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High Voltage Ceramic Capacitors for High Pulse Current Applications

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Control Discharge Capacitor (CDC) Development

- Vishay developed a new X7R (X5P) dielectric system having a Low Coefficient of Electrostriction (Low Q_E).

- The Low Q_E material has less mechanical strain when an electric field is applied.

- This new material is incorporated in MLCCs for high voltage and high pulse current applications.

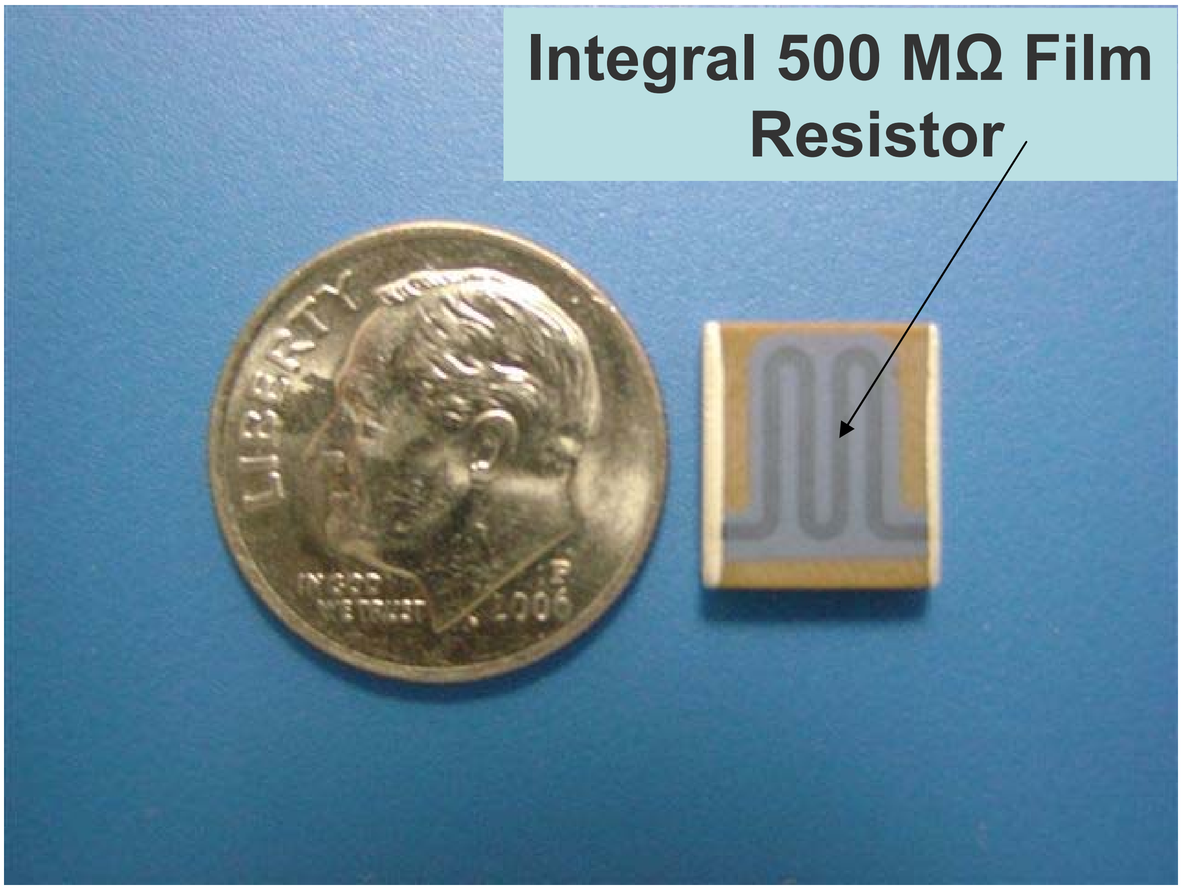
- The CDC was developed specifically for Electronic Fuze applications.

Overview

- **CDC properties**
- **Comparison of Electrical Characteristics**
  - Voltage Breakdown Levels (VBD)
  - Temperature Coefficient of Capacitance (TCC)
  - Voltage Coefficient of Capacitance (VCC)
- **Pulse Discharge Current of Experimental CDCs**
- **Fireset Ringdown Measurements at (-40, 25, 75) Celsius**
- **Conclusions**

