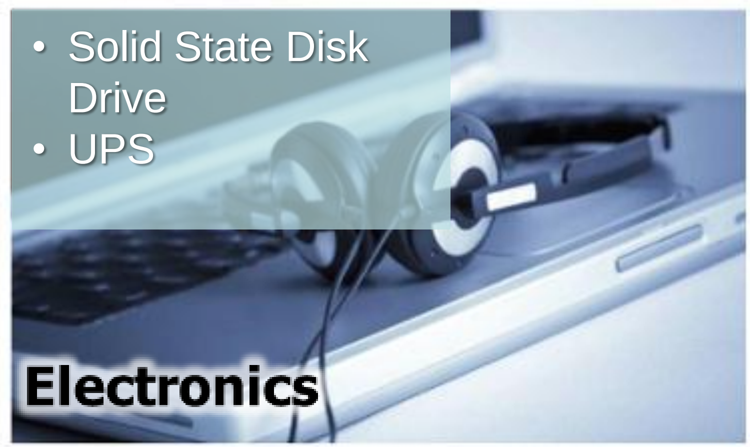
IMPROVE SSD PERFORMANCE WITH ULTRACAPACITOR POWER BACKUP

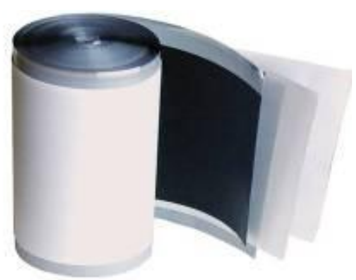
Jens Keiser - Sr. Manager, Product Marketing
Dave Wright - Director, Application Engineering
Maxwell Technologies
August 23, 2012

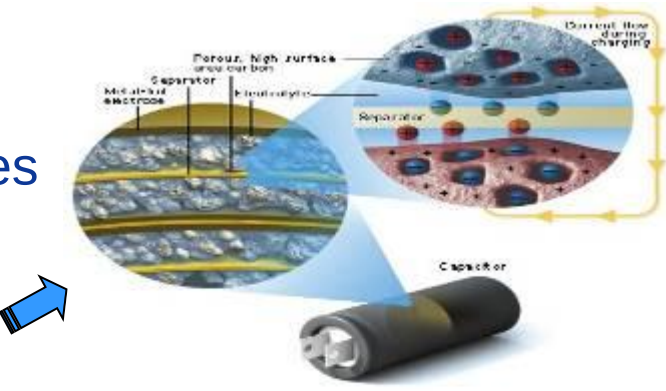
Maxwell Industry Involvement



Ultracapacitor Basics

- Ultracapacitors, Electric Double Layer Capacitors, Supercapacitors are synonyms
- Operating principle
  - An electronic charge accumulator having extreme capacitor plate specific area and atomic scale charge separation distance.
  - No chemical reactions
- Performance
  - 100k to >1M charge/ discharge cycles
  - Up to 15 year DC life



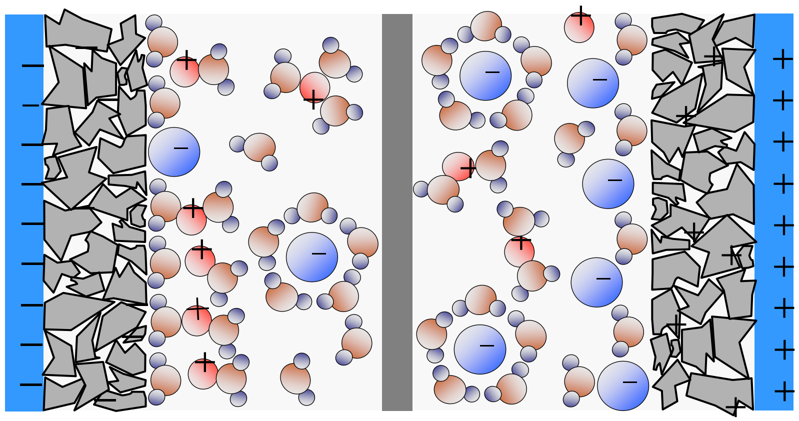


Graphic: IEEE Spectrum, Jan 2005

Electrode

Intellectual Property:

- ~ 55 Patents
- ~ 20 Patents pending



$$\text{Capacitance} \sim \frac{\text{Surface Area}}{\text{Separation Distance}}$$

