6th International Conference on New Developments In Photodetection
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Front-end multi-channel PMT-associated readout chip for hodoscope application

Introduction

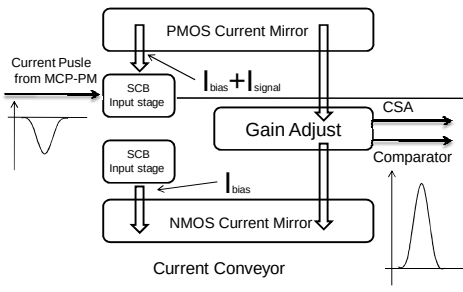
- Context: Scintillating fibers arrays and read out by multi-anode photomultipliers or multi-channel plates (MCP-PMTs).
- Application: Hadron therapy
- Project: Time-of-Flight Compton Camera for real time visualisation of the nuclear treatment (Prompt gamma imaging using a beam hodoscope)
- Hodoscope: X,Y position of the beam, time tagging 128 channel X , 128 channel Y
- Instrumental solution: Scintillating fibers coupled to photomultiplier tubes (PMT)

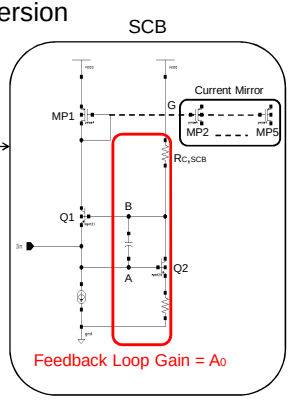
  Detector Capacitance = 35pF
  Signal rise time 4ns
  Signal fall time 16ns
  Input charge 2pC ~ 10pC
  Counting rate of the whole detector : 10^8 pps for ^{12}C ions (10ns)
- Funding: GAMHADRON project fund by the ANR (Agence Nationale pour la Recherche) and the European project ENVISION

Readout ASIC Description

- Signal current preamplifier : Current Conveyor
  a) Very Low Input Impedance (Super Common Base Topology)
  - Reduce crosstalk
  - Minimize effects of detector
  - Suitable for high channel density applications
  - Low noise and High speed

  b) Variable Gain (Multi Current Mirror)
  - Compensate the optic fiber ageing
  - Compensate multi-anode PM gain dispersion

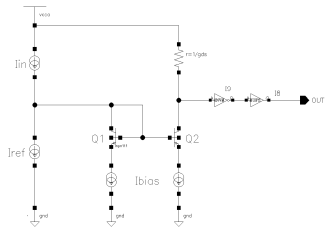




$$Z_{in} \approx \frac{1}{(1+\frac{A_0}{(1+s/\omega_A)(1+s/\omega_B)})*g_{m,Q_1}+sC_A}$$

At low frequencies $$Z_{in} \approx \frac{1}{A_0 * g_{m,Q_1}}$$

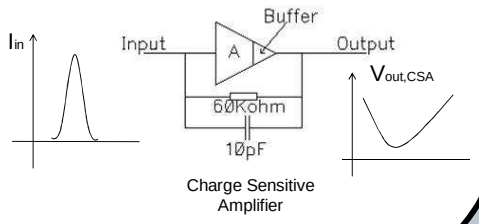
- Signal Event Detection : Current Comparator
  - Current Mode
  - High speed
  - Adaption for new technology (Low Voltage Process)