Controlled Discharge Capacitor

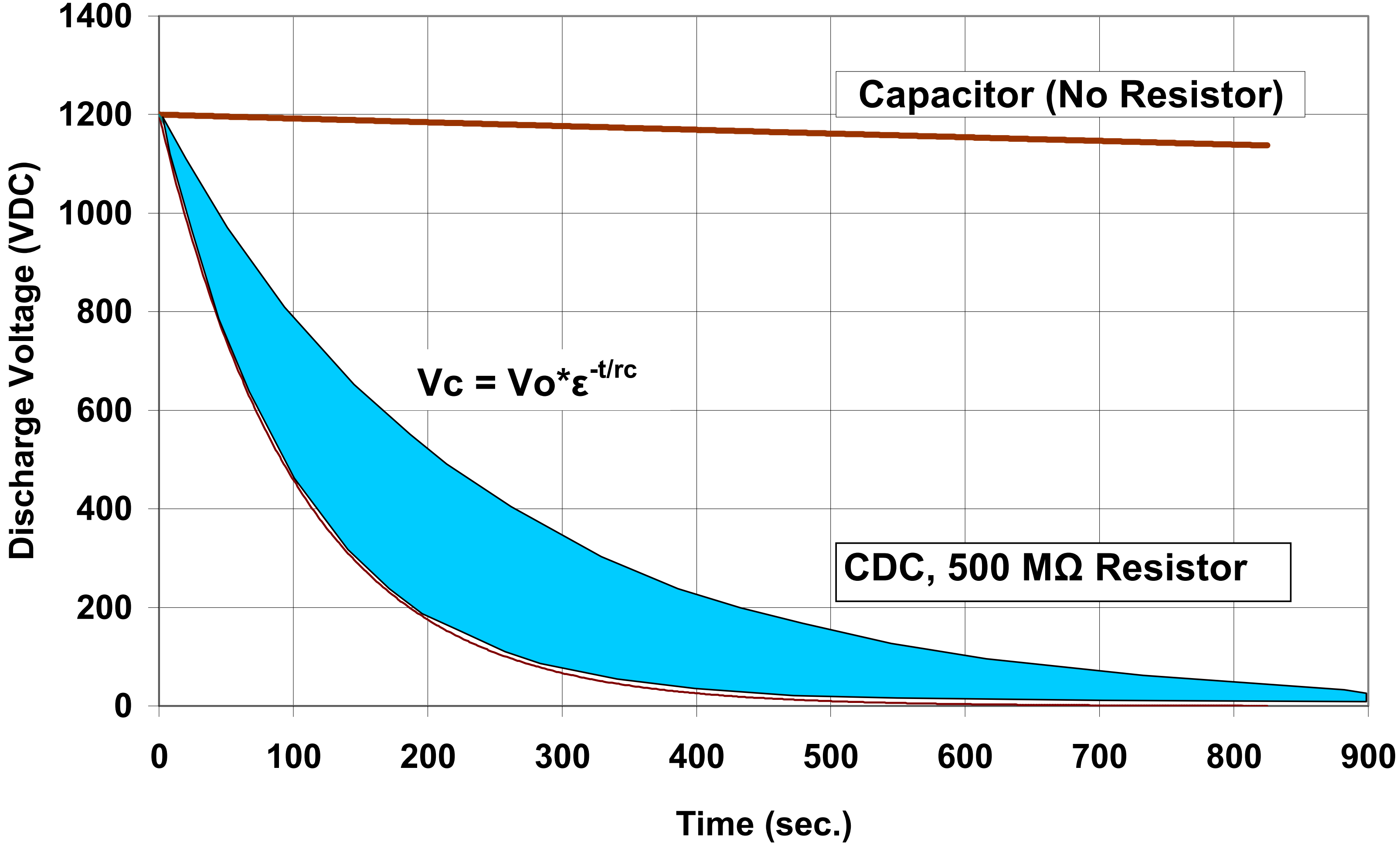
CDC - 3640, 180nF, 1500Vr



CDC Discharge Time

- The discharge voltage vs. time curve of a CDC is compared to that of a regular high voltage capacitor.
- The capacitor with no parallel resistor maintained 95% of the initial charge voltage 800 seconds after the bias is removed.
- The CDC safely discharges below the firing threshold and closely follows a typical RC discharge function $Vc = Vo*\varepsilon^{-t/rc}$

Self Discharge Curve
CDC: 4044, 330nF, 1500V



CDC Dimensions

CDC DIMENSIONS inches [millimeters]			
P/N CASE CODE	LENGTH	WIDTH	MAXIMUM THICKNESS (T)
VJ3640	0.360± 0.015 [9.14 ± 0.38]	0.400 ± 0.015 [10.20 ± 0.38]	0.086 [2.18]
VJ4044	0.400± 0.015 [10.16 ± 0.38]	0.440 ± 0.015 [11.17 ± 0.38]	0.120 [3.05]

Comparison of Electrical Characteristics

- Three experimental CDC capacitor designs
- Testing:
  - Voltage breakdown,
  - Temperature coefficient
  - Voltage coefficient

Experimental Capacitors

Case Size	4044	3640	3640
Dielectric	Low Q_E	Low Q_E	Standard X7R
Capacitance	330 nF	180 nF	270 nF
DC Rated Voltage	1500	1500	1500

Voltage Breakdown Levels

- Three 1500V rated CDC designs are subjected to voltage breakdown analysis.
- 50 samples of each design tested to failure by applying a uniform voltage ramp at a rate of 500 VDC/sec (EIA-198-2-E. Method 103)
- Capacitors using low Q_E dielectric averaged 600V higher VBD – a 33% improvement over the standard dielectric.

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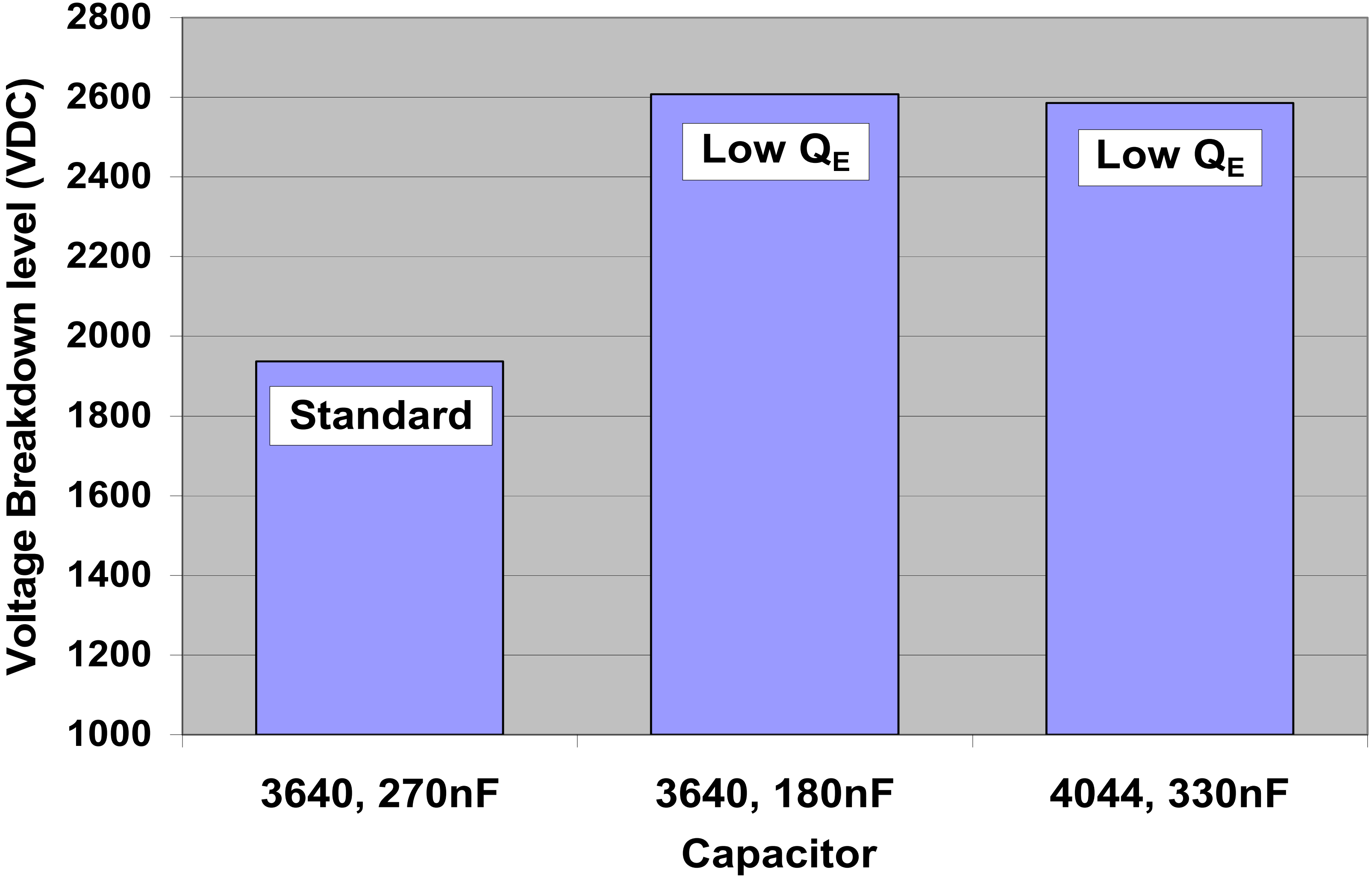
Voltage Breakdown Levels of Experimental Capacitors



