Testing of Cables for KPiX Pulse Load

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Yale University

ALCPG, University of Oregon, OR
19 – 23 March, 2011
- Voltage Kick / Overshoot @ turn off
- ICs Operating = 2.5 V  Max Operating = 2.75V  Abs max = 3 V Life tests
- Power Efficiency / Inefficiency / wasted Power
- Cable Tests. No KPiX Chip current
- DC-DC Converter with Air Core Coil
- Radiation Tolerance Why Thin Oxides ?
CMS ECAL: 5 Oodles (50 kamps).

- Power Supply output = 315 kW
- Power loss in Leads to SM = 100 kW
- Power loss in Regulator Card = 90 kW
- Power Delivered @ 2.5 V = 125 kW

1 Oodle = 10,000 amps

# of Power Supplies ~ 700
# of ST LDO Chips = 35 K
LHC Radiation Hard made by ST Microelectronics
# of LVR Cards = 3.1 K.

Yale: Designed, built, burn-in and Tested.

Power Supply
6.3 V
64 Amps
30 m

Vdrop = 2V
Pd = 128 W

50 mm² (AWG 00)

Remote Enable / Disable
4 LVR Boards

2.5V
64 amps
160 W

4.3 V

Junction Box

2x16 mm² (AWG 6)

1 to 3 m

6 volt Kick

Current OFF
Power Efficiency _ Inefficiency _ Wasted Power

Input Power

315 kW

--- Wasted Power ---

100 kW

90 kW

Load Power

125 kW

Power Supply
380 VDC input

30 meters
50K Amps

LDO 1.8 V drop

10 cm
50K Amps

Front End Electronics

6.3 V

4.3 V

2.5 V

----- in Hall -----  on Detector

CMS – ECAL Power Delivery System
Why use DC-DC for Pulse powering?

Current = 1 amp

ΔV = 1 V if C = 1000 UF
ΔV = 10 V if C = 100 UF

Current = 0.1 amp if Voltage ratio = 10
Waveforms when 1 amp flowing thru 130 Ohms twisted pair is interrupted /switched off. 27 Volt Spike appears across KPiX chip. In principle it should be 130 volts but due to finite switching time and cable length it is 27 V.
GOERTZ audiophile speaker cable
Copper or Silver (Need good ears & Deep pockets)
**ALPHA-Core Interconnect Pairs**

"Analogue-like dynamics from CD, seamless top-to-bottom smoothness, 3D imaging, dead silent background..."

Ed Osborne, Executive Producer BMG Special Products

<table>
<thead>
<tr>
<th>Stereo Pairs</th>
<th>.5m</th>
<th>1m</th>
<th>1.5m</th>
<th>2m</th>
<th>2.5m</th>
<th>3m</th>
<th>4m</th>
<th>5m</th>
<th>6m</th>
<th>7m</th>
<th>8m</th>
<th>9m</th>
<th>10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Purl Cu RCA</td>
<td>$68</td>
<td>$101</td>
<td>$121</td>
<td>$157</td>
<td>$194</td>
<td>$216</td>
<td>$255</td>
<td>$334</td>
<td>$413</td>
<td>$470</td>
<td>$549</td>
<td>$628</td>
<td>$708</td>
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<tr>
<td>Micro Purl Cu XLR</td>
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<td>$133</td>
<td>$166</td>
<td>$201</td>
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<td>$318</td>
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<td>$550</td>
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<td>Triode Quartz TQ2/Cu RCA</td>
<td>$100</td>
<td>$138</td>
<td>$190</td>
<td>$234</td>
<td>$280</td>
<td>$324</td>
<td>$381</td>
<td>$444</td>
<td>$539</td>
<td>$632</td>
<td>$702</td>
<td>$797</td>
<td>$893</td>
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<td>$393</td>
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<td>$534</td>
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<td>$735</td>
<td>$872</td>
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<td>$228</td>
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<td>$457</td>
<td>$533</td>
<td>$647</td>
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<td>$843</td>
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<tr>
<td>Tourmaline XLR</td>
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<td>$234</td>
<td>$291</td>
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<td>$471</td>
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<td>$640</td>
<td>$768</td>
<td>$882</td>
<td>$1,046</td>
<td>$1,448</td>
<td>$1,640</td>
</tr>
</tbody>
</table>