Thickness of Helmholz layer ~ 1nm
Carbon powder surface area up to 3,000m²/g

⇩

Capacitors up to 3,000F

Fundamental Materials

Basic material is carbon

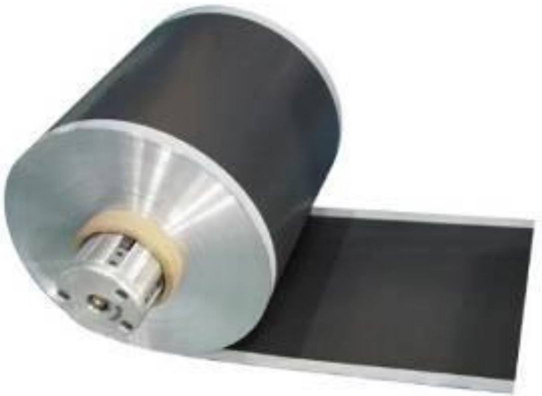
Charred Carbon

Grind

Activation

Activated Carbon

Coating
Rolling
Kneading
Pasting



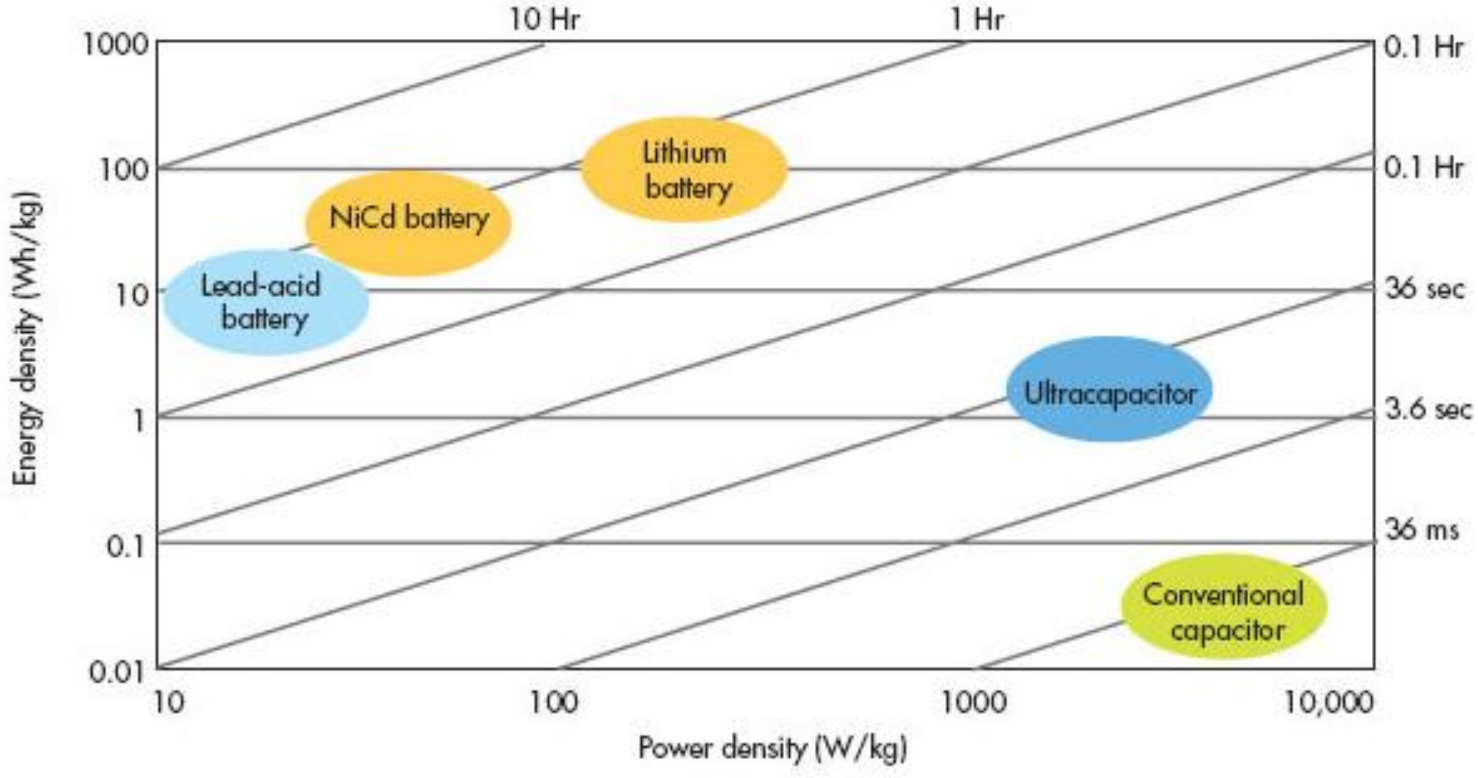
Maxwell Electrode

Maxwell Ultracapacitor Product Lines

Maxwell offers a variety of sizes and configurations of ultracapacitors.