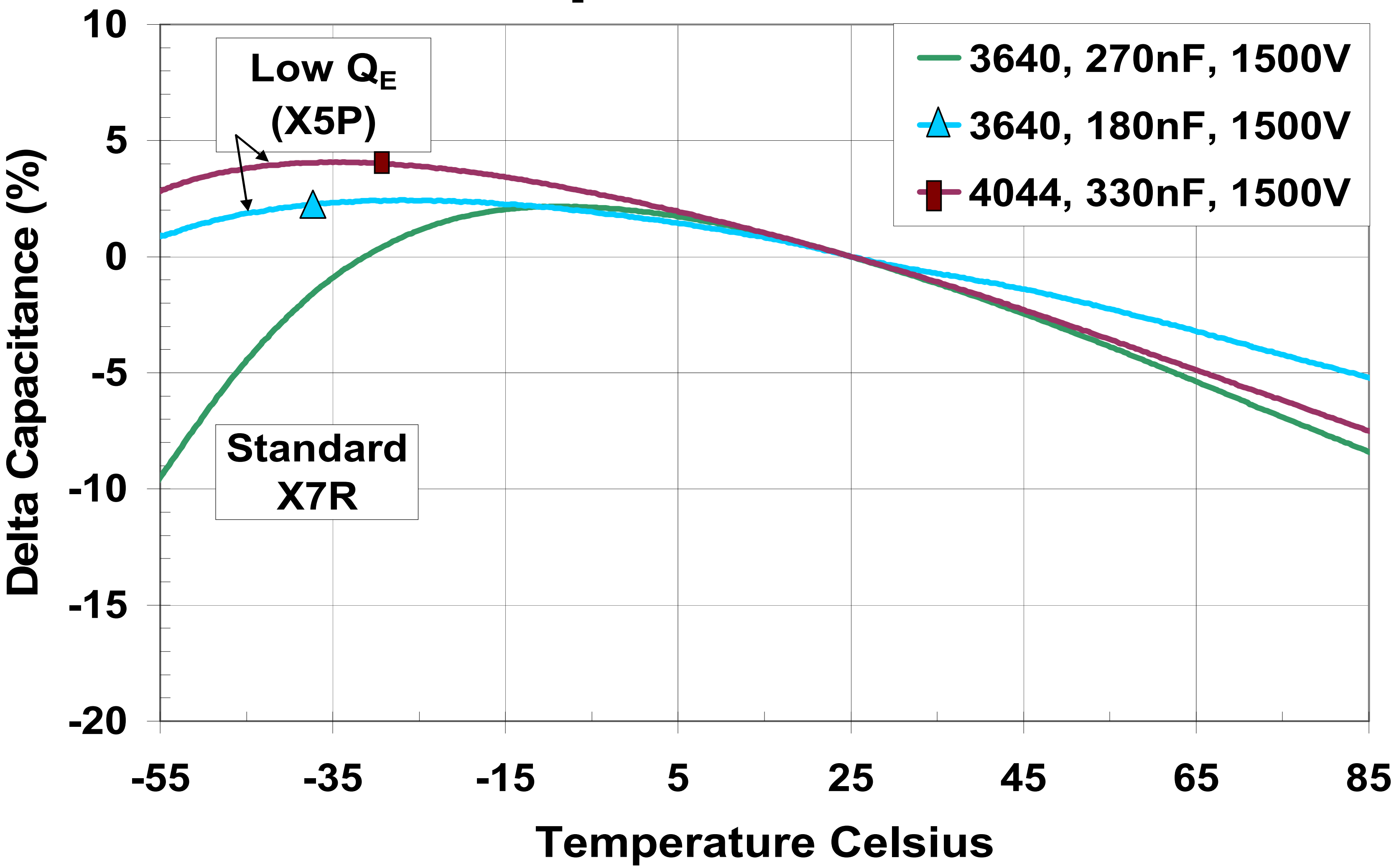
Voltage and Temperature Coefficient of Capacitance

- EIA Class II dielectrics utilize ferroelectric materials.
- Capacitors made with these dielectrics will undergo a capacitance delta when either a bias voltage is applied or ambient temperature conditions change.
- Capacitors made with the low Q_E dielectric retain more capacitance when subject to voltage and temperature compared to standard X7R capacitors.

