Bipolar monolithic front-end preamplifier for use with silicon photodetectors

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BIPOLAR MONOLITHIC FRONT-END PREAMPLIFIER FOR USE WITH SILICON PHOTODETECTORS.

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ABSTRACT

A front-end transimpedance preamplifier is studied to be matched with photodetectors in the CMS electromagnetic calorimeter. A fast low noise preamplifier has been designed using Harris Semiconductor UHF1 bipolar transistors process for detectors capacitances in the range of 10 to 100pF. Preliminary results have shown that this technology seems well suitable for fast and low noise analog signal processing. New and complementary results for NPN design are presented before and after neutrons irradiation.

1. INTRODUCTION

The photosensors which are studing for the CMS-ECAL are silicon APD's devices. From 1 or 10 nA in initial conditions, the silicon detector bulk current increases up to 1μA or more due to radiation effect. A fast shaping is the best solution to solve these problems and the bipolar junction transistor is a good technology for short shaping time and relatively large photodetector capacitances. Now, the design of a front-end with a good performance is easier by high quality UHF devices. A transimpedance preamplifier configuration SLCC32 has been designed[1]. Experimental results, transient response and noise have been measured. Some noise results obtained after neutrons irradiation are given.

2. NOISE EVALUATION

The APD noise contribution has been calculated for a gain M=50, excess noise factor F=2 and a bipolar junction transistor (BJT) input device of transimpedance amplifier SLCC32. A shaping amplifier is used to define the bandwidth. The block diagram is shown in figure 1.

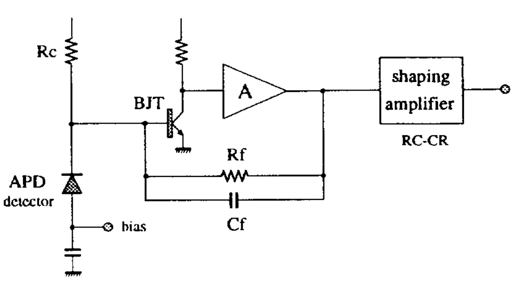

figure 1: schematic view

The classical noise expressions[2,3,4] are used for ENC calculations with the following parameters values:

BJT,
collector current Ic=0.4mA, Beta = 100, base spreading resistor Rbb' = 40Ω,

APD detector,
Cd = 50pF and 100pF, Ibulk = 10nA and 1μA, F=2, M=50, serial resistor Rs = 10Ω.

PREAMP,
Rf=10KΩ, Cf=5pF, Rc = 100KΩ.

In figure 2 the ENC results are normalized at gain 1.

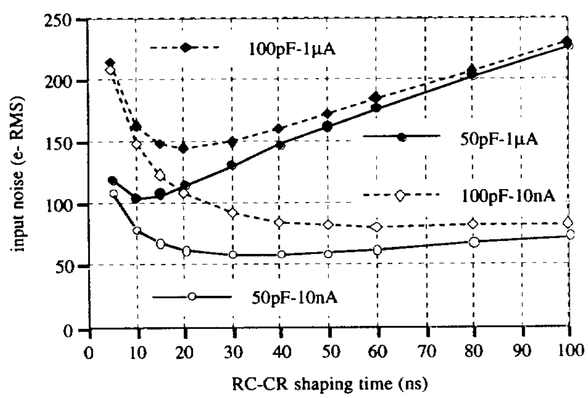

figure 2: noise calculation

For a 10ns RC-CR shaping time, the variation of the noise is moderate for a bulk current ranging from 10nA to 1μA.

3. EXPERIMENTAL RESULTS

The chip has been packaged in a single layer chip carrier (figure 3) for limiting the parasitic serial inductance introduce by the wires bonding length.

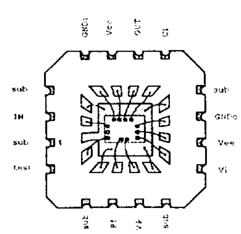

figure 3: SLCC32 mounting

3.1 Peaking time

Measured transient pulse responses on 50Ω load are shown in figure 4 for input capacitance Cin=100pF, Rf=20KΩ, Cf=0.5pF and with four collector current (Ic) values for the input bipolar transistor.
The current gain is dominated by [Cin/Ic].KT/q terms.

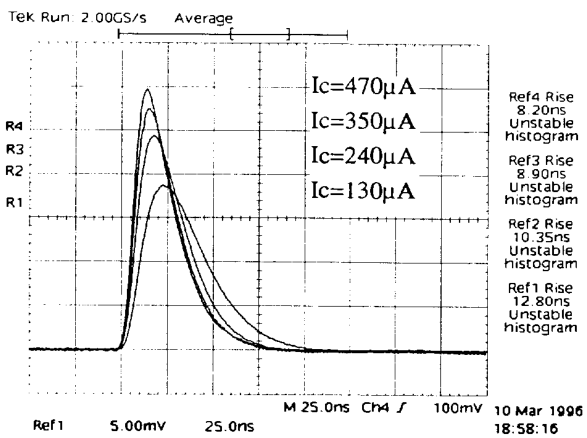

figure 4: output pulse waveform

3.2 Response time

The responses of the different charge injection have been measured with Hamamatsu APD S5345 (Cd=90pF). At 320V bias voltage the gain is approximatively 50. A collector current of 300μA is used for the NPN input transistor of preamplifier. It is a good compromise with respect to speed and noise.
First the APD is exposed to a nitogen laser pulse. Typical ligth pulse width is 3ns and wavelength equal to 337.1nm. Figure 5 shows the response of APD associated to SLCC32 preamplifier on 50Ω load.