Specification	PC Series	HC Series	BC Series	K2 Series
Capacitance (F)	10	1–150	310–350	650–3,000
Rated Voltage (V DC)	2.5	2.7	2.7	2.7
ESR, DC (mohm)	180	14–700	2.2–3.2	0.29–0.8
Leakage current (mA)	0.04	0.006–0.5	0.3–0.45	1.5–5.2
Emax (Wh/kg)	1.4	0.9–4.3	5.2 – 5.9	4.1 – 6.0
Pmax (W/kg)	660	2400 - 7000	9500 – 14,000	12,000 – 14,000

Power and Energy Density – Ragone Plot



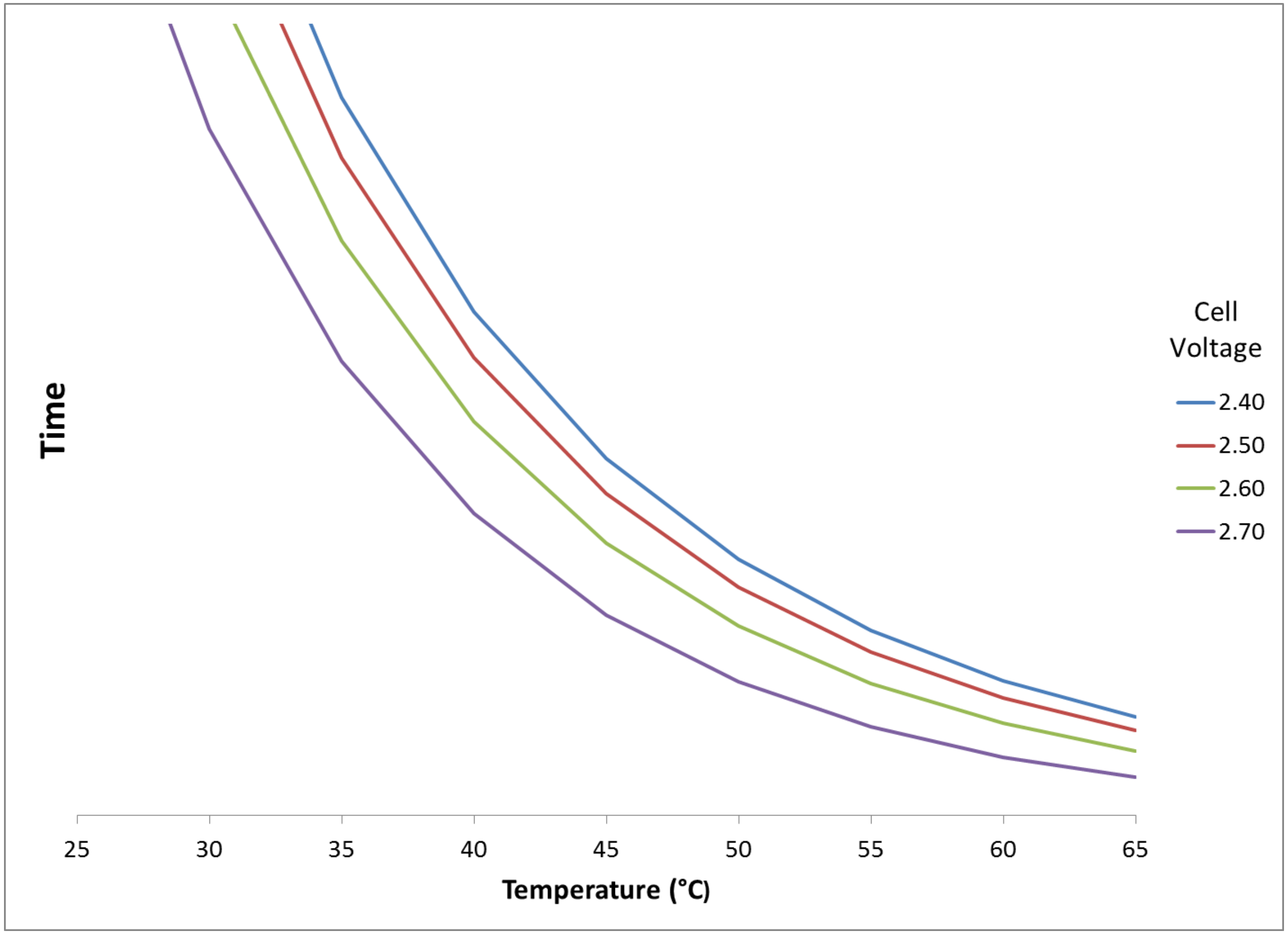
Source: ElectronicDesign.com
November 15, 2007

Ultracapacitor Aging Behavior

- Ultracapacitors exhibit a gradual decline in performance over time
  - Decrease in capacitance
  - Increase in ESR
- “End of Life” becomes a defined point – not an actual failure
- Maxwell defines EOL when one of two things happen:
  - Decrease in capacitance below 70 - 80% of rated value
  - Increase in ESR to 200% of rated value
- In practice, the decrease in capacitance is usually the limiting factor
- Parts still function, but these parameters are degraded
- Decrease in performance must be accounted for when doing initial system design

