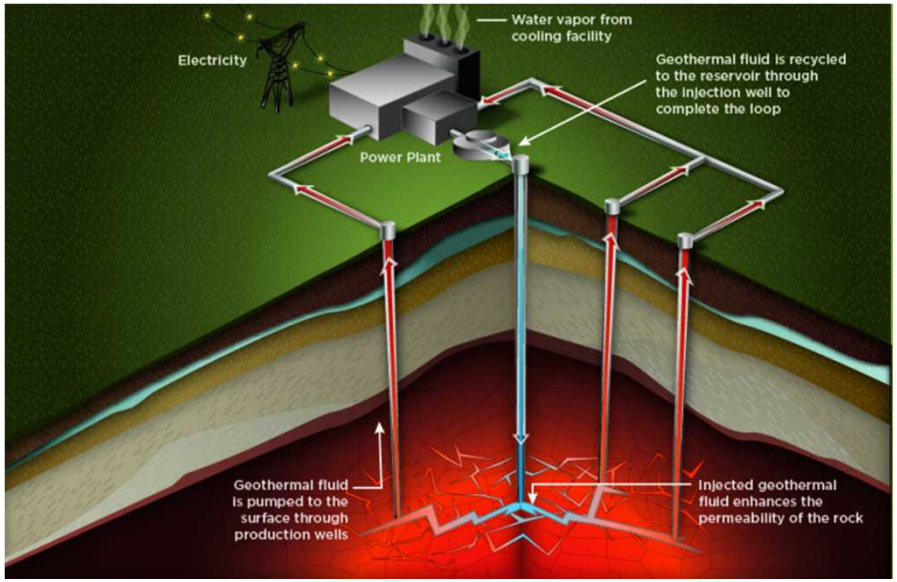
Oil and Gas HT Definitions (Halliburton)

	Borehole Temperature
HP/HT	>300°F (150°C) - 350°F (175°C)
Extreme HP/HT	>350°F (175°C) - 400°F (200°C)
Ultra HP/HT	>400°F (200°C) and above

Source: Halliburton Website: http://www.halliburton.com/en-US/ps/solutions/high-pressure-temperature/about-hp-ht-ht.page?node-id=hgjyd46b



Geothermal Temperature

- Higher temperature means higher efficiency
- Target environments are often in excess of 300C

Program Objectives

- Assist global geothermal tool development through independent high temperature component evaluation.
  - New HT component developers benefit from 3rd party evaluation of functionality and lifetime at temperature.

- Address the scarcity of COTS components rated for geothermal temperatures.
  - Public dissemination of beyond spec performance evaluations of select commercial components.
  - Helps geothermal developers who do not have the resources to dedicate to out-of-spec performance evaluation of components.

Data presented is for designer reference only and is not to be considered complete. No intent is made to endorse any components tested in this program.

TI HT-Flash Specifications

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Parameter	Descriptor/Condition	Specification
I/O Voltage	VIO	3.1V to 3.6V
Core Voltage	VCORE	1.8V to 1.98V
Junction Temperature	TJ	-55C to 210C
Package		Ceramic HKN
Communication	Serial Peripheral Interface	Max 10MHz
Flash Clock	Fclk	Max 12MHz
Life Time	@210C	1000 hours
Write/Erase cycles	@30C	1000 cycles
Memory Capacity	2-M X 16-Bit Word Access	32Mb

- Bulk Silicon
- NAND Flash
- Silver-Glass Die Attach
- BIST Function (not at temperature)
- EVM module available for 200C

APPLICATIONS

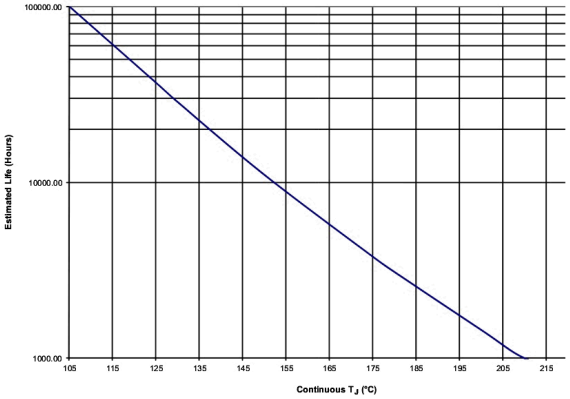
- Down-Hole Energy Drilling
- Test and Measurement Equipment
- Seismic Data Collection at Extreme Temperatures
- General Data Collection Applications at Extreme High- and Low-Temperatures

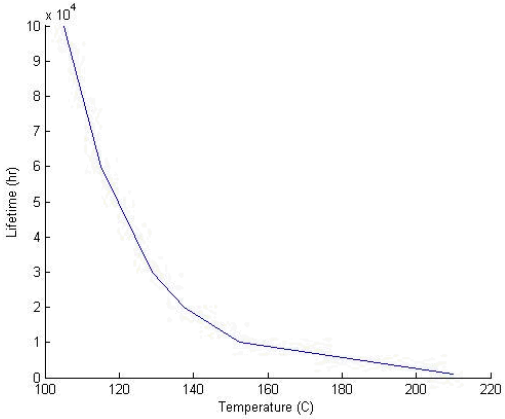
HKN PACKAGE
(TOP VIEW)