**SILVER INTERCONNECT** (Micro Purl - 25 awg, TQ2 - 21 awg, Sapphire - 18 awg)

<table>
<thead>
<tr>
<th>Stereo Pairs</th>
<th>.5m</th>
<th>1m</th>
<th>1.5m</th>
<th>2m</th>
<th>2.5m</th>
<th>3m</th>
<th>4m</th>
<th>5m</th>
<th>6m</th>
<th>7m</th>
<th>8m</th>
<th>9m</th>
<th>10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Purl Ag RCA</td>
<td>$111</td>
<td>$165</td>
<td>$198</td>
<td>$256</td>
<td>$316</td>
<td>$351</td>
<td>$416</td>
<td>$545</td>
<td>$673</td>
<td>$766</td>
<td>$894</td>
<td>$1,023</td>
<td>$1,153</td>
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<tr>
<td>Micro Purl Ag XLR</td>
<td>$157</td>
<td>$217</td>
<td>$270</td>
<td>$328</td>
<td>$397</td>
<td>$438</td>
<td>$517</td>
<td>$660</td>
<td>$818</td>
<td>$896</td>
<td>$1,082</td>
<td>$1,537</td>
<td>$1,754</td>
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<td>Triode Quartz TQ2/Ag RCA</td>
<td>$163</td>
<td>$242</td>
<td>$309</td>
<td>$381</td>
<td>$456</td>
<td>$527</td>
<td>$621</td>
<td>$724</td>
<td>$878</td>
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<td>$1,298</td>
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<td>Triode Quartz TQ2/Ag XLR</td>
<td>$231</td>
<td>$318</td>
<td>$395</td>
<td>$476</td>
<td>$557</td>
<td>$640</td>
<td>$749</td>
<td>$869</td>
<td>$1,042</td>
<td>$1,197</td>
<td>$1,420</td>
<td>$1,966</td>
<td>$2,226</td>
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<td>Sapphire RCA</td>
<td>$250</td>
<td>$443</td>
<td>$633</td>
<td>$805</td>
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<td>$1,599</td>
<td>$1,797</td>
<td>$2,053</td>
<td>$2,308</td>
<td>$2,566</td>
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<tr>
<td>Sapphire XLR</td>
<td>$333</td>
<td>$566</td>
<td>$793</td>
<td>$1,000</td>
<td>$1,040</td>
<td>$1,123</td>
<td>$1,453</td>
<td>$1,742</td>
<td>$2,032</td>
<td>$2,214</td>
<td>$2,490</td>
<td>$2,800</td>
<td>$3,111</td>
</tr>
</tbody>
</table>

Shaded area: Recommended Interconnects, function of length
### Cable Parameters

<table>
<thead>
<tr>
<th>Cable Type</th>
<th># of Conductors</th>
<th>Cross Section</th>
<th>C</th>
<th>L</th>
<th>R Ohms</th>
<th>DCR</th>
<th>Z</th>
<th>Reflection</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length = 2 meters</td>
<td>Conductor</td>
<td>mils</td>
<td>pF</td>
<td>nH</td>
<td>1 MHz Ohms</td>
<td>Ohms</td>
<td>Ohms</td>
<td>Peak V</td>
<td></td>
</tr>
<tr>
<td>Twisted Pair</td>
<td>2</td>
<td>AWG 22</td>
<td>95.6</td>
<td>1100</td>
<td>0.734</td>
<td>0.197</td>
<td>130</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Micro Strip</td>
<td>2</td>
<td>5 x 250</td>
<td>1440</td>
<td>168</td>
<td>0.171</td>
<td>0.105</td>
<td>10.8</td>
<td>10 E</td>
<td></td>
</tr>
<tr>
<td>Strip Line</td>
<td>3</td>
<td>5 x 250</td>
<td>4930</td>
<td>103</td>
<td>0.092</td>
<td>0.066</td>
<td>4.6</td>
<td>7.4 H</td>
<td></td>
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<tr>
<td>Strip Line -Twisted</td>
<td>3</td>
<td>5 x 125</td>
<td>2520</td>
<td>154</td>
<td>0.195</td>
<td>0.142</td>
<td>7.8</td>
<td>9 F</td>
<td></td>
</tr>
<tr>
<td>Strip Line -Twisted</td>
<td>3</td>
<td>3 x 80</td>
<td>2353</td>
<td>177</td>
<td>0.544</td>
<td>0.420</td>
<td>8.7</td>
<td>8.8 G</td>
<td></td>
</tr>
</tbody>
</table>