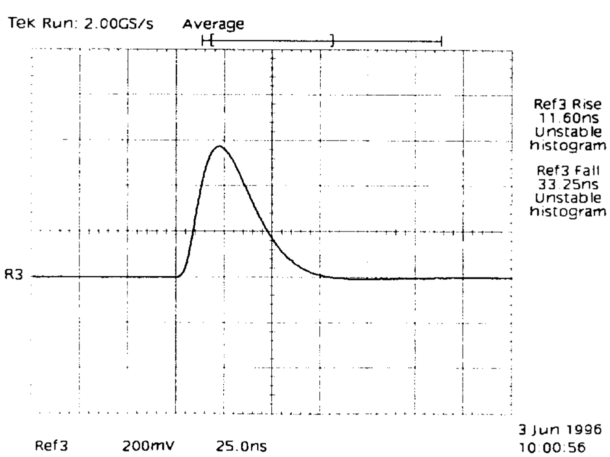

figure 5: light pulse response

Charges collection is very fast. In fact the shaping time observed is given by electronic response.
After this, a comparison between electrical charges injection and the gamma source ^{55}Fe has been realized. Charge pulse is produced by step voltage generator. The rise time is 2ns and equivalent charge equal to 4.10^6e-.

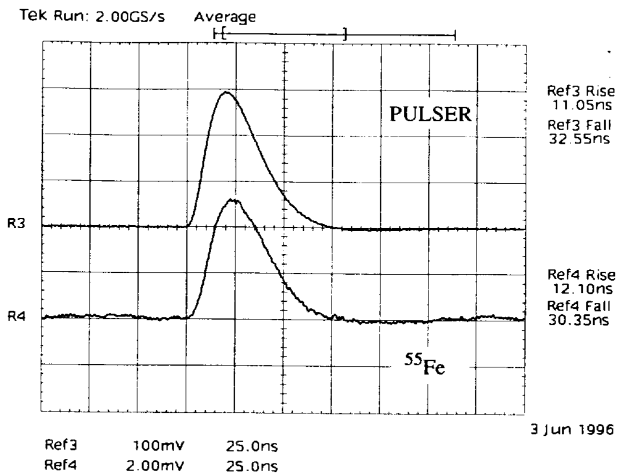

figure 6: pulser and γ source responses

These responses are very similar. It is a typical feature of whole photodetector system.

3.3 Noise measurement

The noise has been measured after RC shaping amplifier (integration =50ns) according to collector current for 2 input capacitance values. The calibration has been done with ^{57}Co source and PIN photodetector. The r.m.s. voltmeter and digital oscilloscope has been used. Results are shown in figure 7

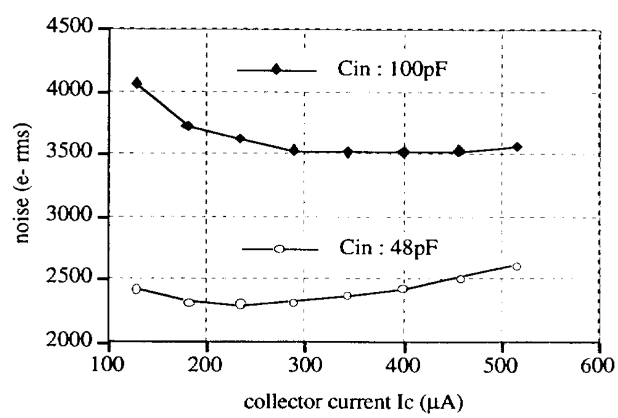

figure 7

These curves show clearly the relative contributions of serial and parallel noise. The choice of collector current fixes the noise and the response time.

4. RADIATION HARDNESS TESTS

Three prototypes SLCC32 preamplifiers have been irradiated at Ulysse reactor at Saclay [5] up to 10^{12} fast neutrons/cm^2 under bias conditions.

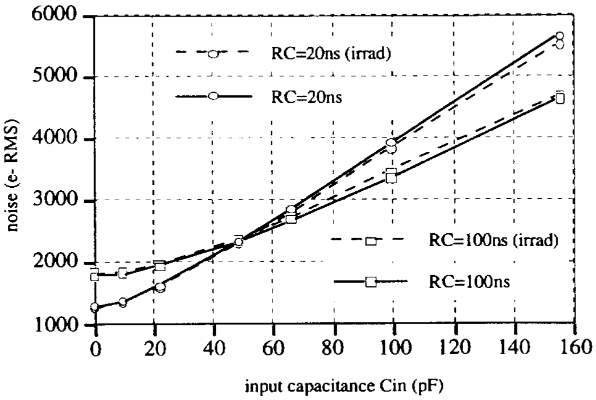

figure 8: noise measurement

At this dose, no significant noise increase has been observed for 20ns and 100ns integration shaping time. More studies are needed to check the radiation hardness at upper dose.

5. CONCLUSION

These additionnal measurements on version1 confirm the feasability of front-end electronics in UHF-1 bipolar transistor technology in fast and low noise applications.
Version 2 is under development with the following characteristics:

- reduce the input transistor base spreading resistance down to values below 50Ω,
- large range gain adaptation,
- DC coupling capability with leakage current control,
- 3 independent functions: preamp, buffer, DCamp,
- total power consumption ≤ 20mW.

ACKNOWLEDGEMENTS

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REFERENCES

[1] M. Goyot, First Workshop on Electronics for LHC Experiments, Lisbon,1995, 248-252

[2] E. Gatti and P.F. Manfredi, Processing the signals from solid-state detectors in elementary-particle physics, Rivista del nuovo cimento, Vol.9, N.1, 1986.

[3] P. Webb, EG&G, Internal Report VEO-TR-94-012.

[4 E. Gatti, A. Hrisoho and P.F. Manfredi, IEEE Trans.Nucl. Science, Vol. NS-30, N 1, February 1983, 319-323.

[5] R. Chipaux et al., DAPNIA/94-05