Miniaturized multi-channels SiPM read-out electronics for medical imaging application

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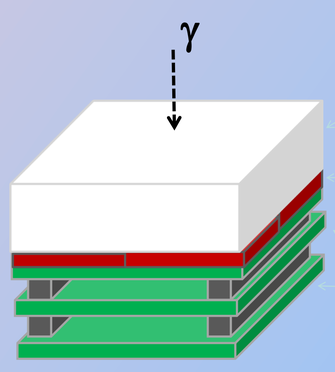
Introduction

The SIPMED is a prototype of a very compact intra-operative gamma camera based on arrays of Silicon Photomultiplier (SiPM) coupled to a scintillator and a dedicated read-out electronics to improve the efficiency and the reliability of the image guided surgery of tumors. The SIPMED consists of 2x2 elementary modules covering a field of view of 5x5 cm^2 and having geometrical dimensions adapted for intra-operative interventions (~ 6 cm width, ~ 5 cm thickness and weight less than 700 gr). Each elementary module is composed of a very compact stack of three different PCBs. 2x2 monolithic SiPM arrays of 16 channels each are mounted on the first PCB. The 2 readout chips EASIROC of 32 channels are directly bonded on the second PCB. The FPGA and the USB interface are mounted on the third PCB. The SIPMED camera will summarize 256 read-out channels.

Elementary module of the SIPMED gamma camera

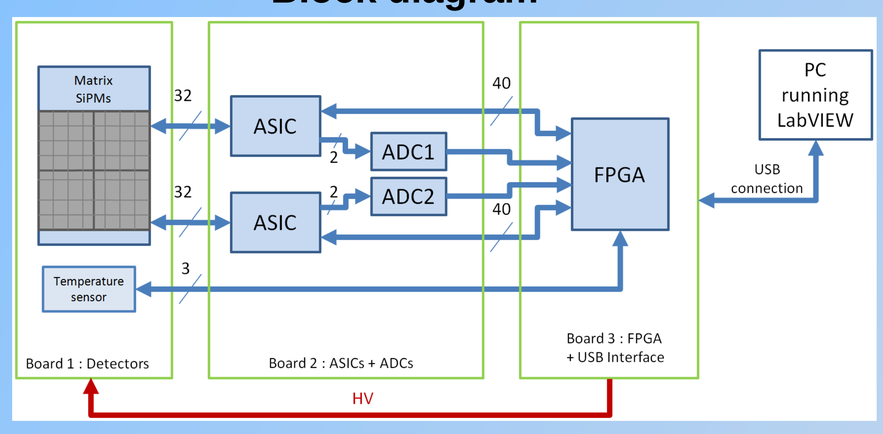


scintillator

4 SiPM arrays
1 array 4x4 SiPM
1 SiPM 3x3 mm^2

miniaturized read-out electronics
(64 channels)

Block diagram



Front end electronics

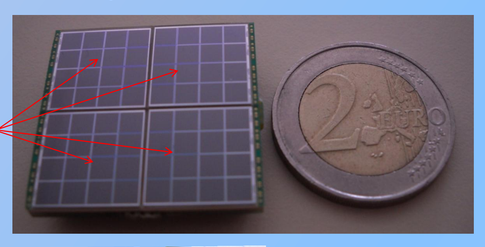
The front end electronics is made of three boards stacked together (28.6 x 27.2 mm^2)

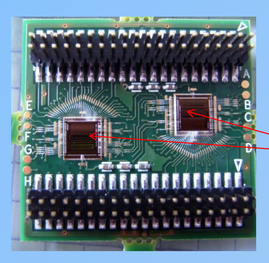
SiPM board :
4 layers PCB
front side: SiPM arrays
back side: temperature sensor
passive elements

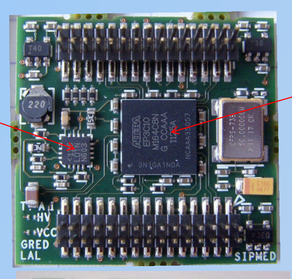
ASIC board :
10 layers PCB
front side: 2 x EASIROC ASIC
back side: ADCs, passive elements

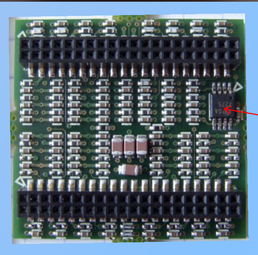
FPGA board :
10 layers PCB
front side: FPGA (Cyclone III)
back side: USB interface

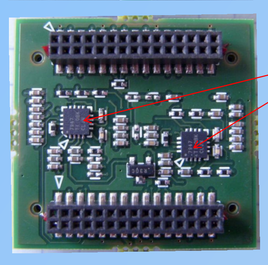
Elementary module stack :
photo-detection system
composed of three boards
stacked together