SM28VLT32-HT Datasheet

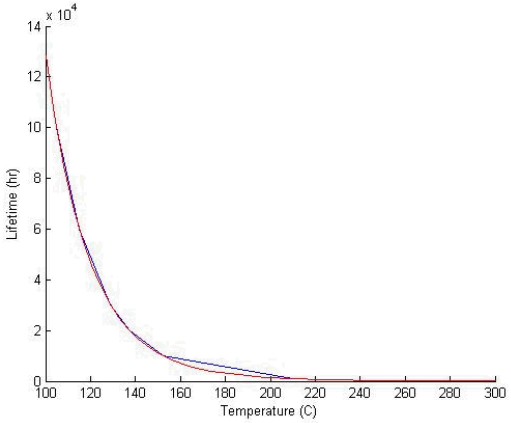
HT Flash Components

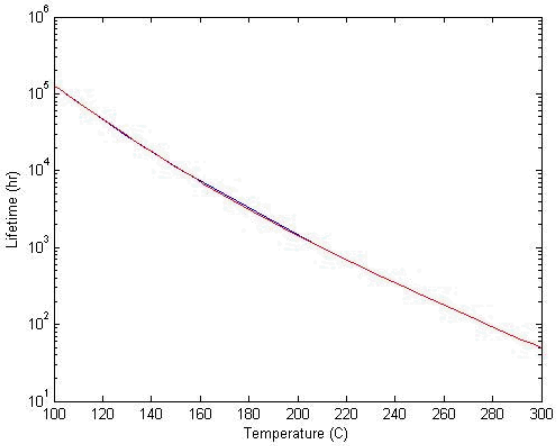
"The predicted operating lifetime vs. junction temperature is based on reliability modeling and available qualification data."



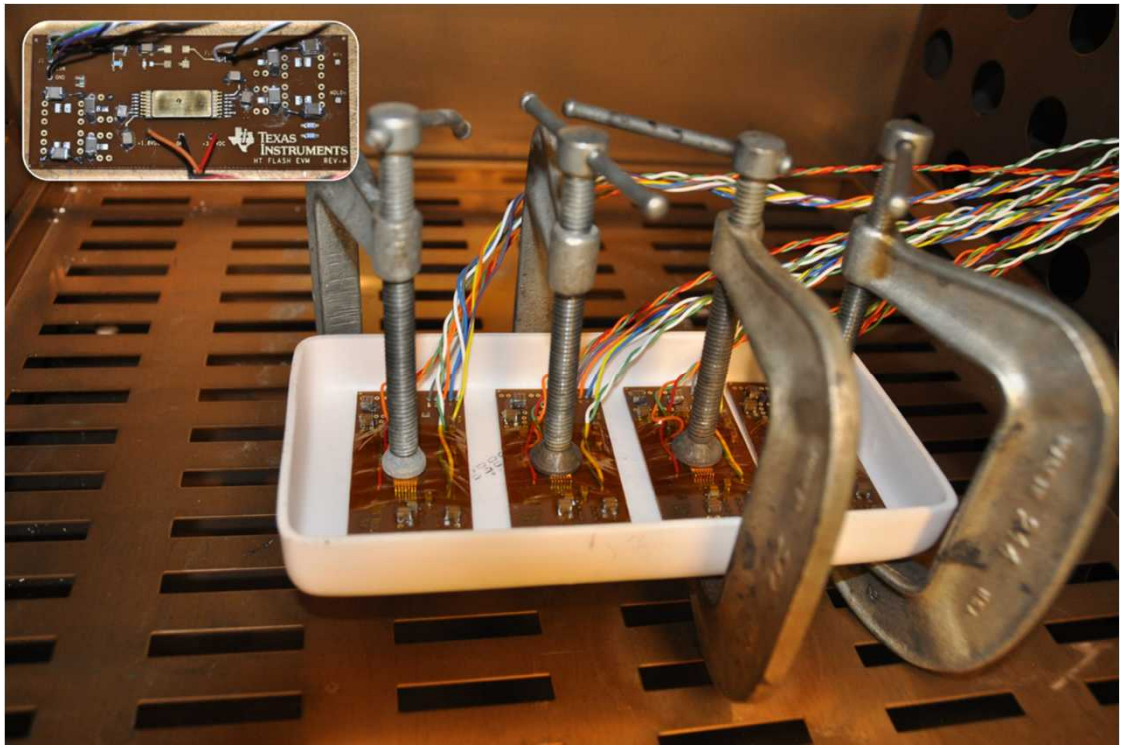


MATLAB Fit and Extrapolation





Modification and Mounting (300C)



Modifications:

- HMP Solder (MP 309C)
- Kapton Tape wrap
- C-clamps

Test Parameters:

