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Development of Radiation-Hard Bandgap Reference Circuit in CMOS 130 nm Technology

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In particle physics experiments a stable sub-1-V reference voltage is needed in spite of harsh ionizing radiation conditions. After such radiation load the bandgap using standard p-n junction of bipolar transistor does not work properly. This is why several sub-1V voltage references based on DTMOS (dynamic threshold MOS) and ELTMOS (enclosed layout transistor MOS), using CMOS 130nm process were proposed. We present and compare post-layout simulations and the preliminary measurements of the developed devices, which show correct operation (<1mV bandgap stability, linear PTAT) in temperature range -20 to 100 degree.

Summary

A voltage reference circuit is a device that generates an exact output voltage which in theory does not depend on the operating voltage, load current, temperature or the passage of time. It is commonly used in most of all analog devices and mix-mode signal systems. In particle physics experiments a stable reference voltage is needed in spite of harsh ionizing radiation conditions, i.e. doses exceeding 100 Mrads and fluences above 1e15 n/cm2. After such radiation load the bandgap using standard p-n junction or bipolar transistor does not work properly. This is why instead of using bipolar transistors, the DTMOS (dynamic threshold transistors) or ELTMOS (enclosed layout transistors) were proposed.

Five prototype of sub-1V radiation-hard Bandgap references voltage circuit has been developed. Two of them are based on standard Banba architecture and three others have also current-mode architecture, but their design additionally allows to add temperature sensor. Special enclosed layout (ELT) and dynamic threshold DTMOS transistors were used to reduce the TID (total ionization dose) effect like threshold shift or leakage current. Designed devices are expected to give stable (less than 1mV per 120 degree) sub-1-V reference equal to 0.6 V.

Unfortunately measurements of first prototypes showed that the transistors were not properly modeled and simulated by Virtuoso - a tool for IC design. This is mainly due to the originality of used enclosed layout transistors, which layout models are not available by default and need to be drown manually. To overcome this problems there have been performed calculations based on these measurements to determine what values should be used during designing next prototypes. With these calculations we were able to get to know the real values of currents that flow through the transistors and their exact characteristics, what enable us to design the secondary prototypes, which result are presented. These new bangaps were also equipped in calibration capability - resistance switching which allows to control the stability of bandgaps and change its referenced voltage values.

The first preliminary measurements of second prototypes indicate that this time bandgaps has been designed correctly, achieving very high stability over a wide temperature range. Most of developed prototypes obtain temperature stability under 1 mV. Only in two cases this parameter in about 1.5 mV. Designed temperature sensor exhibit linear PTAT, and around 2.2 mV per degree in all rage from -20C to 100C . Power consumption depending on circuit varies between 45W and 95W and the PSRR values does not fall below 29.5 dB at all bandgaps. Measurements show that bendagps meet their expectations and can be successfully used.

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