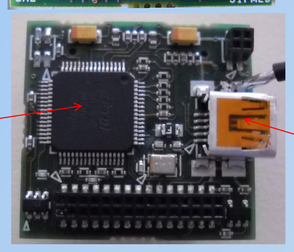






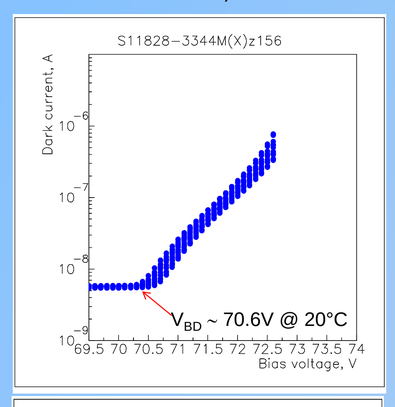


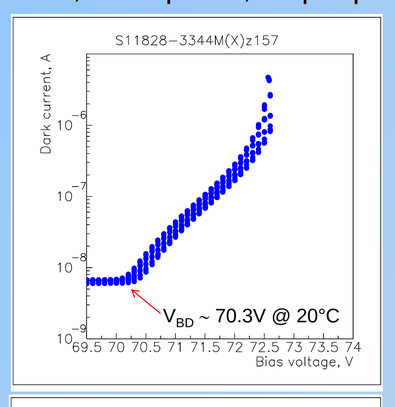


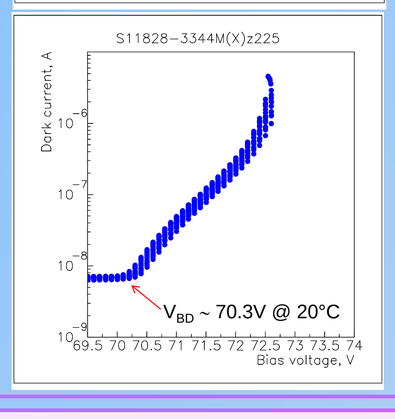


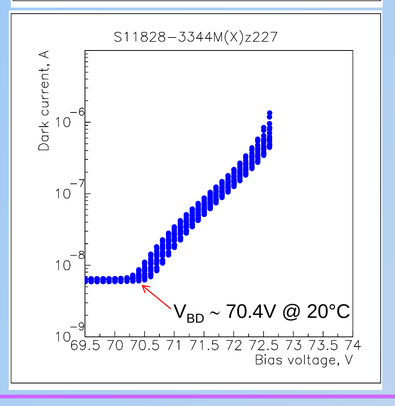
Monolithic SiPM array

Monolithic Hamamatsu MPPC array in SMD package S11828-3344M
16- channels (4x4 ch) monolithic MPPC mounted on a surface-mount package
Each channel: MPPC, 3x3 mm^2 total area, 3600 pixels, 50 µm pitch



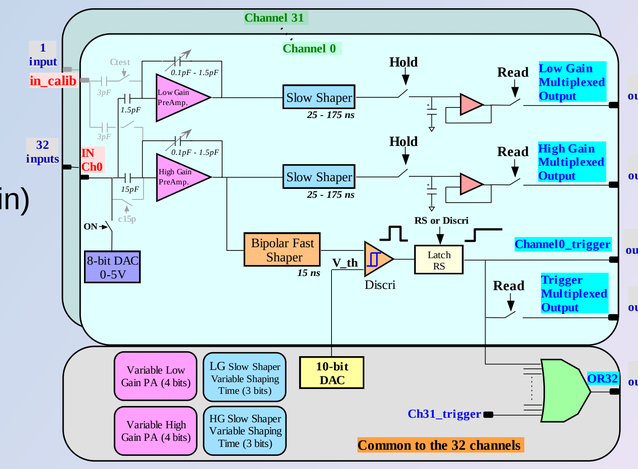






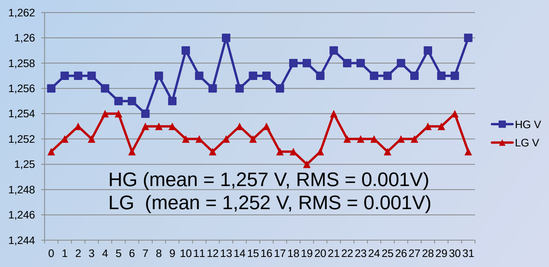
The EASIROC chip

- 32-channels front-end readout
- Individual 8-bit DAC for SiPM gain adjustment
- Energy measurement from 160 fC to 320 pC (1pe to 2000pe @ SiPM gain = 10^6)
  - 1 pe/noise ratio ~11
  - Variable gain preamplifier
  - Variable shaping time from 25 to 175ns
  - Common 10-bit DAC for threshold adjustment
  - 2 multiplexed analog outputs (high gain, low gain)
- Trigger output
  - 1 pe/noise ratio ~24
  - Trigger on 1/3 pe (50 fC)
  - 32 Trigger outputs
  - Trigger multiplexed output
- Individually addressable calibration capacitance
- Low power : 4.84 mW/channel, 155 mW/chip

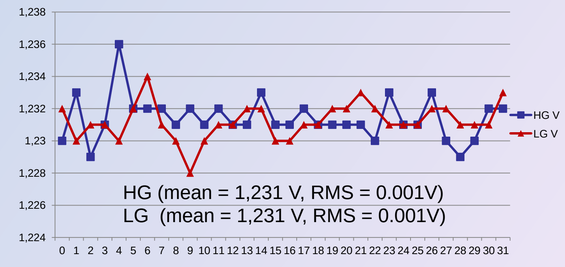


http://omega.in2p3.fr

Pedestals dispersion



ASIC1 Channel



ASIC2 Channel

Work under study and perspectives :
Electronics: DAC linearity on the 32 channels, charge measurements, signal to noise ratio, linearity tests on analog channels
SIPMED elementary module: temperature dependence @ 36°C (breakdown voltage, dark count rate), photon detection efficiency, energy resolution