Temperature Coefficient of Capacitance

- Low Q_E dielectric has improved capacitance stability across the operating temperature range and meets X5P TC Code.
- X5P Code: Capacitance delta will not exceed ± 10% within a -55 to 85 °C operating temperature.
- Below 25 °C the capacitance delta of Low Q_E dielectric is positive, affording more energy at the fireset's bias voltage.

Temperature Coefficient of Capacitance

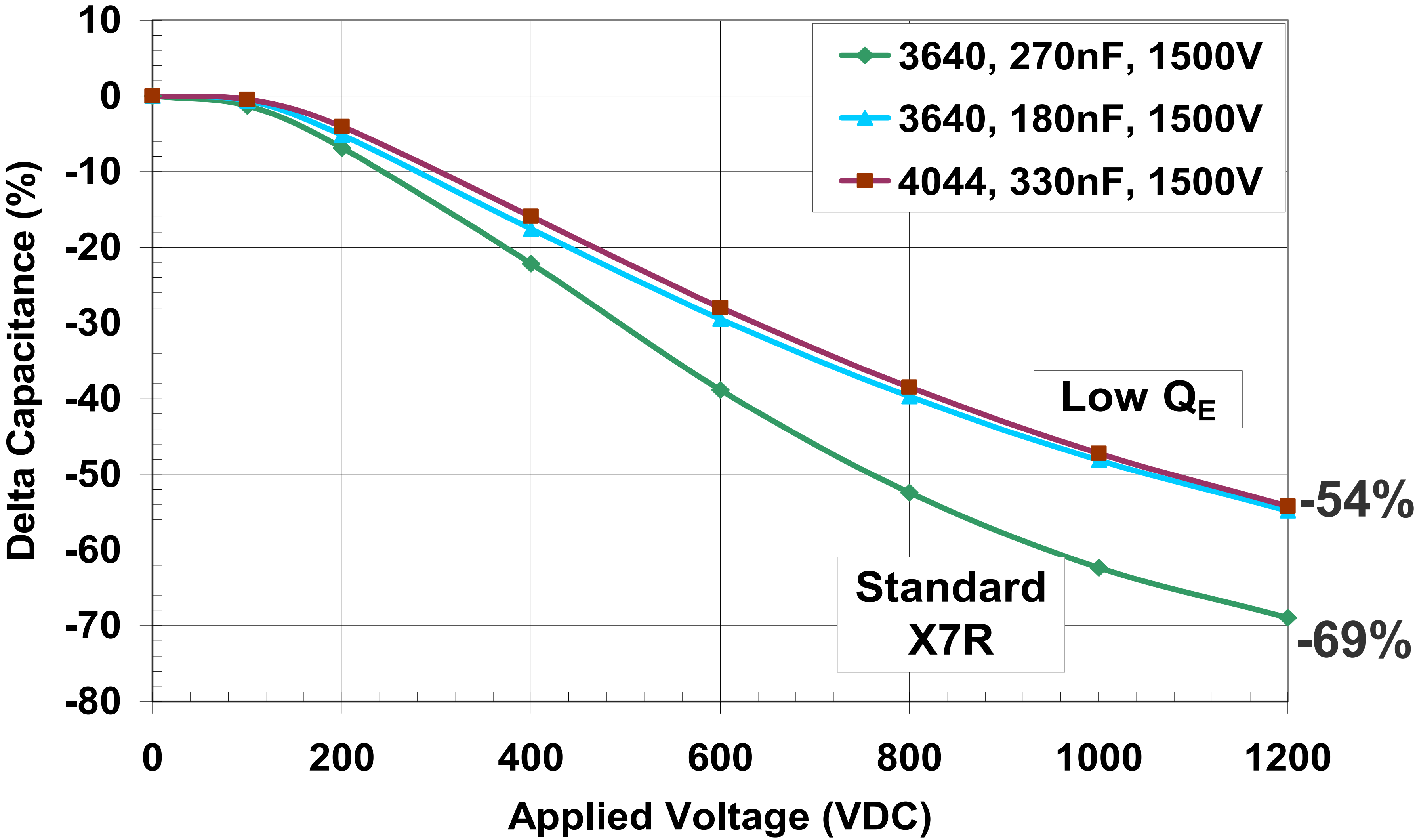


Voltage Coefficient of Capacitance

- Because of the improved dependence of K on voltage, the low Q_E dielectric exhibits decreased capacitance loss at the use voltage.
- At a bias of 1200 VDC capacitors using low Q_E dielectric material have 15% improved capacitance retention over standard dielectric.

Voltage Coefficient of Capacitance

Ambient test conditions (T = 25 °C)

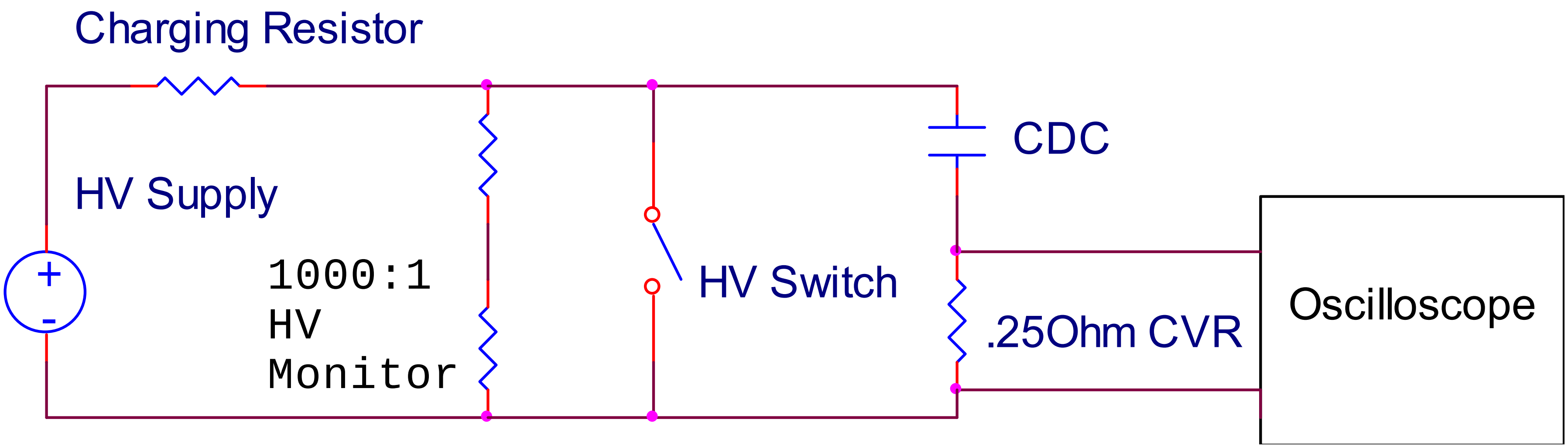


Pulse Discharge Current

- To obtain the pulse discharge currents of the experimental capacitors a capacitor discharge unit is constructed per Figure A-1 of MIL-DTL-23659E.