Lifetime Model

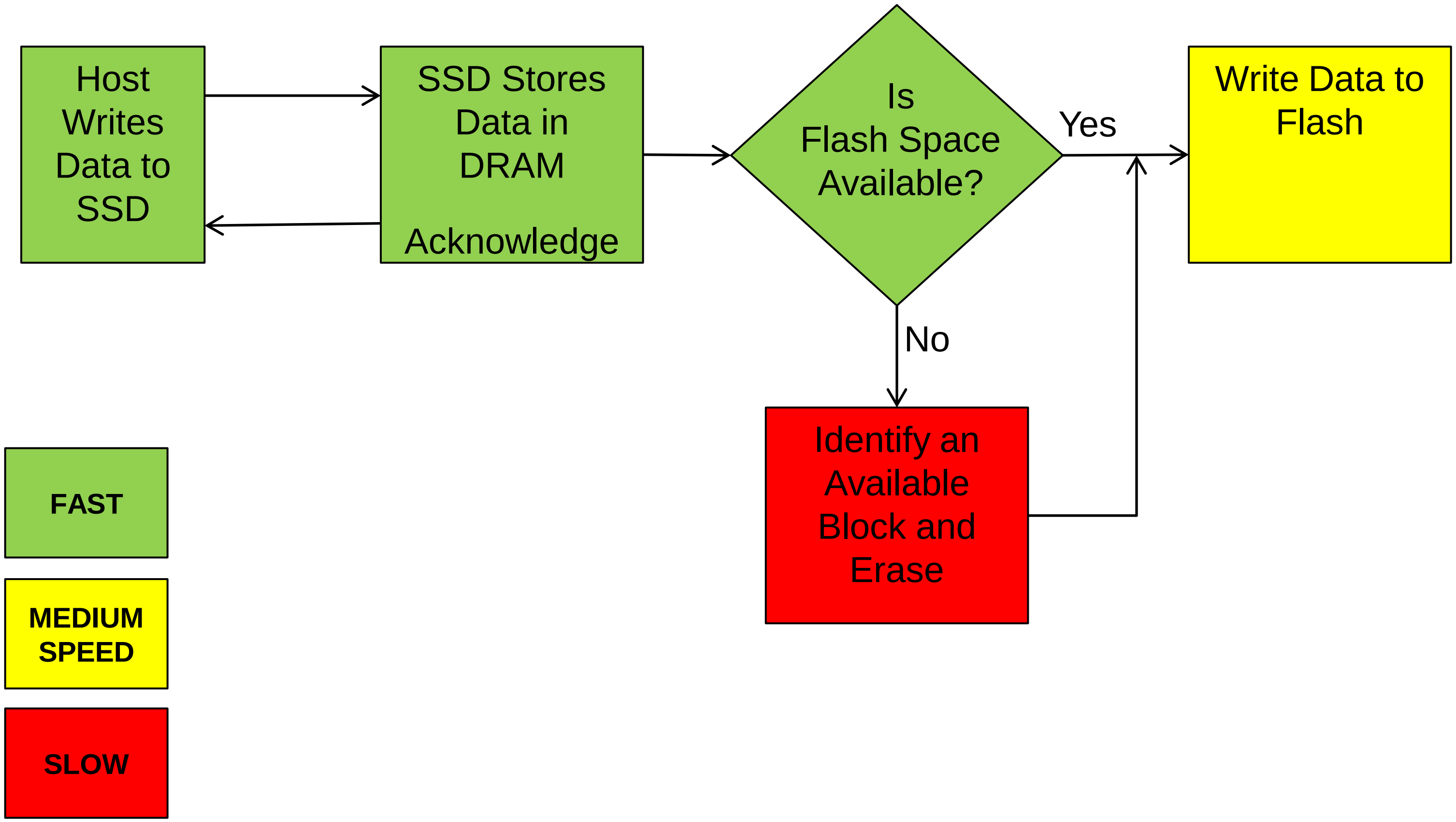
Mean Service Life vs. Temperature



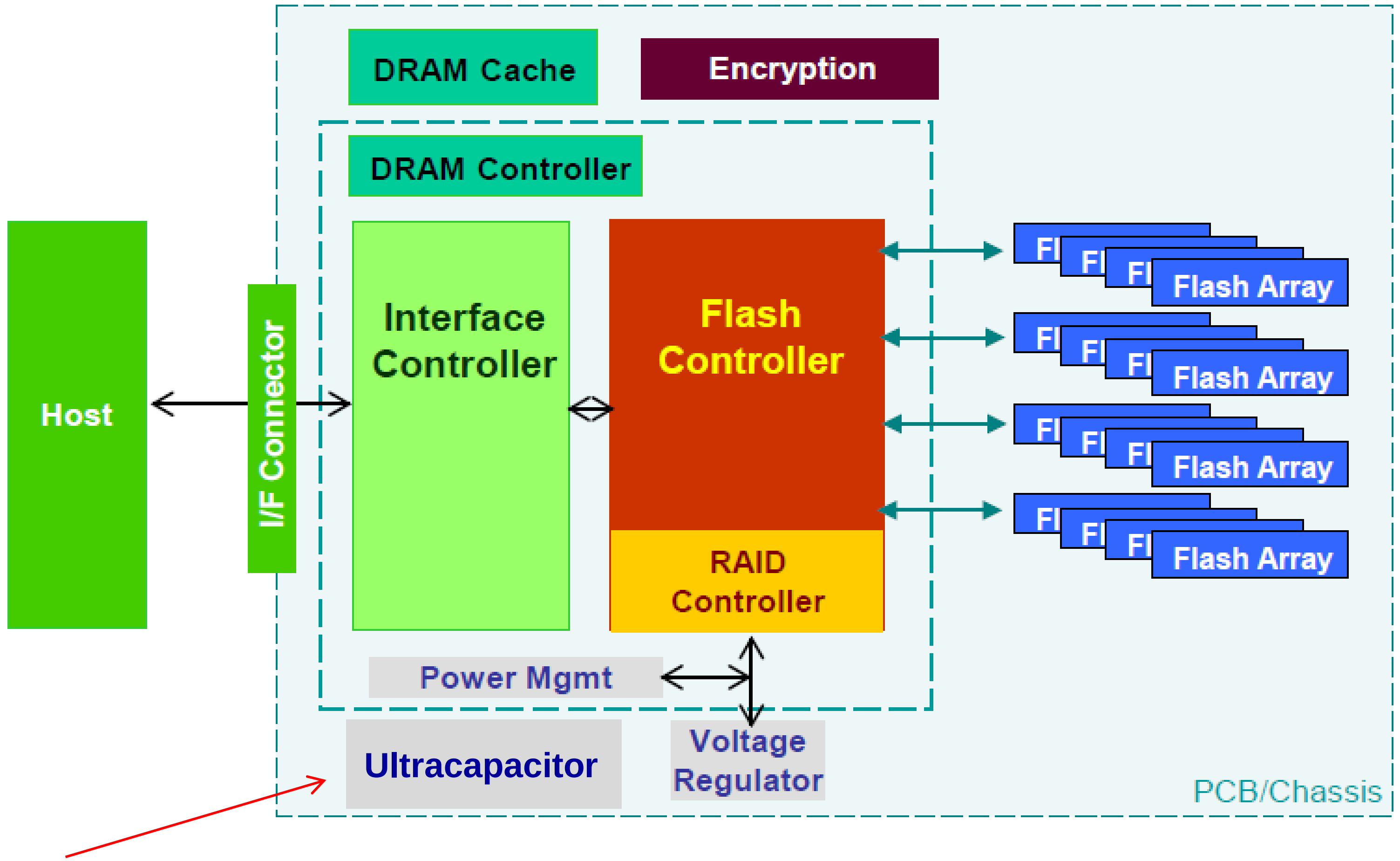
Need for Backup Power in Enterprise SSDs

- SSDs used for
  - Computation Intensive Applications
  - Online Transaction Processing (OLTP)
  - Database Warehousing
  - Image Processing
- Faster Input/Output performance a key metric
- Larger DRAM caches improve performance
  - More backup power required