- 10 Modules Total
- I/O Pwr Voltage: 3.5 V
- Core Pwr: 1.95 V
- Clock: 12 MHz

Function Maximum Temperatures

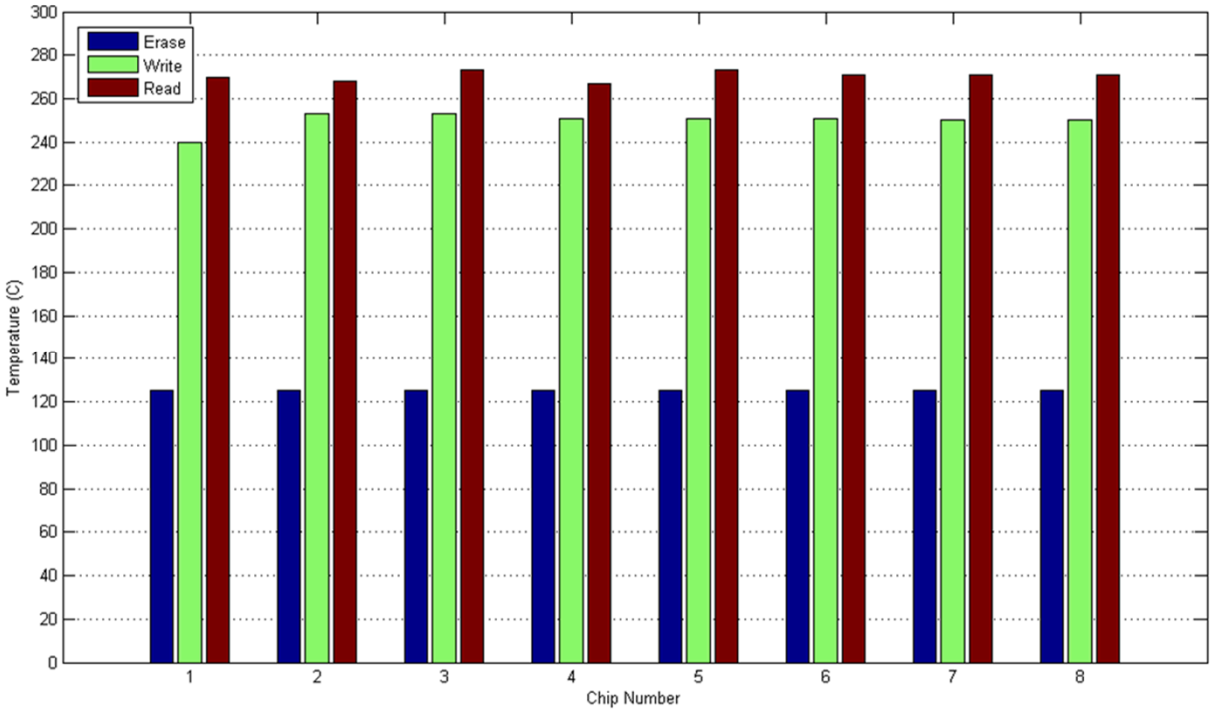


Figure 2. Maximum temperature of each function. The maximum read temperatures in these 8 modules range from 267°C to 273°C with an average of 270.5°C. The maximum write temperatures range from 240°C to 253°C with an average of 249.9°C. To avoid depletion faults, the maximum erase temperature shown (125°C for all) is the highest temperature the erase function was tested.

Latency and Current vs Temperature

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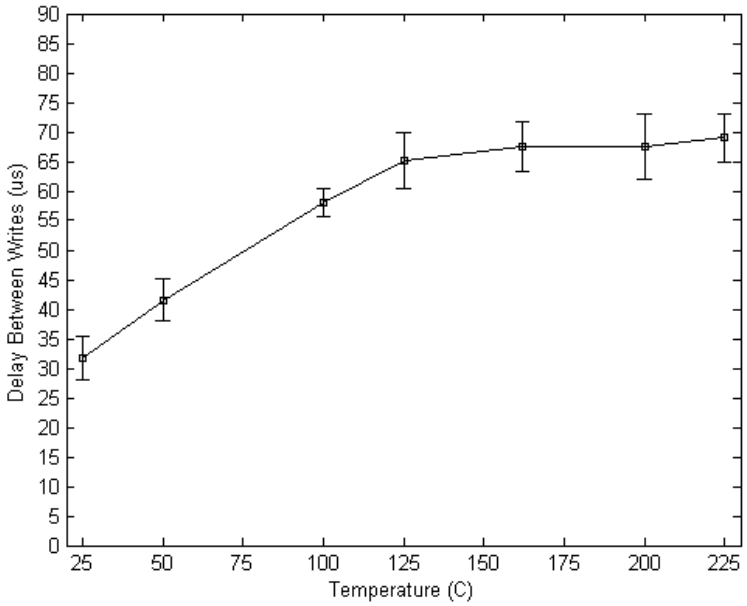
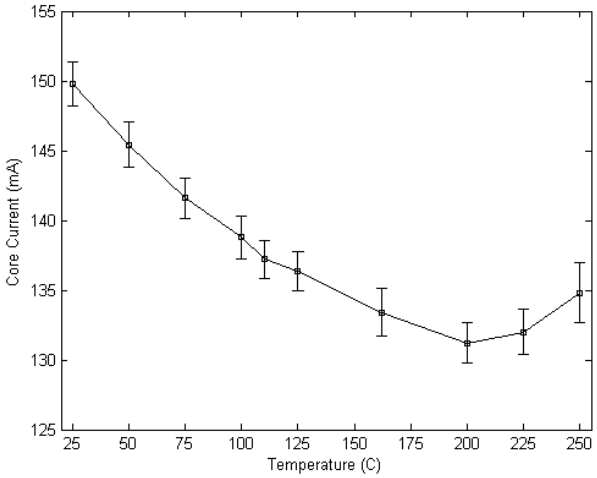
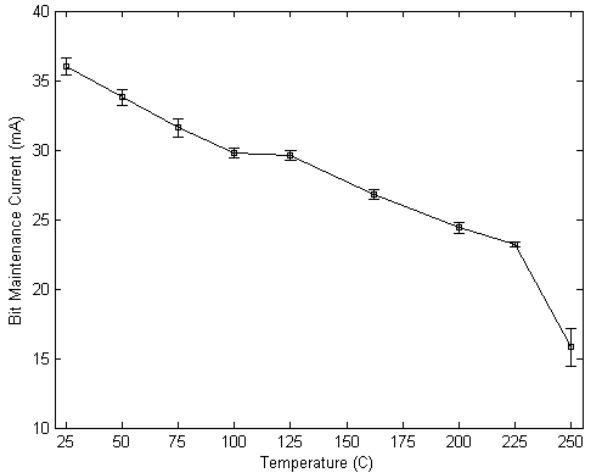
Latency vs. Temperature