- The experimental capacitors are charged to DC voltage levels and then discharged through a low inductance loop and a 0.25 Ω current viewing resistor.

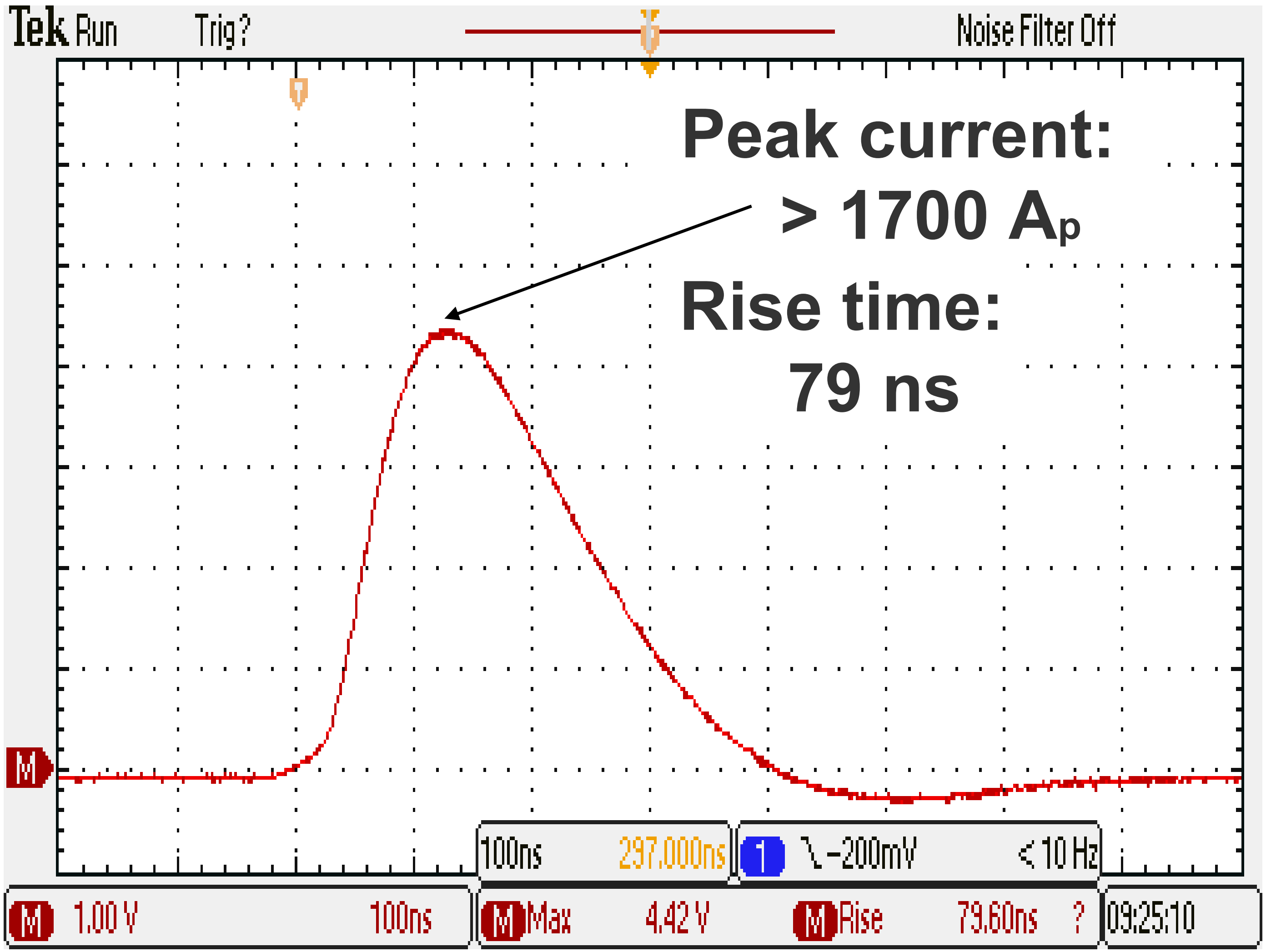
Capacitor Discharge Unit



Per Figure A-1 of MIL-DTL-23659E

Discharge Pulse

CDC: 4044, 330nF, 1500Vr



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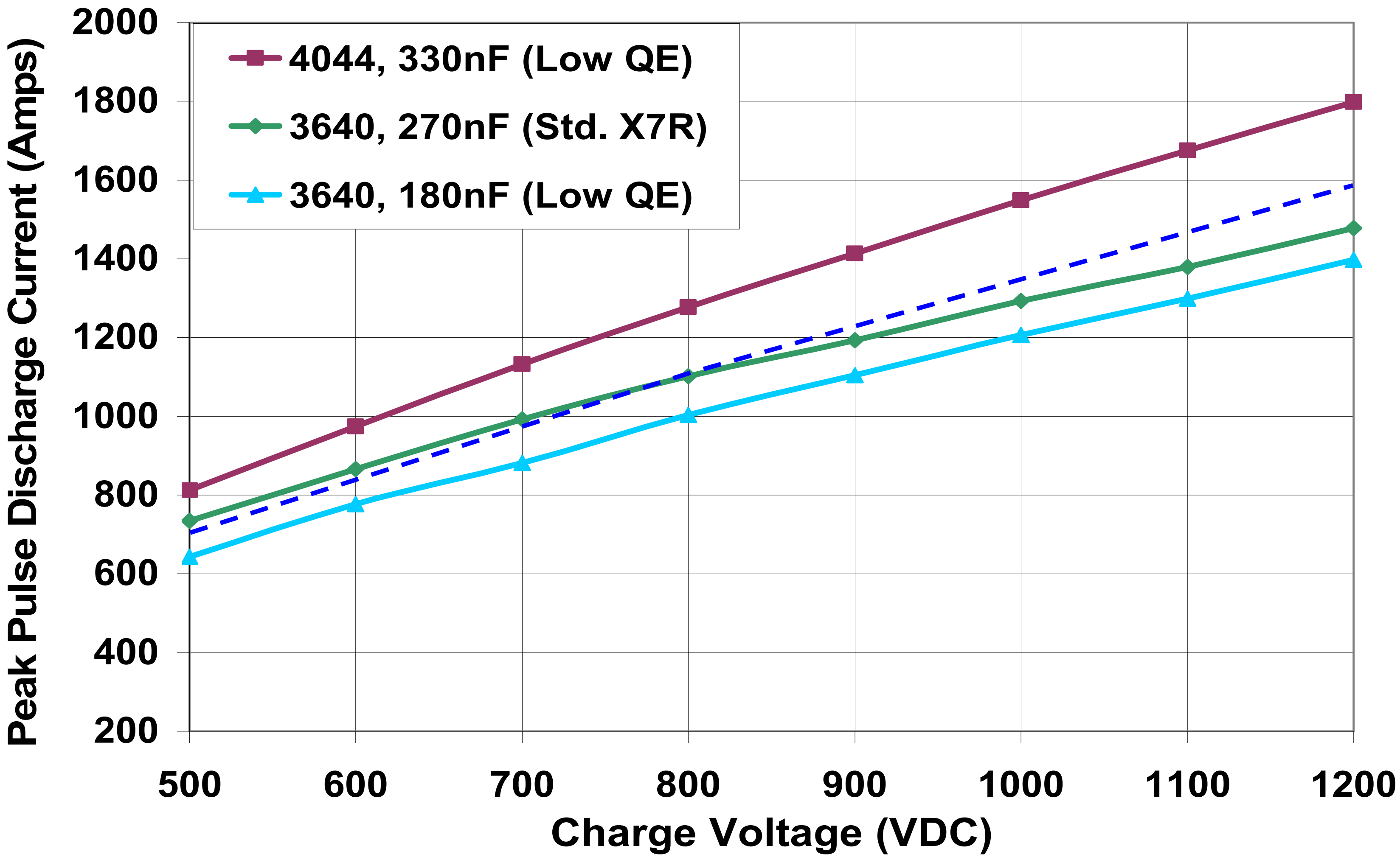
Discharge Current vs. Charge Voltage



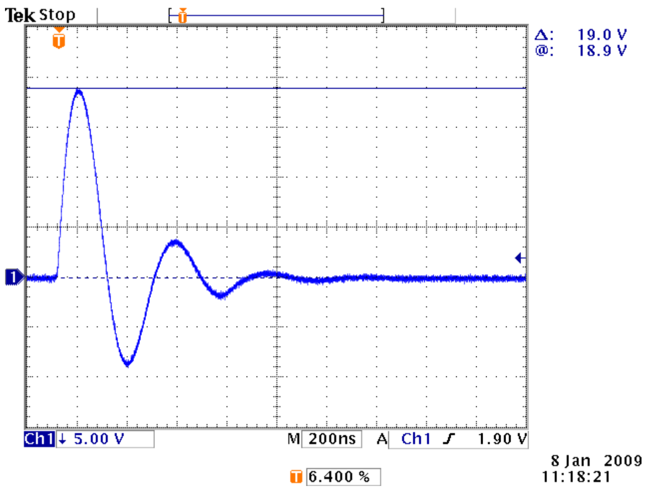
