Spark protection scheme for the SAMPA-based ALICE TPC electronics

6th December 2018

Christian Lippmann
• Overview
• Issues found with input protection
• Testing
• Diode packages
• Resistors
• Tests with additional diodes
• System test status
ALICE TPC overview

- Diameter: 5 m, length: 5 m
- Gas:
  - Ne–CO₂–N₂,
  - (Ar–CO₂ in 2015, 2016 and 2018)
- Max. drift time: ~100 µs
- 18 sectors on two sides
- Inner readout chambers: IROC
- Outer readout chambers: OROC
Continuous operation

Typical data taking with TPC in Run3: High luminosity Pb-Pb collisions

- Maximum drift time of electrons in TPC: ~ 100us
- Average event spacing: ~20us
- Event pileup
- Triggered operation does not make sense
- Minimize ion backflow (IBF) in different way

Drift time in TPC

Continuous read-out
Micro Pattern Gas Detectors
New Readout chambers

18 sectors on two sides $\Rightarrow$ 72 chambers

Inner readout chambers: IROC
Outer readout chambers: OROC
New TPC FEC (1)

TPC Front End Card Rev 1 with integrated flexible signal cables (rigid flex)
New TPC FEC (2)

TPC Front End Card Rev 1 with integrated flexible signal cables (rigid flex)

- Input protection
- SAMPAs
- GBT-SCA
- GBTs
- Power connector
- Optical links
Spark protection

- **SAMPA**: Device-level ESD protection for handling (diodes and 7 Ω series resistor)
- **System-level protection on FEC**: Diodes and resistors

**Resistor value (100 Ω) chosen based on tests with SAMPA MPW2 and prototype GEM chamber**
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2 Problems:

1. Protection resistors may get damaged by (a few) discharge pulses with the expected pulse energy (while the SAMPA is protected)

2. Availability of the back-to-back diode package (NUP4114) used so far on all prototypes became critical (full quantity only end of January 2019)
Problems found (2)

Issues:
1. **NUP4114 diode package** not available in sufficient numbers until end of January 2019
2. **Resistor (SMD, 0603 package)** not reliable after discharges
• Overview
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**Testing**
• Diode packages
• Resistors
• Tests with additional diodes
• System test status
ATLAS “chip killer”

• Worst case (discharge propagation to pad plane, 0.32 mJ into pad) can be simulated with capacitor and HV

• ATLAS “chip killer” makes such tests straightforward

• 1 nF, 1 kV capacitor

Thank you to ATLAS, BNL and University of Athens
George Iakovidis, Venetios Polychronakos
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NUP 4114 diode package

Problem: Circuit diagram was updated some years ago, part number not changed!

This is current diagram:

This used to be the diagram:
SP3004 diode package

Alternative product: Littlefuse SP3004 Series
Same package available: SOT563, pin compatible

