Catania-Torino laboratory network & FPGA controller for Intelligent Camera SiPM

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LABORATORIO DI MICROELETTRONICA APPLICATA

STAFF: Sergio Billotta, Massimiliano Belluso, and TNT group: www.oato.inaf.it/gruppotnt

Attivita:
- Progettazione su dispositivi a logica programmabile (FPGA)
- Studio e modellizzazione Sensori Silicio
- Progettazione elettronica di Front-end per rivelatori al silicio
- Collaborazione all’interno dell’ICT per applicazioni di FPGA in ambito astrofisico (HPC)
- Collaborazione tecnico scientifica con l’INAF – OA Torino: Laboratorio in rete, interferometria d’intensità
- Trasferimento tecnologico
- Progetto lauree Scientifiche
Intelligent Camera SiPM for Astrophysical Applications: Assessment Work
Authors: M. Belluso (a), S. Billotta (a), V. Da Deppo (b), V. De Caprio (c), D. Gardiol (d), D. Loreggia (d), L. Paoletti (e)

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(b) CNR- Institute for Photonics and Nanotechnologies of Padua (IT)
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(e) INAF- Astronomical Observatory of Padua (IT)
Abstract:

World scale projects dedicated to ground based astronomy require new technology developments in many fields and also for realization of compact focal plane cameras. Usually these cameras are dedicated to specific astrophysical applications and optimized for a particular telescope configuration. However in many cases single telescopes (as well as arrays) can be well suited for scientific studies that were not driving the requirements in the project-planning phase. The objective of this work is an assessment towards the development of an Intelligent Camera SiPM (IC-SiPM) for astrophysical applications, based on silicon multiplier (SiPM) and programmable electronics (FPGA). IC-SiPM should be easily adaptable to different plate scale of currently existing or under construction telescopes for big science projects. The flexibility will be guaranteed by multi-size SiPM arrays, multi-function channels conditioning electronics, auto-focus and centring electro-mechanical system based on FPGA.
XILINX ARTIX 7 - FPGA System

Auto focus and Centroid Algorithms

DAC Blocks

CTR USB

Optical Module

OPT CTR

MUX

I/V Temperature Sensors

XYZ Movements

Vpower module ANL + DGL

Vpower module SIPM

Torino New Technologies
TSV MPPC array  

* S13361-3050NE-08, S13361-3050NS-08  
* S13361-3050AE-08, S13361-3050AS-08

**Overview**

The S13361 series are the MPPCs for the precision measurements. The strongest point of these MPPCs is drastically reduced cross talk, compared to our previous products. The S13361 series use the TSV (Through Silicon Via) technology. There is no wire bonding, so the package outline is very close to the MPPC array. The outer gap from active area edge to package edge is only 0.21mm. The pitch between ch is 3.2mm. This package realizes the 4-side buttable arrangement.

These MPPCs are designed for the applications in the photon counting region, including medical, non-destructive inspection, environmental chemical analysis, high energy physics experiments, and many other fields.

**Features**

- Significantly reduced Cross talk
- Low after pulse
- Very compact package with small dead space
- Superior photon counting capability
- Low voltage (Vop=33V Typ.) operation
- High gain, $10^5$ to $10^8$

**Application**

- Astro physical application
- High energy physics experiment
- Nuclear medicine
- PET
- Environmental analysis
Citiroc is a 32-channel front-end ASIC designed to readout silicon photo-multipliers (SiPM).

Citiroc allows triggering down to 1/3 pe and provides the charge measurement with a good noise rejection. Moreover, Citiroc outputs the 32-channel triggers with a high accuracy (100 pe).

An adjustment of the SiPM high-voltage is possible using a channel-by-channel DAC connected to the ASIC inputs. That allows a fine SiPM gain and dark noise adjustment at the system level to correct for the non-uniformity of SiPMs.

Timing measurement down to 100 ps RMS jitter is possible along with 1% linearity energy measurement up to 2500 p.e. The power consumption is about 2mW/channel, excluding ASIC outputting buffer.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector Read-Out</td>
<td>SiPM, SiPM array</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>32</td>
</tr>
<tr>
<td>Signal Polarity</td>
<td>Positive</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>Trigger on 1/3 of photo-electron</td>
</tr>
<tr>
<td>Timing Resolution</td>
<td>100 ps RMS in single photo-electron</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>0-400 pC, i.e. 2500 photo-electrons @ 10^7 SiPM gain</td>
</tr>
<tr>
<td>Packaging &amp; Dimension</td>
<td>Naked die - 4.1 x 4.1mm - 16.5mm^2 / 16FTR 160</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>60mW Analogue Core (excluding outputting buffer)</td>
</tr>
<tr>
<td></td>
<td>95mW Asic Outing (all outputs on)</td>
</tr>
<tr>
<td>Inputs</td>
<td>32 voltage inputs with independent SiPM HV adjustments</td>
</tr>
<tr>
<td>Outputs</td>
<td>32 trigger outputs</td>
</tr>
<tr>
<td></td>
<td>1 multiplexed charge output</td>
</tr>
<tr>
<td></td>
<td>1 ASIC trigger output (Trigger OR)</td>
</tr>
<tr>
<td>Internal Programmable Features</td>
<td>32 HV adjustment for SiPM (6x8bits), Trigger Threshold Adjustment (10bits), channel by channel gain tuning, 32 Trigger Masks, Channel by Channel Output Enable, Trigger Latch</td>
</tr>
</tbody>
</table>
Power supply for MPPC®

C11204-01

Bias power supply with built-in high precision temperature compensation for MPPCs

Features:
- Wide output voltage range: 50 V to 90 V
- Low ripple noise*: 0.1 mVpp typ.
- Superb temperature stability: ±10 ppm/°C typ.
- Finely adjustable resolution (in 1.8 mV steps)
- Serial interface

*1: No load, using the recommended circuit

Applications:
- Power supply for MPPCs

Absolute maximum ratings:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>Vs</td>
<td></td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>Temp</td>
<td>No condensation</td>
<td>0 to +50</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>Temp</td>
<td>No condensation</td>
<td>-20 to +70</td>
<td>°C</td>
</tr>
</tbody>
</table>

Note: Exceeding the absolute maximum ratings even momentarily may cause a drop in product quality. Always be sure to use the product within the absolute maximum ratings.

Recommended operating conditions:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>Vs</td>
<td></td>
<td>4.75</td>
<td>5</td>
<td>5.25</td>
<td>V</td>
</tr>
<tr>
<td>High level input voltage</td>
<td>Vo</td>
<td>±5 V</td>
<td>0.65 Vcc</td>
<td>-</td>
<td>-</td>
<td>Vcc</td>
</tr>
<tr>
<td>Low level input voltage</td>
<td>Vo</td>
<td>±5 V</td>
<td>0</td>
<td>-</td>
<td>0.6 Vcc</td>
<td>Vcc</td>
</tr>
<tr>
<td>High level input voltage</td>
<td>Vo</td>
<td>±5 V</td>
<td>Vcc</td>
<td>2.0 V</td>
<td>2.0 V</td>
<td>Vcc</td>
</tr>
<tr>
<td>Low level input voltage</td>
<td>Vo</td>
<td>±5 V</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Vcc</td>
</tr>
</tbody>
</table>
SiPM  |  PCB 1  |  PCB 2  |  PCB 3

Through-hole

Threaded-hole

Unit in mm

2  |  9.2  |  2  |  9.2  |  2  |  9.15

2  |  9.2  |  2  |  9.2  |  2  |  9.15

1.7  |  20.4  |  31.55  |  35.25

55.5  |  55.5

1.5