Pulse Discharge Ringdown

- **4 types of fireset capacitors tested with a low impedance fireset:**
  1. 120nF, 3040, 1500V Control Cap A
  2. 120nF, 5090, 1500V Control Cap B
  3. 270nF, 3640, 1500V Vishay CDC
  4. 330nF, 4044, 1500V Vishay CDC

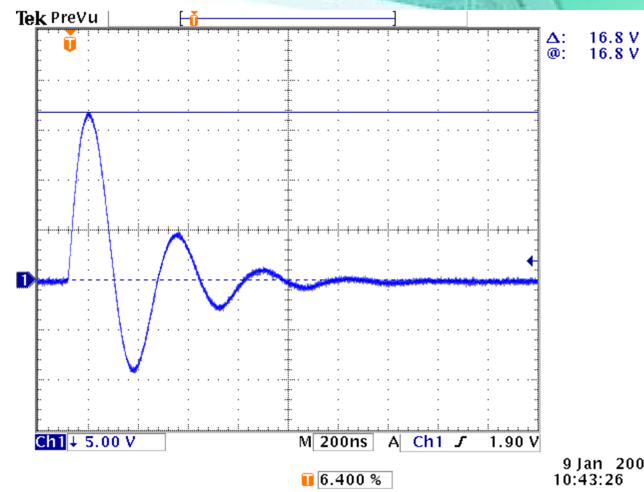
- Test data supplied by PerkinElmer
- Control Caps A&B are commercially available pulse discharge capacitors

Cold Ringdowns

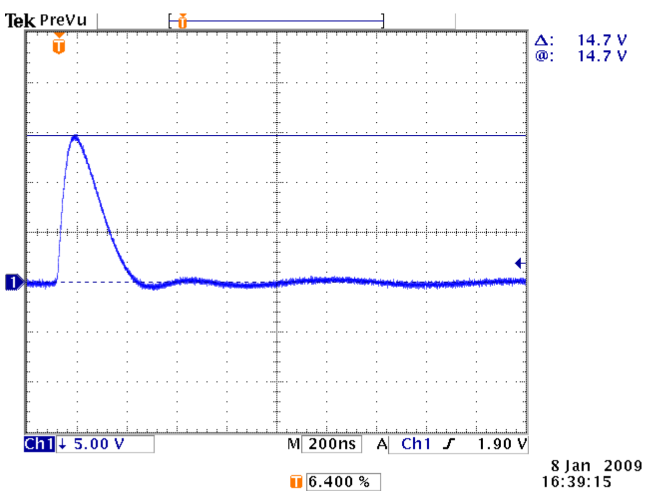
(T = - 40 °C)