Core Current vs. Temperature



All 0xFFFF

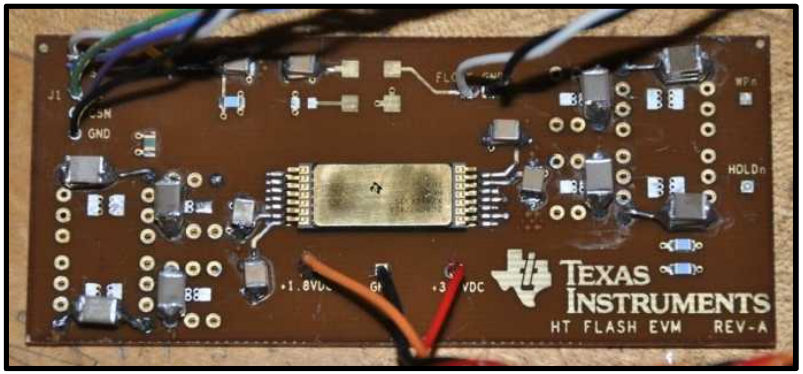


0xFFFF – 0x0000

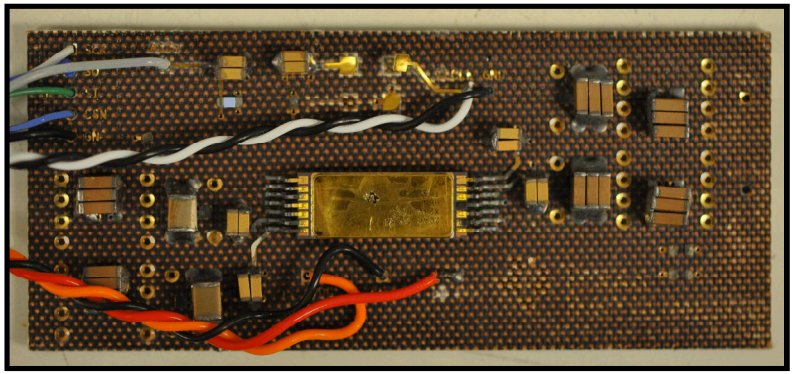
Out-of-Range Examination

- Above about 250C, Write functionality ceases
- Above about 270C, Read functionality ceases
- Erase functionality was not tested beyond 125C

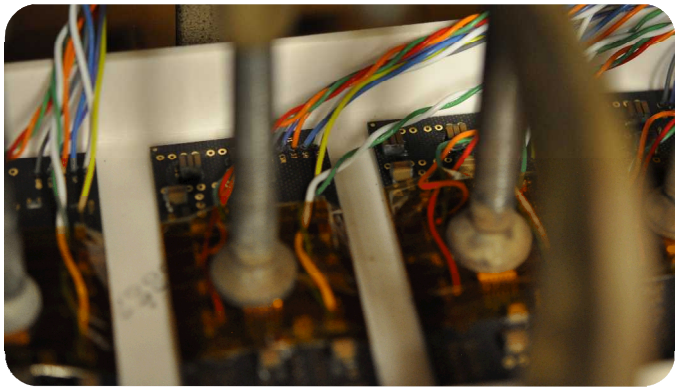
Representative Before



Representative After



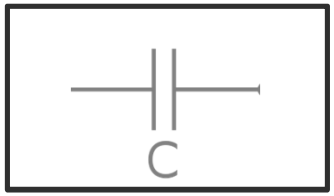
Flash Lifetime Results



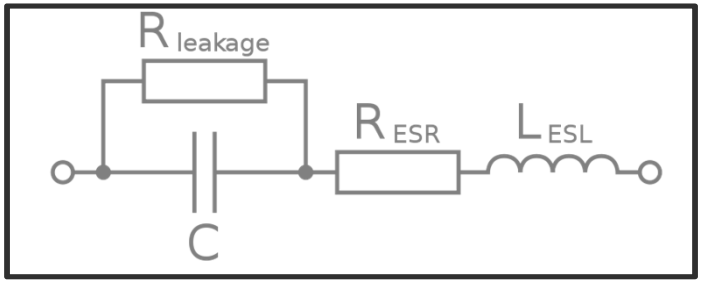
- Lifetime @ 225C: > 1000hrs
  - 1 module
- Lifetime @ 240C: > 1000hrs
  - 2 modules
- Lifetime @ 250C: > 1500 hrs (Test to failure on-going)
  - 3 modules
- Lifetime @ 265C: ~200hrs (Read function only)
  - 4 modules

