A charge sensitive preamplifier made with SiGe bipolar transistors

Claudio Arnaboldi, Giuliano Boella, Gianluigi Pessina*

INFN Istituto Nazionale di Fisica Nucleare and Università di Milano - Bicocca, Facoltà di Fisica, P.zza della Scienza 3 20126 Milano, Italy

Abstract

We have characterized some commercial SiGe bipolar transistors to be used at low injection level and in a wide temperature range, in view of their possible application in experiments with large number of channels. After having observed that they are very suitable for low noise and high-speed applications we have designed and built a charge sensitive preamplifier able to work at tens of nsec shaping time. In this paper, the preamplifier performances at room temperature are described.

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1. Introduction

SiGe bipolar transistors are well known for their high-speed capability even at small biasing currents [1]. Thanks to their engineering construction, the base region can be heavily doped [2]. This features gives to these transistors some very peculiar properties, such as a negligible base spreading resistance, with a related small series noise.

2. Experimental results

In order to verify the power of this technology for nuclear application, we have built a charge sensitive preamplifier (CSP) using only discrete, commercial, SiGe bipolar transistors from Infineon, the BFP620. Our CSP is a dominant-pole single-stage circuit, having a cascode configuration in input. The collector current of the input transistor has been made variable to study the speed of response of the circuit vs noise. The noise is measured using a RC-CR filter having the time constants settable from 36 to 530 ns. A δ-like charge is injected at the CSP input trough a test capacitance $C_T$. $C_T$ and the CSP feedback capacitances, $C_F$, are varied while maintaining their ratio constant. This way it is possible to study the effect of the series noise, proportional to $C_T+C_F+C_i$, $C_i$ being the CSP input capacitance, while maintaining almost constant the loop gain, therefore minimizing any possible measurement error.

The results obtained are very interesting. SiGe bipolar transistors show transition frequency in
excess of 60 GHz at current levels of the order of 10 mA. The frequency range needed for typical nuclear applications is, roughly, about one order of magnitude lower, which allows operating these transistors at a small level of biasing currents, saving power dissipation. In Fig. 1 this is evidenced by the signal response of the realized CSP. As it can be seen the rise time observed is about 6 ns. Frequency bandwidth results about 60 MHz ($C_F = 2 \text{ pF}$, $C_T + C_i = 3 \text{ pF}$), adequate to work at moderate rate, with shaping time of the order of 10 ns. In the operating conditions the supply voltage of the CSP is 2.5 V and its input transistor is biased at 0.12 mA of collector current. Total power dissipation of the CSP results to be about 0.4 mW.

In Fig. 2 it is shown the equivalent noise charge (ENC) as a function of both the shaping time and the capacitance $C_{TOT} = C_T + C_F$ in a 3D-plot. We have interpolated the measured noise with the $\chi^2$ technique. Parallel noise results consistent with the Shot noise of the base current, 0.7 $\mu$A. The white component of the series noise results totally consistent with the shot noise of the collector channel: the base spreading resistor is therefore negligible for this devices, as predicted. Nevertheless the $1/f$ noise coefficient is found of the order of $10^{-11} \text{ V}^2$, this suggests that SiGe npn transistors, at least for the selected kind, should be used mainly with short shaping time [3].

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References