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A 89dBΩ, 400Mhz transimpedance amplifier with improved radiation and temperature tolerance and 1:1600 dynamic range.

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A chip is developed in a 130nm technology, containing a transimpedance amplifier with a 405MHz bandwidth, 89dBΩ transimpedance gain and a dynamic input range of 1:1600 for a photodiode capacitance of 0.75pF. The equivalent input noise is 216nA. The gain of the voltage amplifier, used in the TIA, degrades less than 3% over a temperature range from −40°C up to 125°C. The transimpedance-bandwidth product of the TIA equals 12THzΩ and has a simulated radiation tolerance larger than 1MGy degrading only 7% and 8.5% over the entire temperature range (-40 up to 125°C).

Summary

The possible use of custom CMOS integrated circuits for radiation environments has gotten a fair share of attention for over a decade. Hardened CMOS is even considered a viable solution for use in extremely radiation-harsh environments such as: the Large-Hadron Collider in CERN, the Experimental Reactor (ITER), or the MYRRHA-reactor which is an Accelerator Driven System under development at the Belgian Nuclear Research Centre, in Mol. The MYRRHA reactor consists of a proton accelerator delivering a proton beam to a liquid Pb−Bi spallation target that in turn couples to a Pb−Bi cooled, subcritical fast nuclear core. One of the requirements of the windowless design is the level control of the target's free surface. The height of this level can be measured by a LIDAR (LIght Detection And Ranging). Existing LIDAR technologies that use the time of flight technique will be extrapolated to reach MYRRHA specific requirements.

The transimpedance amplifier (TIA) is one of the most critical building blocks of the LIDAR system. It consists of a voltage amplifier with a feedback resistor (RTIA) which converts the current generated by the photodiode into an output voltage. Several of the specifications (bandwidth, transimpedance and the transimpedance-bandwidth product) tend to degrade when the TIA is subjected to high temperature or radiation. Therefore, a novel technique is presented for improved temperature and radiation stability in a TIA. A TIA with low sensitivity to temperature and radiation effects requires a temperature and radiation tolerant voltage amplifier. This means that the open loop gain (A0) must be kept constant despite shifts of the device parameters due to irradiation or temperature. To achieve a constant A0, a constant transconductance(GM)-circuit is proposed utilizing a closed loop technique.

This technique effectively links the value of a transconductor replica to the conductance of a physical feed forward resistor. In the original voltage amplifier, a 10 times larger transconductance is loaded with an identical resistor, hereby achieving 20dB voltage gain. As the load resistor and feedforward resistor are equal and experience the same temperature and radiation behaviour, a voltage amplifier with improved radiation and temperature tolerance is attained.

In turn, the robust voltage amplifier is integrated in a TIA suitable for the LIDAR system. In addition, the TIA is preceded by a Gilbert cell which enlarges the dynamic range of the TIA.

A chip is developed, using these techniques, in a 130nm technology, containing a TIA with 405MHz bandwidth and 89dBΩ transimpedance gain for a photodiode capacitance of 0.75pF and a dynamic input range of 1:1600. The equivalent input noise is 216nA @ 25°. The gain of the voltage amplifier, used in the TIA, degrades less than 3% over a temperature range from −40°C up to 125°C or 164ppm/°C without calibration. The transimpedance-bandwidth product of the TIA equals 12THzΩ and has a simulated radiation tolerance larger than 1MGy degrading only 7% and 8.5% over the entire temperature range (-40 up to 125°C).

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