Observation: Some modules survived brief (hours) excursions to 300C

Out-of-Range Capacitor Testing

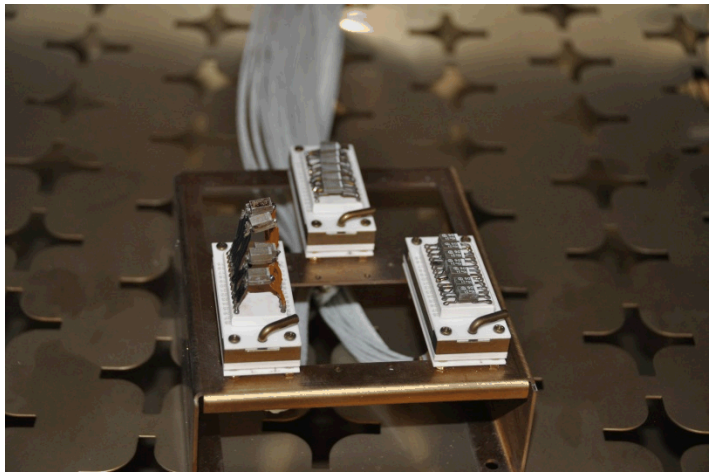


Ideal Capacitor

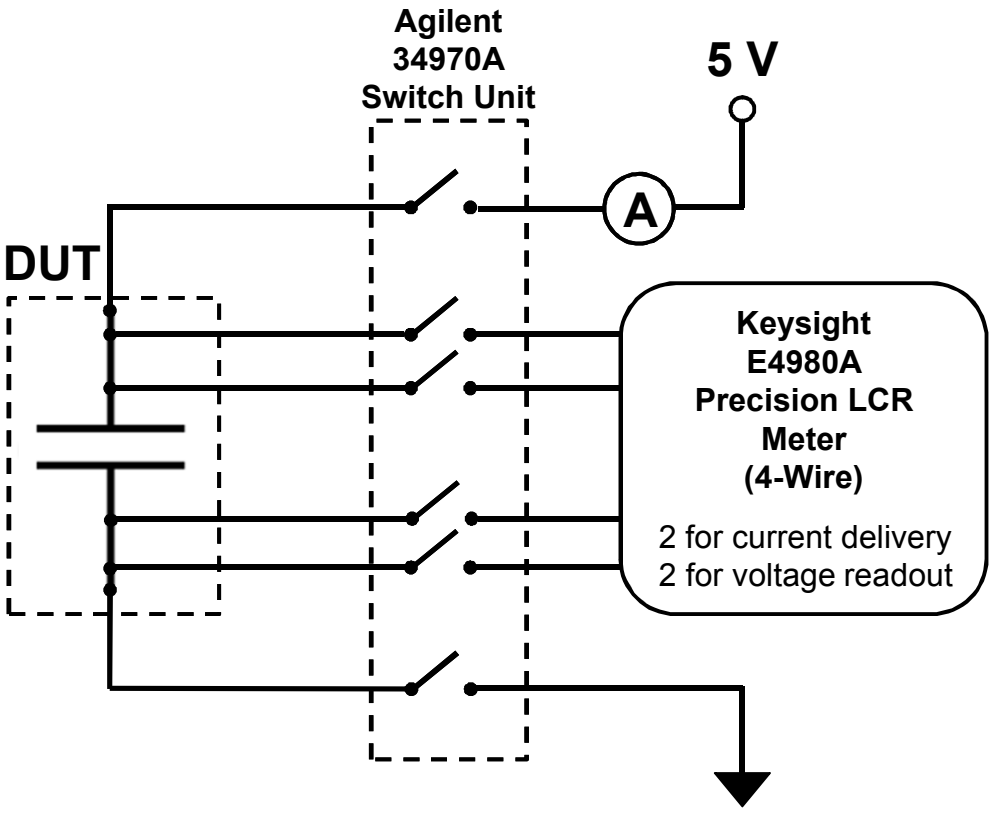


Real Capacitor

- Ceramic ZIF sockets for simultaneous HT evaluation of commercial capacitors
- Switch matrix enables multiple parallel tests using a single LCR/ESR Meter
- MatLab Control Interface