Enabling Higher Write IOPS



Typical SSD Architecture

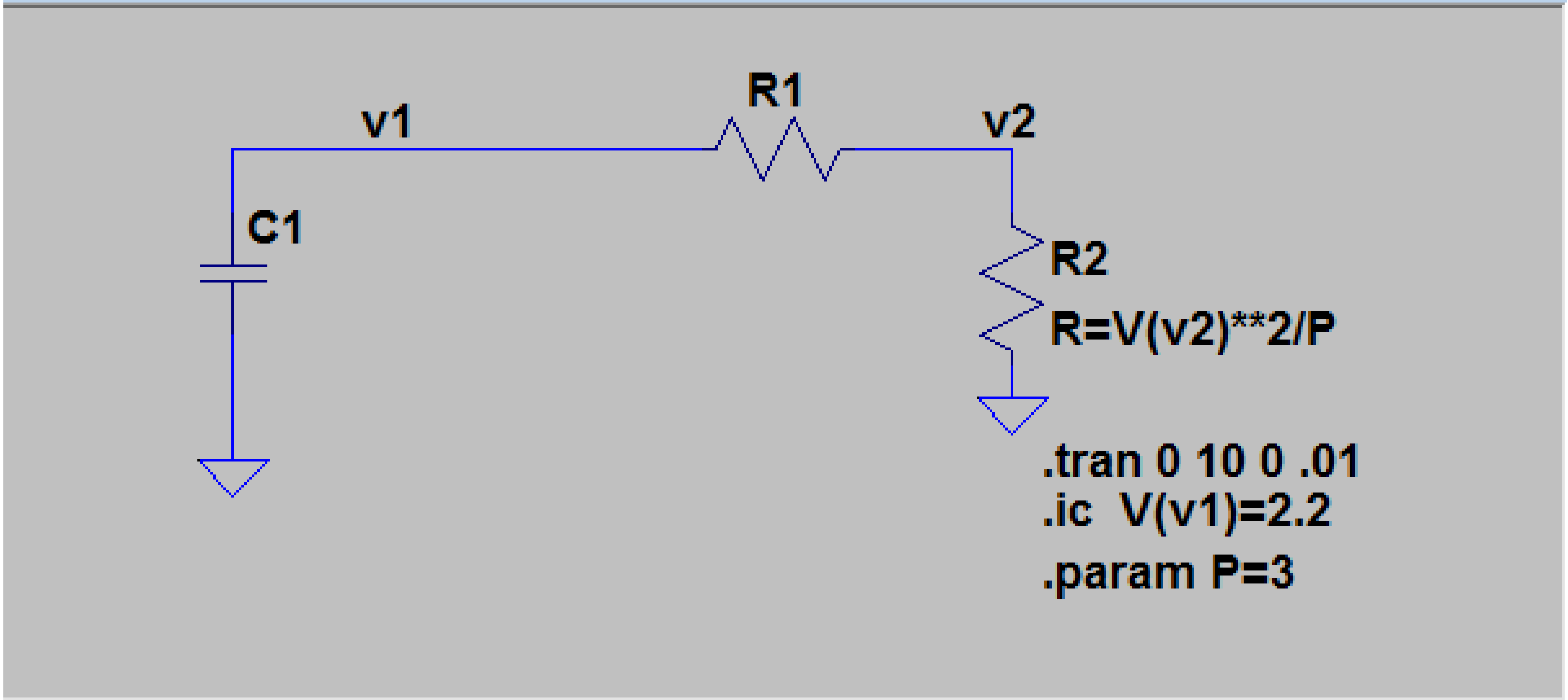


Source: IMEX Research.com ©2011. With permission.

Example

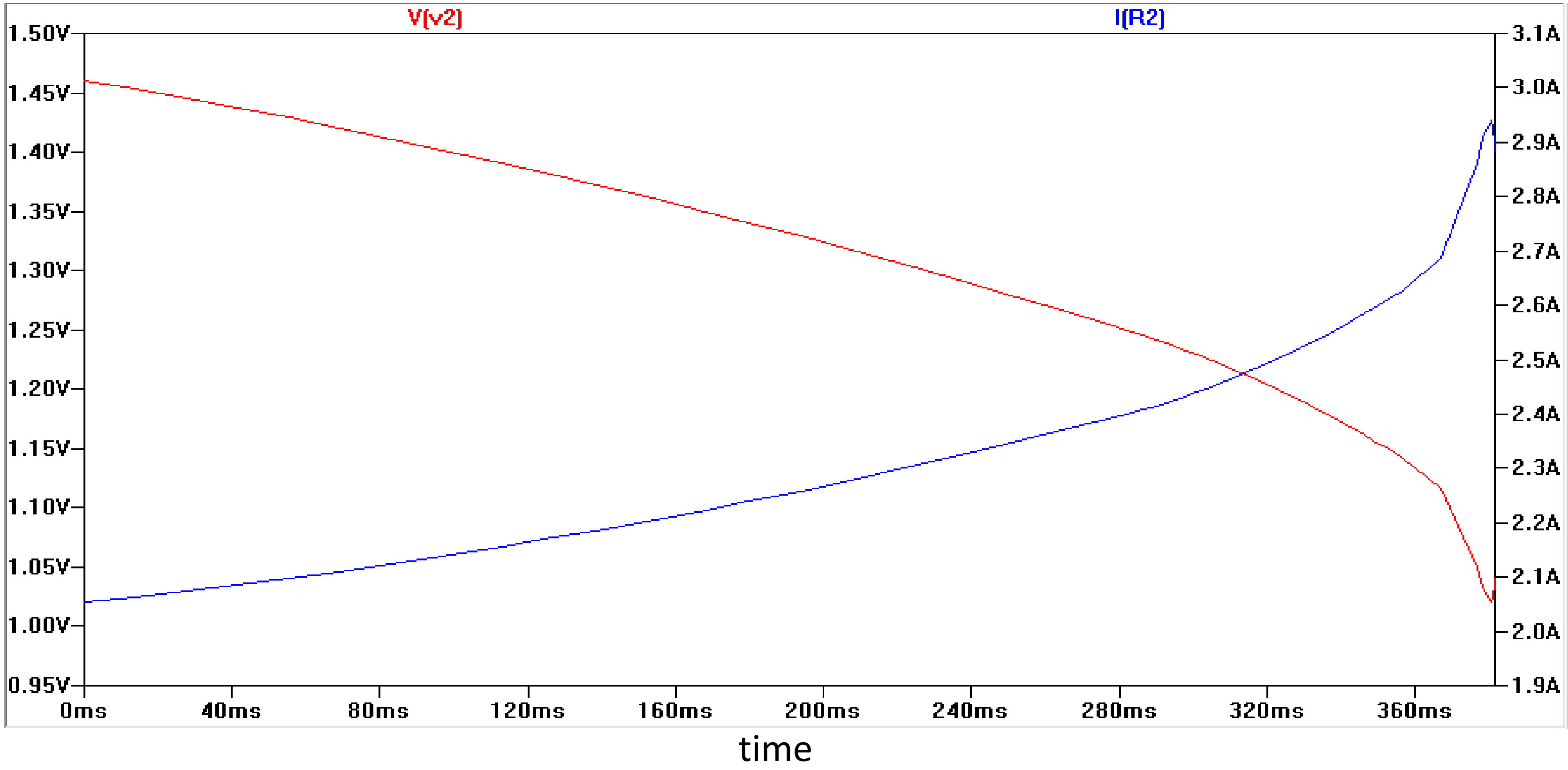
- Backup Requirement = 3W
- Minimum Backup Time = 2 seconds
- Starting Voltage = 2.2V
- Ending Voltage = 1.1V
- Required Energy
  - 3W x 2 seconds = 6J
- Minimum Capacitance
  - (2x6)/(2.2^2-1.1^2)=3.3F