The ATLAS NSW group are using this component. They have moved to this product because of the circuitry changed in the NUP4114.
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• ATLAS TRT and NA62 straw. No channel lost in all these years
• MELF resistors TOKEN RDM16
• Double protection diodes (BAV99 A7W, 1 channel per package)
• Problem: Takes a lot of space! MELF hardly available with short lead times
# Resistor test summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Size</th>
<th>Power rating</th>
<th>Resistance (Ω) after 1 spark</th>
<th>Resistance (Ω) after 11 sparks</th>
<th>Resistance (Ω) after 201 sparks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default resistor (Yageo)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>100</td>
<td>102</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>YAGEO RT0603FRE07100RL (automotive qualified)</td>
<td>Thin film SMD</td>
<td>0603</td>
<td>0.1 W</td>
<td>107</td>
<td>200</td>
<td>✗</td>
</tr>
<tr>
<td>Vishay MCT0603MD1000DP500 (automotive qualified)</td>
<td>Thin film SMD</td>
<td>0603</td>
<td>0.15 W</td>
<td>101</td>
<td>102</td>
<td>105</td>
</tr>
<tr>
<td>TE Connectivity RP73PF1J100RBTD</td>
<td>Thin film SMD</td>
<td>0603</td>
<td>0.166 W</td>
<td>100</td>
<td>103</td>
<td>✗</td>
</tr>
<tr>
<td>Vishay PCAN0603E1000BST3</td>
<td>Thin film SMD</td>
<td>0603</td>
<td>0.5 W</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>ROHM ESR03EZPF1000 (anti-surge, discharge resistant)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.25 W</td>
<td>100</td>
<td>100</td>
<td>102</td>
</tr>
<tr>
<td>ROHM KTR03EZPF1000 (high voltage, automotive)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.1 W</td>
<td>100</td>
<td>100</td>
<td>101</td>
</tr>
<tr>
<td>ROHM SFR03EZPF1000</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.063 W</td>
<td>100</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>BOURNS CRS0603AFX-1000ELF (pulse withstanding)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.125 W</td>
<td>100</td>
<td>100</td>
<td>103</td>
</tr>
<tr>
<td>MULTICOMP MCHVR03JTEX1000 (high voltage rated)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.1 W</td>
<td>100</td>
<td>100</td>
<td>103</td>
</tr>
<tr>
<td>VISHAY MCT06030C1000FP500 (automotive)</td>
<td>Thick film SMD</td>
<td>0603</td>
<td>0.125 W</td>
<td>100</td>
<td>101</td>
<td>✗</td>
</tr>
<tr>
<td>VISHAY CMA02040X6809GB300 (automotive, high pulse load)</td>
<td>Carbon film MiniMELF</td>
<td>1.4 x 3.6 mm²</td>
<td>0.4 W</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
TVS diode test boards

Semtech 3321ZA, recommended by ATLAS, 4.2 pF, ultra-small

Semtech 3321P, only 0.35 pF

Test boards designed by Michel Morel, CERN EP-ESE. Thank you!
TVS test summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Stand-off voltage</th>
<th>Capacitance</th>
<th>Size</th>
<th>Resistance (Ω) after 1 spark</th>
<th>Resistance (Ω) after 11 sparks</th>
<th>Resistance (Ω) after 201 sparks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semtech RCLAMP3321P.TNT</td>
<td>3.3 V</td>
<td>0.35 pF</td>
<td>1 x 0.6 mm²</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Semtech UCLAMP3321ZATFT</td>
<td>3.3 V</td>
<td>4.2 pF</td>
<td>0.6 x 0.3 mm²</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

- Very good protection against large number of discharges with both TVS diodes
- Larger capacitance of 3321ZA is more “noisy”
- Resistor value could be decreased, from 100 Ω probably to 10 Ω (as in ATLAS), with benefit of reducing noise (not tested)
- For the TPC FEC we did not have the time for an additional prototype cycle, so this option was excluded unfortunately
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Purpose: Test of a fully equipped IROC to evaluate mechanical aspects and performance under realistic conditions

- 33 Front-End-Cards, cooling and final LV system
- IROC and FECs located in clean room where TOC upgrade will take place
Target value: 1 ADC (=760e)

Noise distribution

Entries: 2720
Mean: 1.021
Std Dev: 0.1788
Summary and outlook

- ALICE TPC FECs based on SAMPA ASIC and GBT readout
- Input protection resistor found to be un-reliable in discharge tests with first FEC versions
- Input protection diodes were changed from NUP4114 (not recommended by ATLAS NSW, lead times not compatible with FEC production schedule) to SP3004 (recommended by ATLAS NSW)
- Testing performed with pulse injection board developed for ATLAS (thanks to University of Athens and BNL) and with real sparks from GEM stack
- Careful choice of series resistor (automotive industry) leads to reliable spark protection
- Additional protection layer (Semtech TVS diode, recommended by ATLAS NSW) looks great in tests, but could not be added to FEC layout due to scheduling reasons
- Successful full system tests