Capacitor Test Set-Up



$$Z = \frac{A_V}{A_i} e^{-i(\theta_V - \theta_i)}$$

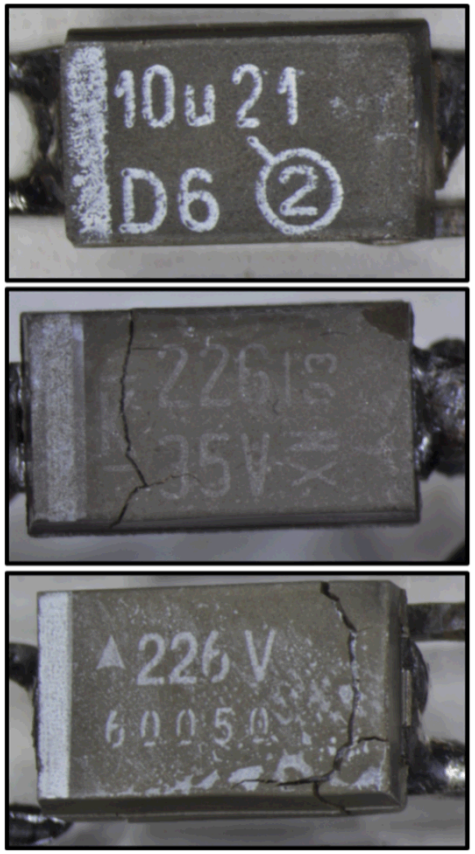
$$|Z| = \sqrt{ESR^2 + \left(\frac{1}{2\pi f C}\right)^2}$$

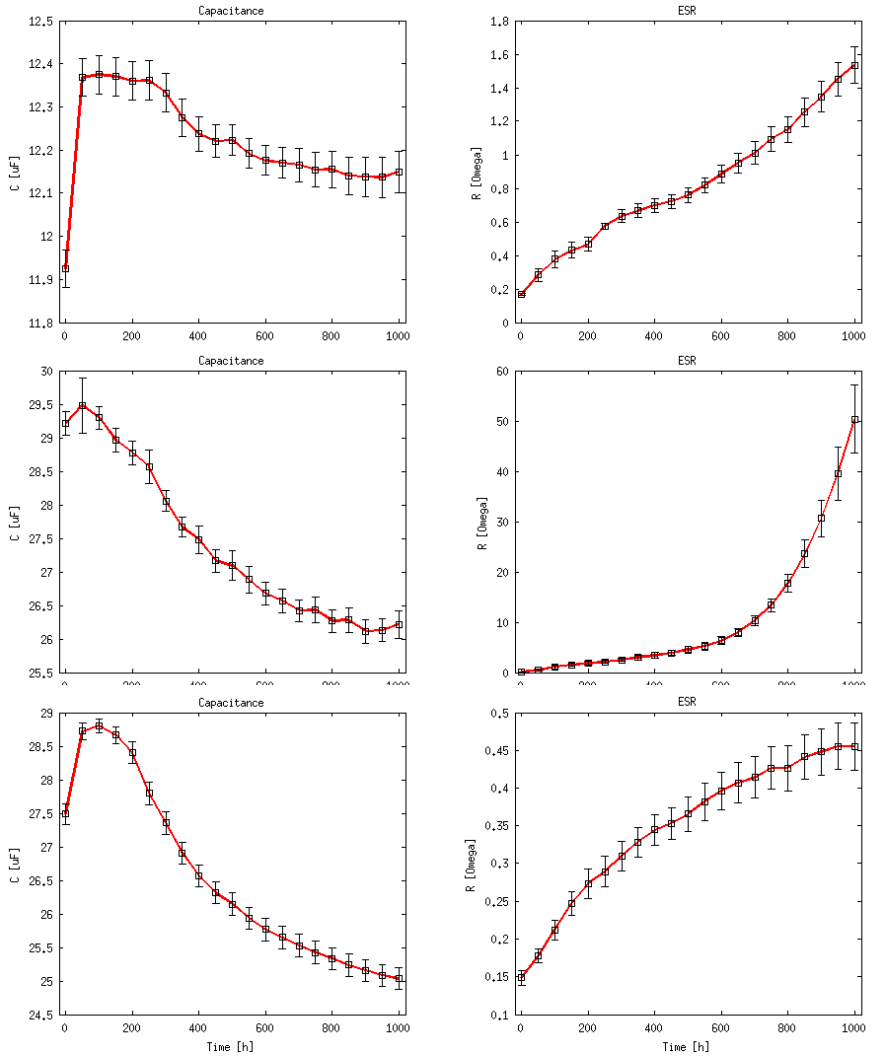
$$\theta = \tan^{-1}\left(\frac{(1/2\pi f C)}{ESR}\right)$$

$$C = \frac{1}{2\pi f |Z| \sin\theta} \qquad ESR = |Z| \cos\theta$$

Preliminary Tests

COTS Solid Tantalum Capacitor Testing (1000hrs @ 260°C)