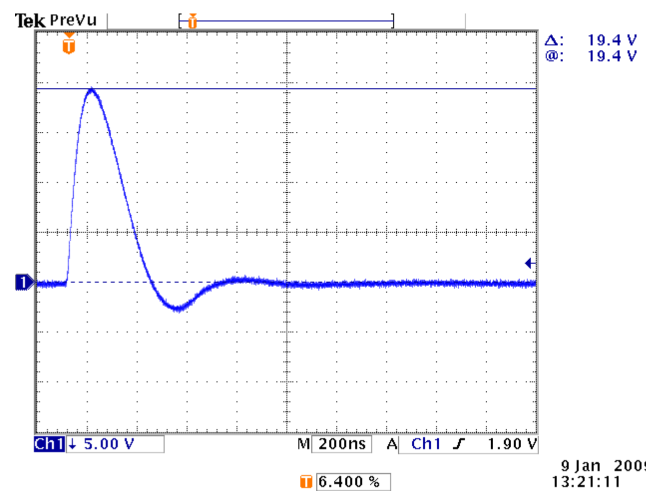
Control A: 1890 A peak



Control B: 1680 A peak



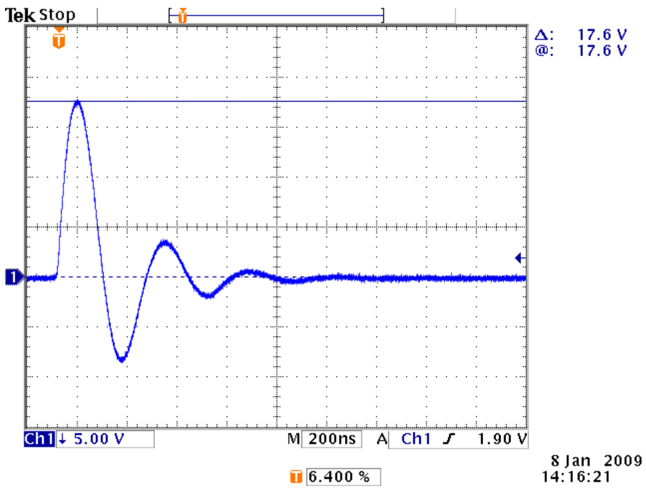
Vishay 3640: 1470 A peak



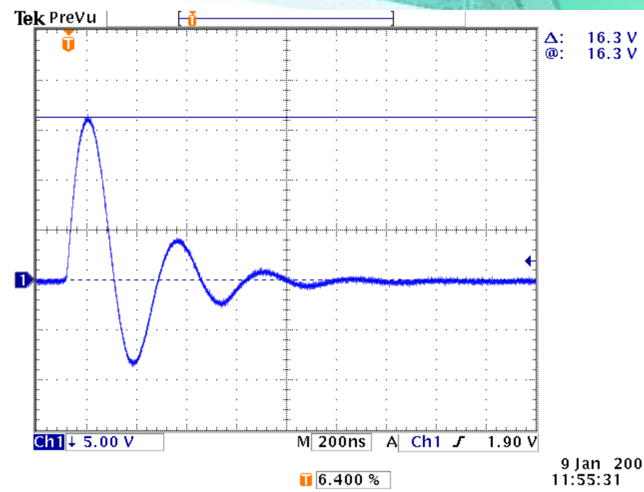
Vishay 4044: 1940 A peak

Ambient Ringdowns

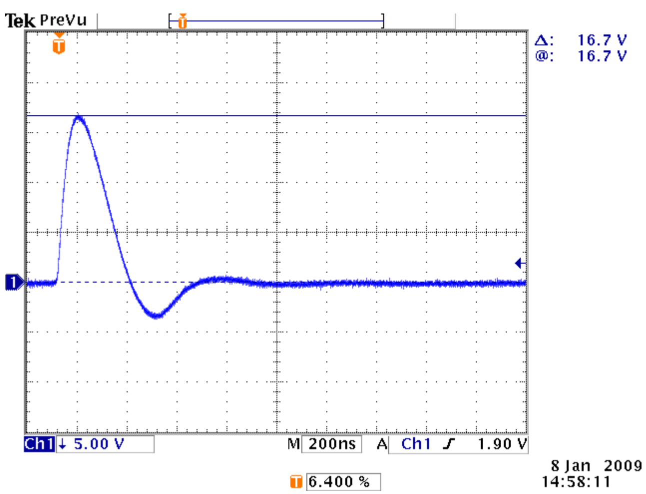
(T = 23 ± 10 °C)



