High Voltage Ceramic Capacitors

February 28th, 2011
HIGH VOLTAGE MARKET
HV Market Landscape
Primary Markets

- Automotive
- Power supply
- Lighting
- Down Hole
- Medical
- Telecom
- Military
- Aerospace
### Potential Customers

<table>
<thead>
<tr>
<th>Automotive</th>
<th>Down Hole</th>
<th>Power Supplies</th>
<th>Military/Aerospace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bose</td>
<td>Schlumberger</td>
<td>Artesyn</td>
<td>Raytheon</td>
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<tr>
<td>Continental</td>
<td>Halliburton</td>
<td>Aztec</td>
<td>Honeywell</td>
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<tr>
<td>Delphi</td>
<td>Baker-Hughes</td>
<td>Delta</td>
<td>Hamilton Sundstrand</td>
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<tr>
<td>Siemens</td>
<td>Pathfinder</td>
<td>Lambda</td>
<td>BAE Systems</td>
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<tr>
<td>TRW</td>
<td>COSL(China Oilfield Services Limited)</td>
<td>Power One</td>
<td>Lockheed Martin</td>
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<tr>
<td>Valeo</td>
<td>CPL Petroleum</td>
<td>ITT Power Solutions</td>
<td>Thales</td>
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<tr>
<td>Visteon</td>
<td>Geoservices</td>
<td>TRC Electronics</td>
<td>GE Aviation</td>
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<tr>
<td>Hella</td>
<td>General Electric</td>
<td>Lineage Power</td>
<td>Goodrich</td>
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<tr>
<td>Denso</td>
<td>Weatherford</td>
<td>Kaga Electronics</td>
<td>ITT</td>
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<tr>
<td>Harman Becker</td>
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<td>Bosch</td>
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<td>Lear</td>
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High Voltage Applications & Functions (typical)

Applications
- Power Supply (#1 Use)
- CRT High Voltage Cathode (16kV to 36 kV)
- Projector lamp circuits (8 kV to 16 kV)
- LASER light source circuits
- Radar circuits
- RF antenna transmitter circuits
- Weapons
- LCD fluorescent backlight ballasts
- HID lighting
- Telecom equipment,
- Industrial and medical equipment/control (Imaging, x-ray, etc.)
- LAN/WAN interface,
- Analog and digital modems
- Automotive.
- X7R dielectrics are not designed for AC line filtering applications.

Functions
- Snubber (transients)
- DC blocking,
- Coupling
- Filtering
- Decoupling
- Charge storage
KEMET’S PORTFOLIO
<table>
<thead>
<tr>
<th>Surface Mount</th>
<th>Commercial</th>
<th>Automotive</th>
<th>Military / Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>0805 – 2225 Flexible Termination</td>
<td>Arc-over prevention (under dev)</td>
<td>(under dev)</td>
<td>1515 – 6560 (M49467 equiv)</td>
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<tr>
<td>Thru-Hole</td>
<td>C3xx / C6xx HV Series VRR/VCR Series</td>
<td>...Special request</td>
<td>HS Series (M49467 equiv)</td>
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<tr>
<td>Stacked</td>
<td>KPS HV KPS HV+</td>
<td>KPS AUTO HV</td>
<td>KPS MIL (M49470)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>SM Series (M49467 equiv)</td>
</tr>
</tbody>
</table>
High Voltage SMD
Commercial / Automotive

Target Markets / Applications
- Telecom, Phone Lines, Modems, FAX
- Set-Top Boxes, Satellite Dish
- Power Supplies, DC/DC Converters
- Ethernet, POS, ATM Hardware
- Closed Circuit TV (CCTVs)
- LCD Displays, Digital Still Cameras

Key Discovery Question
- Do you use line voltages >200V?

Under Development
- Automotive Grade 2011
- 500V & 1000V X7R Cap Ext. 2011
- New Arc-Over prevention technology 2011

Form Factor
- Surface Mount

Voltage
- 250 – 3000V

Dielectrics
- X7R, C0G

Cap Range
- 1.0pF – 2.2uF

Case Size
- 0805 - 2225

Options
- Flexible Termination
- SnPb

KPN
- C0805C332KDRAC
Large Chip High Voltage SMD
High Reliability

Target Markets / Applications
- Military
- Space
- Down-hole
- High Reliability

Notes
- Large Chips, low volume production
- Group A & B Screening Available per MIL-49467
- Terminations: Pd/Ag, Ag, Sn/Pb, 100% Sn
- Lower volume, higher ASP

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>Surface Mount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>500 – 10,000V</td>
</tr>
<tr>
<td>Dielectrics</td>
<td>X7R, C0G</td>
</tr>
<tr>
<td>Cap Range</td>
<td>1.0pF – 2.2uF</td>
</tr>
<tr>
<td>Case Size</td>
<td>1515 - 6560</td>
</tr>
<tr>
<td>KPN</td>
<td>4545B472M202PM</td>
</tr>
</tbody>
</table>
HV Thru-Hole (Commercial) “HV Goldmax”