All Cables 2 meter long.
HP 4284A Precision LCR Meter 20 Hz - 1 MHz. Test Fixture 16047C

February 28, 2011
Output Goes 4V below GND

A

B 2m Twisted Pair 1 nF at Output

C 2m Twisted Pair 80 nF at Output
High Voltage
Low Current
Input

Control Switch
30 mΩ

Low Voltage
High Current
Output

Synch Switch
20 mΩ

Power Stage Drivers

Error Amp

Logic

PWM: Pulse Width Modulator

V reference

Logic

PWM: Pulse Width Modulator

V reference
Coupled Air Core Inductor Connected in Series

Plug In Card with Shielded Buck Inductor

12 V

2.5 V @ 6 amps

0.35 mm

1.5 mm
20 Ohms Load

2 Ohms Load

TI Device in Development
Fast Transient Response
Threshold shift in MOS transistors with Radiation vs Oxide Thickness

Threshold Shift vs Gate Oxide Thickness

Hole removal process by tunneling in thin-oxide MOS Structures

Shifting $V_t$ of MOSFET With Gammas


## Radiation Tolerance of CMOS Devices

<table>
<thead>
<tr>
<th>Company</th>
<th>Device</th>
<th>Process Name/Number</th>
<th>Foundry</th>
<th>Oxide (nm)</th>
<th>Dose before (Rad)</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHP</td>
<td>ASIC custom</td>
<td>SG25V GOD 12 V</td>
<td>IHP, Germany</td>
<td>5</td>
<td>53 MRads</td>
<td>Minimal Damage</td>
</tr>
<tr>
<td>XySemi</td>
<td>FET 2A</td>
<td>HVMOS20080720 12 V</td>
<td>China</td>
<td>7</td>
<td>52 Mrads</td>
<td>Minimal Damage</td>
</tr>
<tr>
<td>XySemi</td>
<td>XP5062</td>
<td>HVMOS20080720</td>
<td>China</td>
<td>12</td>
<td>44 Krad</td>
<td>Loss of output regulation</td>
</tr>
<tr>
<td>Enpirion</td>
<td>EN5365</td>
<td>CMOS 0.25 μm</td>
<td>Dongbu HiTek, Korea</td>
<td>5</td>
<td>64 Krad</td>
<td>Increasing input current</td>
</tr>
<tr>
<td>Enpirion</td>
<td>EN5382</td>
<td>CMOS 0.25 μm</td>
<td>Dongbu HiTek, Korea</td>
<td>5</td>
<td>111 Krad</td>
<td>Loss of output regulation</td>
</tr>
<tr>
<td>Enpirion</td>
<td>EN5360</td>
<td>SG25V (IHP)</td>
<td>IHP, Germany</td>
<td>5</td>
<td>100 Mrads</td>
<td>Minimal Damage</td>
</tr>
<tr>
<td>National</td>
<td>LM2864</td>
<td>PVIP25</td>
<td>In House</td>
<td>11.8</td>
<td>3 Mrads</td>
<td>Loss of output. Short after power off/on</td>
</tr>
</tbody>
</table>

*Table I. Radiation Tolerance of Devices with thin oxide*
• Measure KPiX turn off spikes
• Movement of Pulsed Current Conductors in 7T
  *Suggestions are welcome*
• Test new commercial converters oxides < 15 nm

More Information
http://shaktipower.sites.yale.edu/