Current Comparator

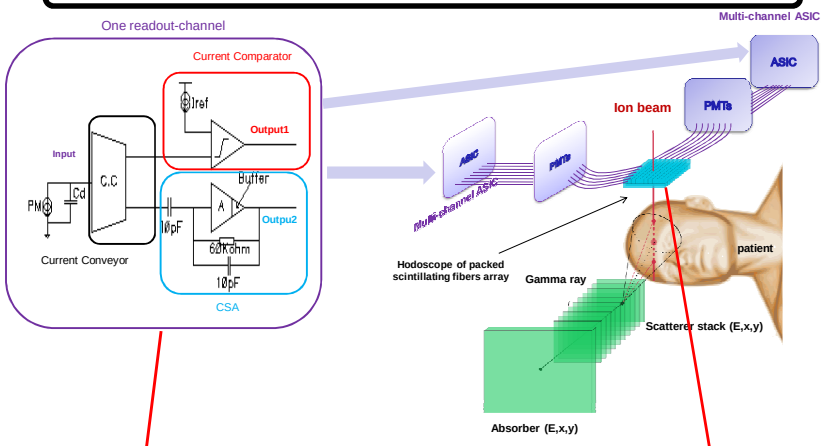
- Signal charge quantification : Charge Sensitive Amplifier
  - Large range
  - Low noise level

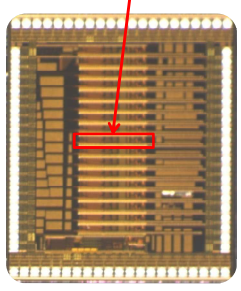
$$\Delta V_{out,CSA} = -\frac{1}{C_f}\int_0^{t_{end}} I_{in}(t)dt$$



Charge Sensitive Amplifier

Prompt gamma imaging using a beam hodoscope

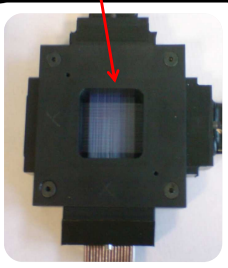




2.2mm X 2.8mm = 6.16mm²

Test board

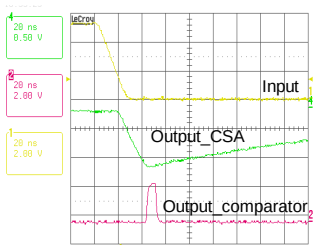
A 16 full-channel ASIC



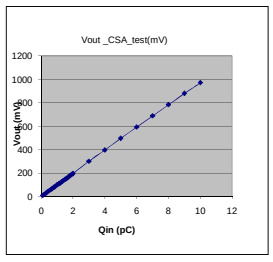
Scintillating fibers array
X = 128 channels
Y = 128 channels

Hodoscope

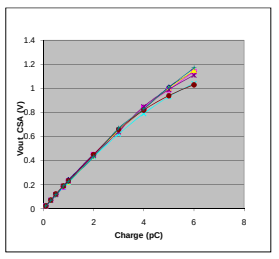
Test Results



1 full-channel output test result



Conversion gain of CSA : 9.8mV/100fC



7 full-channel CSA outputs test result

Summary of characteristics of the designed readout ASIC

	Post-layout results	Test results
Power consumption /channel (under 3.3V) @ current gain from 0.25 to 2	15 to 22 mW	16 to 23 mW
Input dynamic range	50µA(525fC) — 2.4mA(25.2pC)	-
Input impedance at I_{bias} = 500 µA at low frequencies	≈4Ω	≈12Ω @ signal frequency
Current conveyor Bandwidth	200MHz	-
Current comparator Bandwidth	667MHz	-
CSA dynamic range	15pC	100fC – 10pC
CSA Peaking time	30ns	28ns
ENC current conveyor	40fC	90fC
ENC CSA	10fC (Cd=100fF)	113fC (Cd=1pF)
1 full-channel ENC	42fC	91fC
Xtalk	-	1.7%
Chip Size	X=2.2mm Y=2.8mm For 16channels	X=2.2mm Y=2.8mm For 16 channels

Summary and Perspectives

- A 16 full-channel ASIC (AMS SiGe BiCMOS 350nm) is realized for this application
- In next version:
  1 Slow Control (I2C)
  2. 64 channels in the next chip (4 ASIC/hodoscope)
- A Time stamper system based on DLL (Delay Locked Loop) with a resulotion 195ps has been designing and when the design is validated, it will be integrated
- A new test board is designed for a real time beam test which will be performed soon.
- Design of a new readout chip with improved speed performance to be coupled with Diamond detectors

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