**Target Markets / Applications**
- Military and Aerospace
- Medical
- High Voltage Power Supplies
- Telecom

**Key End Products**
- LED Backlight Inverters
- Modems, Phone Lines, FAX Machines
- Wireless Base Stations
- DVR Set-Top Boxes
- Satellite Dish, Cable Set-Top Boxes
- DC/DC Converters

**Form Factor**
- Thru-Hole

**Voltage**
- 250 – 3000V

**Dielectrics**
- X7R, C0G

**Cap Range**
- 1.0pf – 2.7uF

**Case Size**
- C3xx – std lead spacing
- C6xx – MIL-PRF- 49467 lead spacing

**KPN**
- C3xxC102KDR5TA
- C6xxC102KDR5TA

**Notes**
- C3xx – std lead spacing
- C6xx – MIL-PRF- 49467 lead spacing
- High Volume Capability
- Automotive grade available upon request
Target Markets / Applications

- Down-hole drilling
- Space applications

Key Customers

- Baker-Hughes, Schlumberger, Halliburton
- Weatherford, Pathfinder

Notes

- More robust designs
- Low volume production
- Many single-source products
- Very high ASP’s

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>Thru-hole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>500 – 10,000V</td>
</tr>
<tr>
<td>Temp</td>
<td>Up to 200C</td>
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<tr>
<td>Dielectrics</td>
<td>X7R, C0G</td>
</tr>
<tr>
<td>Cap Range</td>
<td>10pF – 5.6uF</td>
</tr>
<tr>
<td>Case Size</td>
<td>lead spacing</td>
</tr>
<tr>
<td>KPN</td>
<td>HV Series C³ (VRR/VCR) (HT) HS Series (Space)</td>
</tr>
</tbody>
</table>
## Commercial/Automotive Stacks

### Target Markets / Applications
- Industrial, Automotive, Military
- Input & Output Filters on Power Supplies

### Features
- 2x Cap in Same Footprint
- Provide Improved Flex Performance
- Improved Microphonics
- Low ESR/ESL
- Qualified to AEC-Q200

### Notes
- High Voltage (500 – 3000V) available
- Higher volume production

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>J Lead Style</th>
</tr>
</thead>
</table>
| Voltage     | 16V – 250V (STD)  
500V+ Available Upon request |
| Dielectrics | X7R, NPO     |
| Cap Range   | 0.47µF - 47µF |
| Case Sizes  | 1210, 1812, 2220 |
| KPN         | C2220C476M3R2C |
Military Stacked Capacitors

Target Markets / Applications
• Military Accounts
• I/O Filters on Power Supplies
• Often found in “Capacitor Banks”

Key Customers
• Raytheon
• Lockheed Martin
• General Dynamics

Notes
• T-Level Stacks coming soon
• M49470 Equiv available in extended ranges

<table>
<thead>
<tr>
<th>Mil Spec</th>
<th>MIL-PRF-49470</th>
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<tbody>
<tr>
<td>DSCC Drawing</td>
<td>87106</td>
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<tr>
<td>Form Factor</td>
<td>N, J, &amp; L Leads</td>
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<tr>
<td>Voltage</td>
<td>50V – 500V</td>
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<tr>
<td>Dielectrics</td>
<td>BX, BR, BQ</td>
</tr>
<tr>
<td>Cap Range</td>
<td>0.15µF - 47µF</td>
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<tr>
<td>Case Size</td>
<td>3, 4, &amp; 5</td>
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<tr>
<td>KPN</td>
<td>L1XN505476KB65</td>
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<tr>
<td>Mil PN</td>
<td>M49470X01476AN</td>
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<tr>
<td>DSCC PN</td>
<td>87106-039</td>
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</tbody>
</table>
High Capacitance Stacks

Target Markets / Applications
- Down-hole drilling
- Industrial
- Power Supplies

Benefits
- Bulk capacitance in small package
- Wet tantalum replacement
- Low ESR, low leakage current
- Long life
- High Ripple current
- Minimizes piezoelectric noise
- Reduces risk of flex cracking

Notes
- To be released in 2011

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>10-pin DIP Surface Mount</th>
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<tbody>
<tr>
<td>Case Size</td>
<td>Multi-Chip Stacks of 1812 – 2220</td>
</tr>
<tr>
<td>Voltage</td>
<td>To 2000V</td>
</tr>
<tr>
<td>Temp</td>
<td>To 200 C</td>
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<tr>
<td>Dielectrics</td>
<td>X7R, C0G</td>
</tr>
<tr>
<td>Cap Range</td>
<td>X7R to 480µF, C0G to 6.6µF</td>
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</table>
APPLICATION CONSIDERATIONS
Common Misconceptions

✓ Ceramic Capacitors: DC applications only
✓ DC rated ceramic capacitors are rated for similar AC rated applications.
✓ Safety Rated capacitors are necessary in all safety circuit designs
✓ X7R dielectric cannot be used in AC applications
✓ There is a simple “Rule of Thumb” for AC rated applications.
✓ MLCCs cannot be substituted for DISCs
DC vs. AC
Direct Current (DC)

Steady DC from a battery or regulated power supply.