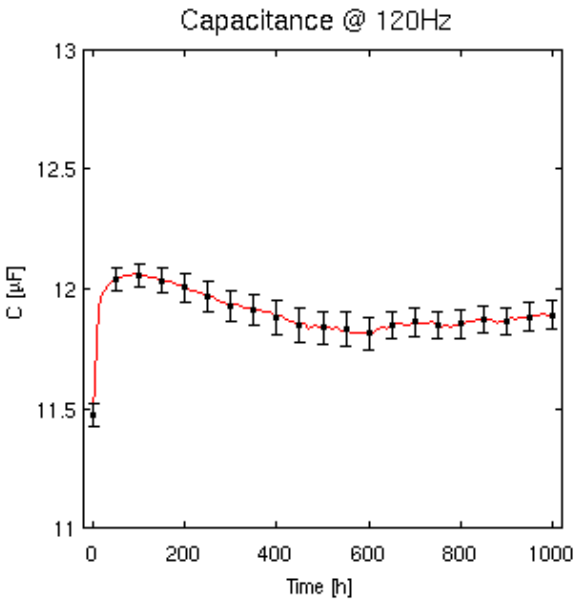


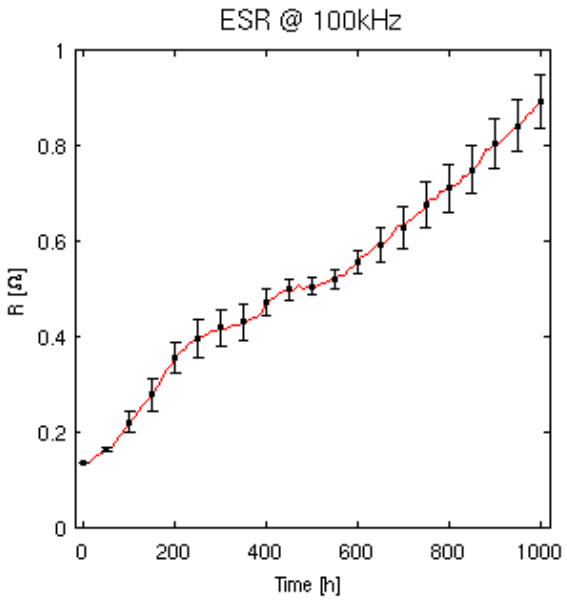
Capacitor Lifetime Results

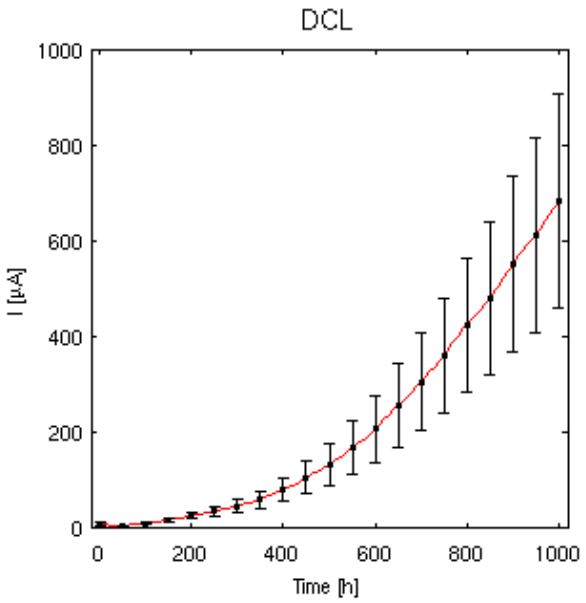
- 10µF Tantalum Capacitor: (Vishay) TH5E106K021A1000
- Max Rated Temp: 200C
- 1000hr Test Temp: 250C

