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Transimpedance amplifier for LGAD noise measurements: Design and Characterization

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In the past decade, thin silicon low-gain avalanche diodes (LGADs) have attracted considerable attention due to their timing applications in High-Energy Physics (HEP) experiments [1]. Experiments such as the High-Luminosity Large Hadron Collider (HL-LHC) require timing resolution in minimum ionizing particles (mips) detection of tens of ps to reconstruct multiple tracks per bunch crossing. A conventional thin silicon sensor cannot achieve this resolution due to the low signal amplitude. The signal-to-noise ratio of the detector-readout electronics system can be increased by incorporating a layer which realize a charge gain in the detector itself (Figure 1). The gain layer constitutes a high electric field region that allows drifting carriers to ionize silicon atoms, increasing the signal amplitude. However, multiplication gain introduces an additional noise component due to the fluctuations in the number of the generated carriers [2]. The noise associated with the multiplication gain dramatically decreases the device's performance. However, no experimental studies of the Noise Power Spectral Density (NPSD) in LGADs are available in literature. In order to measure the NPSD in LGAD structures, a wideband low-noise transimpedance amplifier (TIA) has been designed (Figure 2). The design focuses on maximizing operating bandwidth and minimizing system background noise. The TIA is based on the OPA818 operational amplifier due to its high gain-bandwidth product (GBWP) (2.7 GHz), low input capacitance (2.4 pF), and low input voltage noise density (2.2 nV/√Hz). A detachable daughter board DC coupled to the TIA's input is used to test various devices. TIA is calibrated by measuring the noise of resistors at different temperatures. The measurements of TIA's input noise revealed an additional OPA's current noise component with respect to the one declared in the datasheet. The NPSD's of an LGAD is measured from 10-28 A2/Hz to 10-24 A2/Hz in the range of frequencies from 10 Hz to 3 MHz, showing a dominant white component, strongly dependent on the device bias condition and temperature. The designed transimpedance amplifier allows the accurate noise characterization of LGAD, which is a fundamental step in the analysis of the multiplication gain in LGAD structures.

[1] N. Cartiglia, et al. "4D tracking: present status and perspectives.", Nucl. Inst. Meth. Phys. Res. A, (2022).
[2] R.J. McIntyre, "Multiplication noise in uniform avalanche diodes.", IEEE Tran. on El. Dev., (1966).

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