DC voltage always flows in the same direction, but it may increase and decrease.
Alternating Current (AC)

AC from a power supply. This shape is called a sine wave. AC voltage is continually changing between positive (+) and negative (-).
Peak Voltage (AC)

Peak voltage is another name for amplitude.
RMS voltage is the DC equivalent voltage in terms of power delivered to a load. RMS voltage (root mean square voltage) is 0.7 of the peak voltage (amplitude):

\[ V_{\text{RMS}} = 0.7 \times V_{\text{peak}} \quad \text{and} \quad V_{\text{peak}} = 1.4 \times V_{\text{RMS}} \]
Peak-peak voltage is twice the peak voltage (amplitude)

\[ V_{\text{peak}} = \frac{V_{\text{peak-peak}}}{2} \]
AC Design Rules

X7R Dielectric
- Cannot be used in AC line filtering applications
- Contact FAE for proper capacitor selection
  - Peak AC voltage
  - Application frequency

C0G Dielectric
- Peak AC voltage must be $\leq 50\%$ of rated DC voltage
  - General “Rule of Thumb”
- Contact FAE for proper capacitor selection
  - Peak AC voltage
  - Application frequency
SAFETY CERTIFIED CAPACITORS
HV Safety Capacitors

**Safety Certified Capacitors** are high voltage capacitors designed for:

- AC voltage conditions (commonly 250 VAC).
- High voltage impulses, transients, or surges.
  Shunt the energy to ground, protecting the circuit and the user from any high voltage surge.

They are classified according to their use in a circuit:

- **X Capacitor:**
  For use in line to line applications. Failure *would not* lead to danger of electric shock.

- **Y Capacitor:**
  For use in line to ground applications. Failure *could* lead to danger of electric shock.

Safety certified capacitors are only needed if the circuit design has not been certified.

KEMET *does* offer ceramic disc safety certified capacitors

- ERO610 Series (Class X1, 440VAC / Class Y2, 250VAC)
- ERK610 Series (Class X1, 440VAC / Class Y2, 300VAC)
- ERP610 Series (Class X1, 760VAC / Class Y2, 500VAC)
DISK VS. MLCC
Disc vs. MLCC

Radial MLCCs can be substituted for single layer ceramic disc capacitors

Dielectric
Voltage Rating
Capacitance
Lead Spacing
Lead Diameter
DISCOVERY QUESTIONS
High Voltage MLCC: Questions you need to ask.....

General Questions:

What is your application voltage and temperature?
What is your capacitance requirement at application voltage and temperature?
Is capacitance stability with respect to temperature and voltage a concern?
Are you interested in downsizing your current footprint?
Are you currently using any high voltage capacitors in your application?
Would you be interested in a HV ceramic solution?

High Voltage Application Specific Questions:

Is your application voltage AC or DC?
What is the peak voltage of your application?
What is your application frequency?
Is this a line filtering application?
Product Management

### Product Line Management
- “CEO” of product line
- VOC to inside org
- R&D Priorities
- Cust need + Capability

### Pricing Specialist
- Tiffany McGee
- Pricing Support for all product lines

### Product Marketing Manager & Technical Marketing Manager
- Scott Carson & Corey Antoniades
- Sales Readiness
- Messaging
- Collateral
- Product Launch

<table>
<thead>
<tr>
<th>Craig</th>
<th>Bill</th>
<th>Tim</th>
<th>Jim</th>
<th>Scott</th>
<th>Corey</th>
<th>Tiffany</th>
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</thead>
<tbody>
<tr>
<td><strong>SPECIALTY</strong></td>
<td></td>
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<tr>
<td>Military &amp; Space (TH &amp; SMD)</td>
<td>✓</td>
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<tr>
<td>Military Stacked Caps</td>
<td>✓</td>
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<td>Custom Products</td>
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<td>Tin/Lead termination</td>
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<tr>
<td>High Temp (SMD≥200C)</td>
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<tr>
<td>High Temp (Thru-hole, SKD)</td>
<td>✓</td>
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<tr>
<td>High Voltage (SMD, Thru-hole, SKD)</td>
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<td>RF HiQ</td>
<td>✓</td>
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<tr>
<td>Comm &amp; Auto Stacks KPS</td>
<td>✓</td>
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<tr>
<td>High Temp SMD (X8L,X8G)</td>
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<td>Arrays</td>
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| **COMMERCIAL** |     |     |     |       |       |         |
| SMD & Thru-hole (NPD) | ✓ |     |     |       |       |         |
| SMD & Thru-hole (Auto, OEM) | ✓ |     |     |       |       |         |
| SMD & Thru-hole (Disty, EMS) | ✓ |     |     |       |       |         |

| **MARKETING / SUPPORT / PRICING** |     |     |     |       |       |         |
| SPICE / FIT Software | | ✓ |     |       |       |         |
| Product Launch | ✓ | ✓ |     |       |       |         |
| Catalogs / Datasheets / Collateral | ✓ | ✓ |     |       |       |         |
| Sales / Channel Readiness | ✓ | ✓ |     |       |       |         |
| Back-up Pricing Support | SMD, Array, FLEX | TH, SMD | TH, SMD | TH, HV, HT | All Product Lines |     |