Simulation Schematic



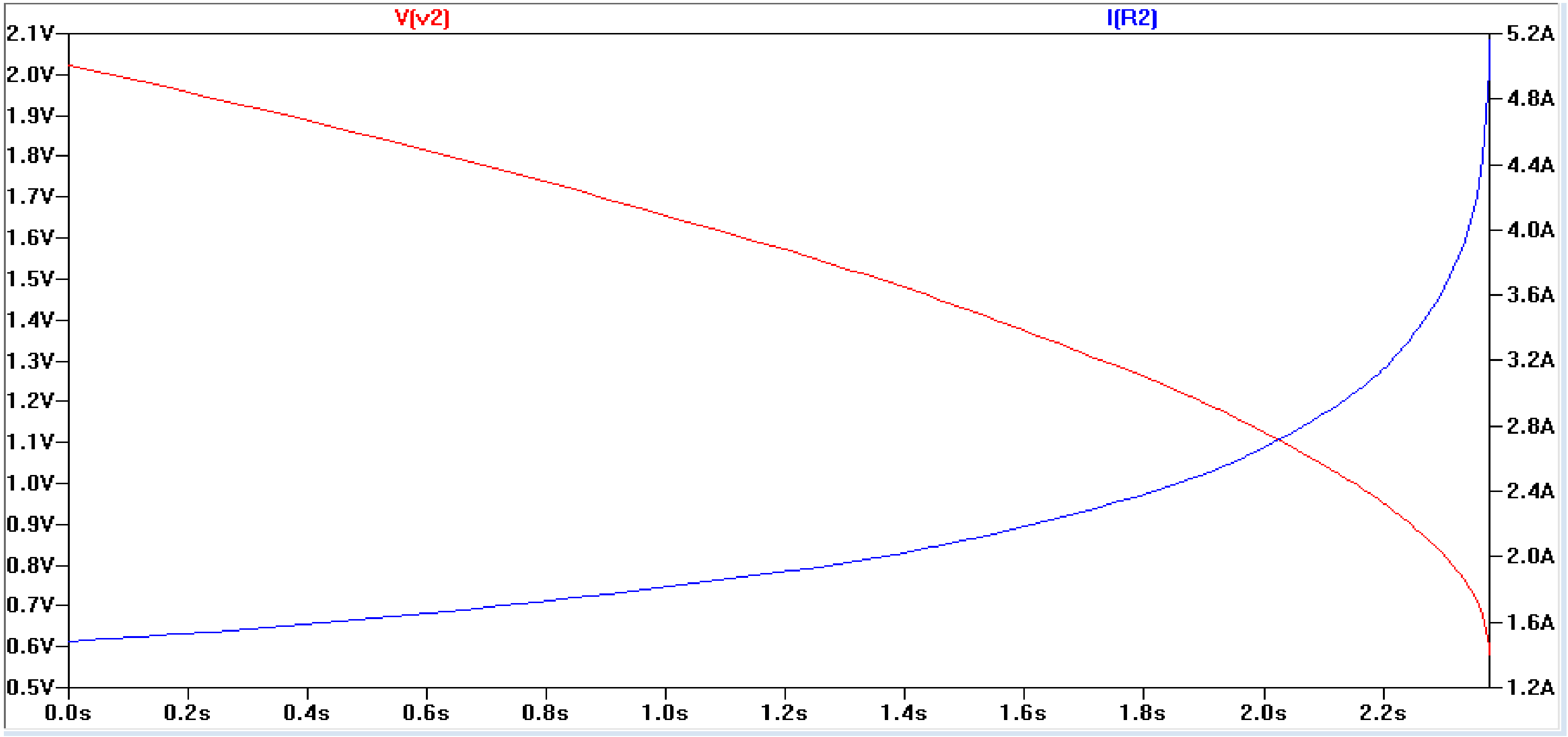
Simulation Results

- C=7.2F
- R=360mΩ
- Requirement not met



Simulation Results

- C=5F
- R=120mΩ
- Requirement met

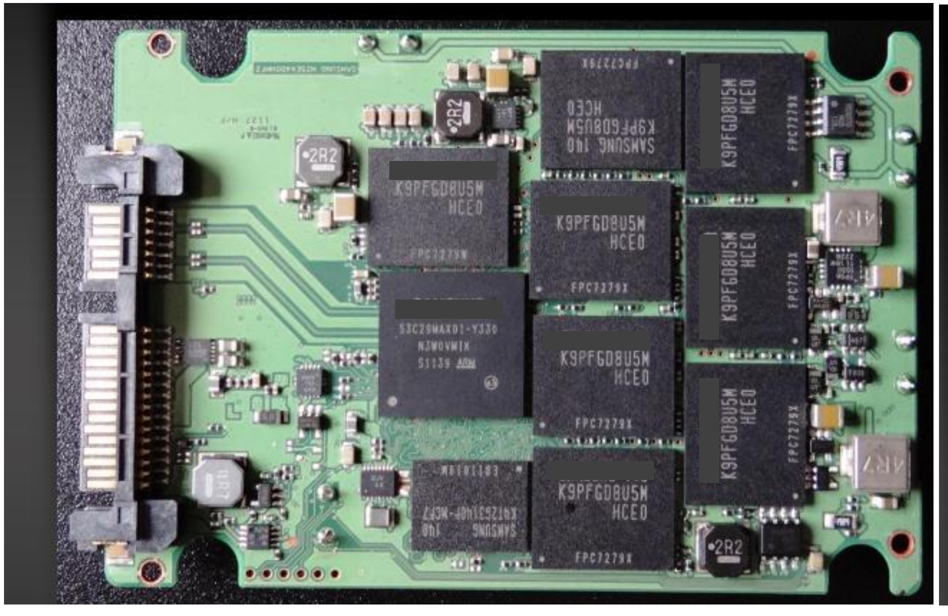


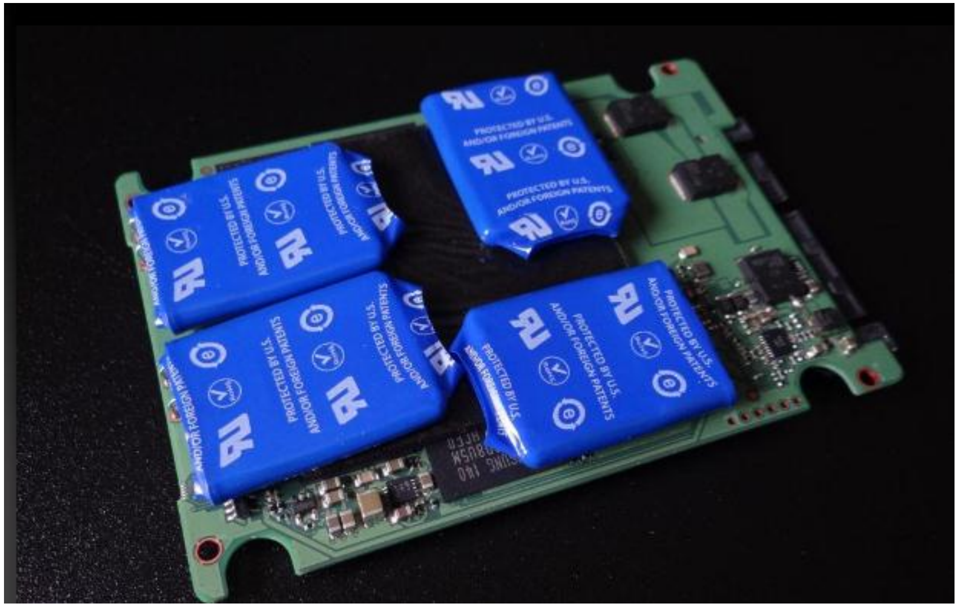
time

Keys to a Successful Design

- Manage temperature carefully
  - Dominant stressor for ultracapacitor life
- Ensure that power requirements are within the capability of device ESR
- De-rate capacitance and ESR to end-of-life values
- Pay close attention to specification details
  - All 10F ultracapacitors are not equal

A Current Implementation





Future Trends

- Ultracapacitor technology is relatively new
- As applications grow, improvement is likely in
  - Cost
  - ESR (Power Density)
  - Operating Voltage (Energy Density)

Conclusions

- Inclusion of DRAM cache in Enterprise SSD requires backup power
- Ultracapacitors are accepted devices to provide required backup capability over SSD life expectancies
- Attention to pertinent device parameters can ensure successful performance