Capacitance Change: +7.3%

ESR Change: 0.3 Ω to 24.7 Ω





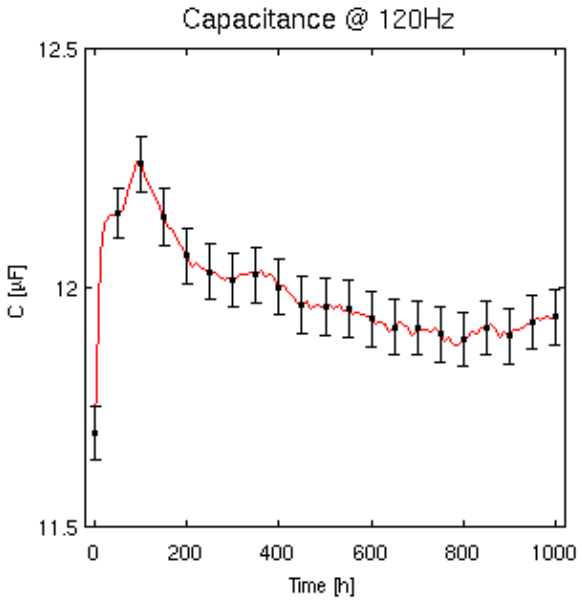


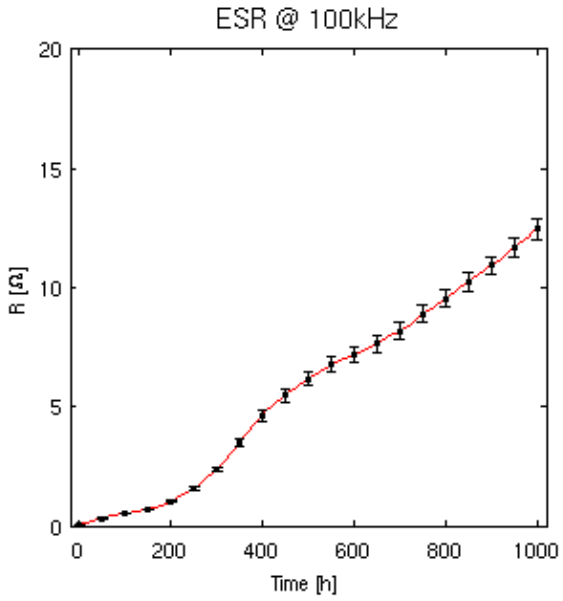
Capacitor Lifetime Results

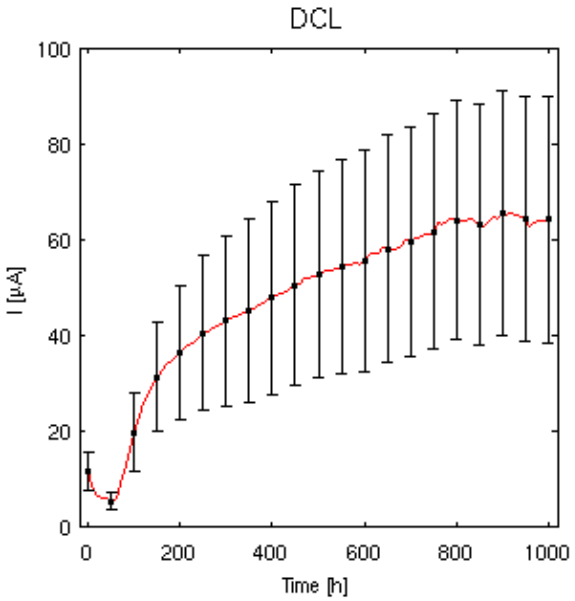
- 10µF Tantalum Capacitor: (Kemet) T499D106K050ATE1K0
- Max Rated Temp: 175C
- 1000hr Test Temp: 250C

Capacitance Change: +2.9%

ESR Change: 0.17 Ω to 93.8 Ω





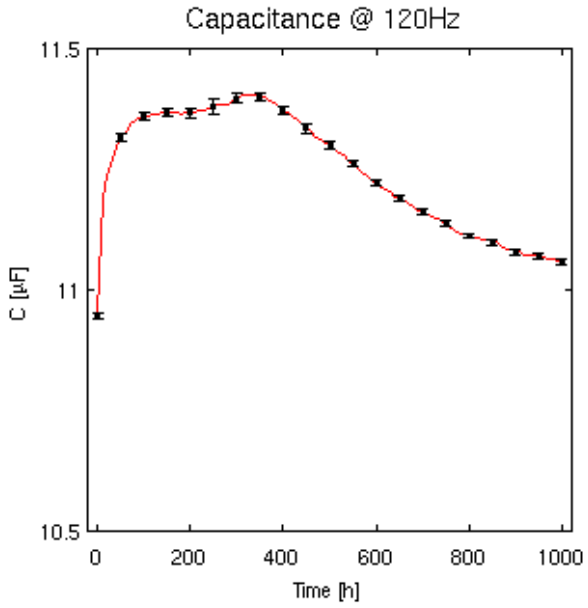


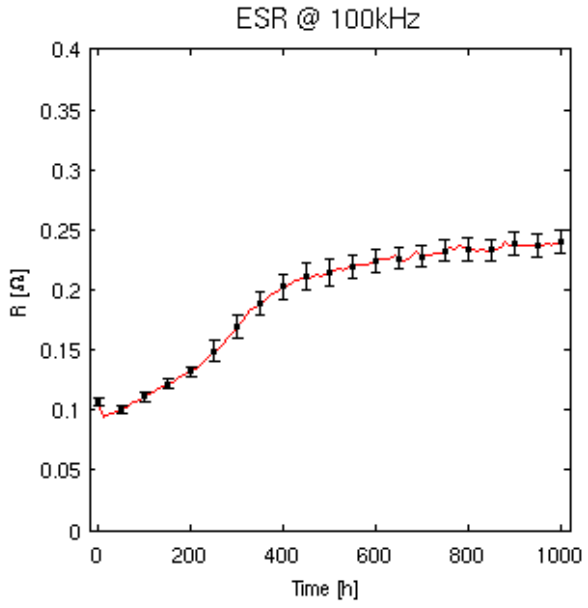
Capacitor Lifetime Results

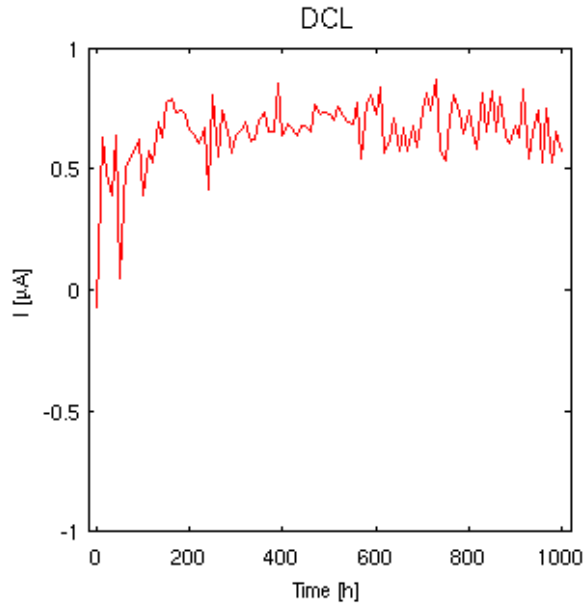
- 10µF Tantalum Capacitor: (AVX) THJD106k050AJN
- Max Rated Temp: 175C
- 1000hr Test Temp: 250C

Capacitance Change: -1.5%

ESR Change: 0.22Ω to 0.42 Ω







Thank You

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Questions?