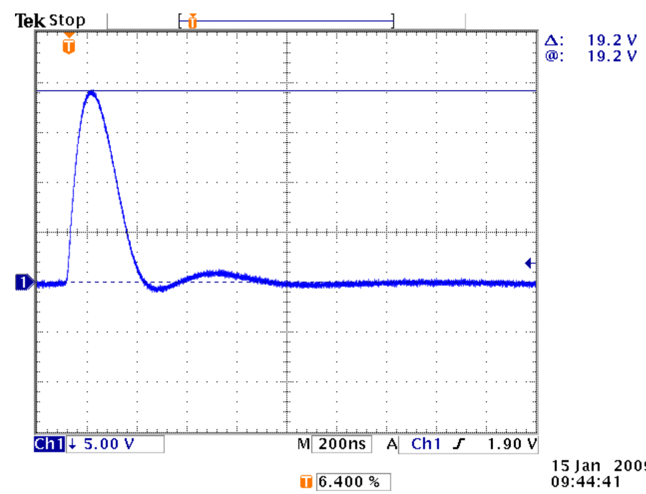
Control A: 1760 A peak



Control B: 1630 A peak



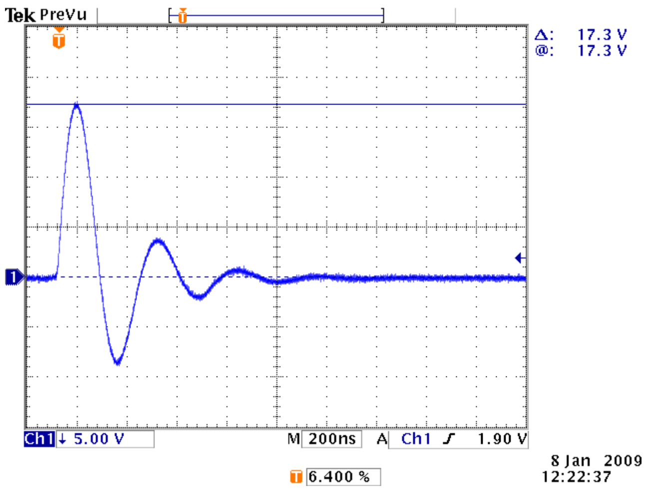
Vishay 3640: 1670 A peak



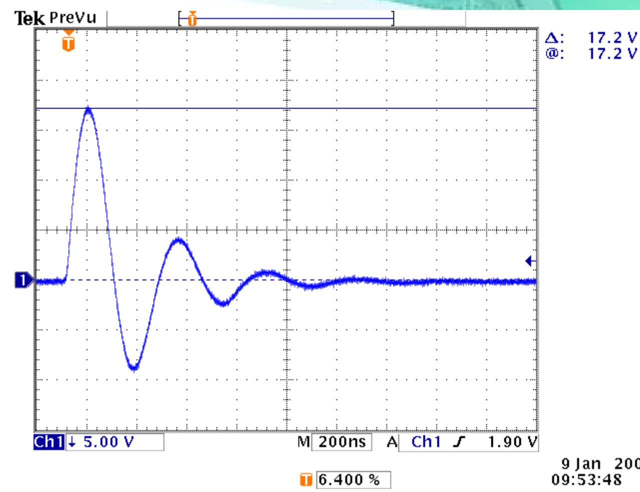
Vishay 4044: 1920 A peak

Hot Ringdowns

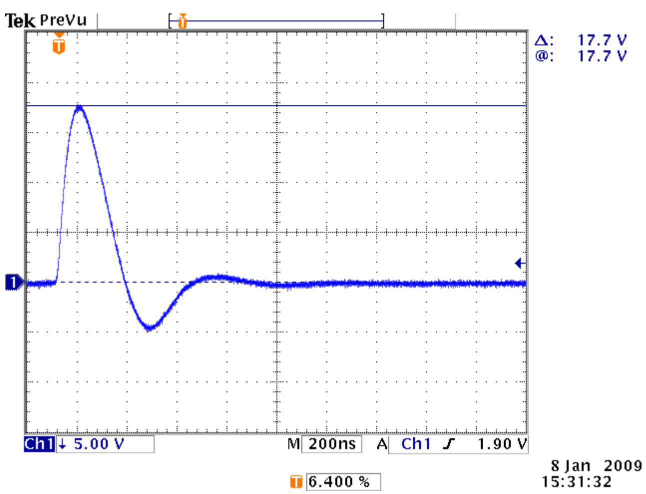
(T = +75°C)



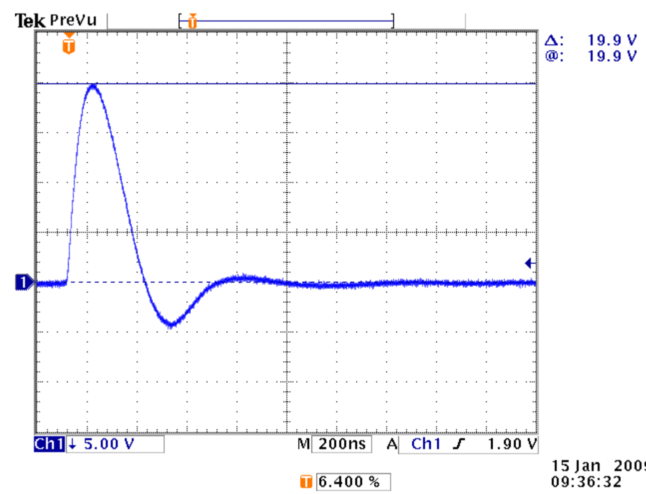
Control A: 1730 A peak



Control B: 1720 A peak



Vishay 3640: 1770 A peak



Vishay 4044: 1990 A peak

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Summary of Pulse Discharge Ringdown comparison

Temperature (°C)	Control Capacitor A (Ap)	Control Capacitor B (Ap)	Vishay Capacitor Standard X7R (Ap)	Vishay Capacitor Low Q_E (Ap)
-40	1890	1680	1470	1940
+25	1760	1630	1670	1920
+75	1730	1720	1770	1990
Current Average	1793	1677	1637	1950
Current Spread	160	90	300	70

- Low Q_E CDC supplied the highest peak current with the least amount of deviation.
- Low Q_E CDC has better controlled energy delivery over temperature.

Conclusions

- Low Q_E material is more temperature stable than standard material.
- Low Q_E material is more voltage stable than standard material.
- CDC exhibits high VBD and high discharge currents.
- Provides controlled energy delivery range over temperature.
- CDCs have high energy levels to fire EFIs in a fireset circuit.

Acknowledgements

- Vishay wishes to thank PerkinElmer Corporation of Miamisburg, OH. for providing fireset comparison data.
- Special thanks to Vito Coppola, Ken Kolesar, Alice Whitcher, Barbara Primerano for support in developing, fabricating and testing this product.

CDC Electrical Specifications

Specification	Dielectric X5P (Low Q_E)
Temperature Range	(-55 to 85) °C
Temperature Coefficient	± 10% max.
Dissipation Factor @1kHz, 1Vrms, 25 °C	2.5% max
Voltage Range	(1000 - 1500) VDC
Insulation Resistance @ 25 °C	100,000 MΩ minimum or 1000 ΩF, whichever is less.
Integrated Resistor	500 MΩ ± 30%
Capacitance Range	(10 - 330) nF

Questions?