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Performance of the Bandgap Reference Circuit, designed in a commercial 0.13um CMOS technology.

A new all-MOS bandgap voltage reference circuit has been developed and implemented in a commercial 0.13-μm CMOS technology. The proposed circuit features dynamic-threshold MOS transistors (DTMOST's) and therefore well fits into the low supply-voltage range of the technology.
Measured Vref is 425±15mV (chip-to-chip statistical spread) for 8 samples. The circuit runs at supply voltages down to 0.85V and occupies 0.015mm2 on the wafer.
The X-ray irradiation facility has been used to examine radiation hardness of the circuit. When being irradiated up to 47 Mrad the reference voltage of the circuit shifts typically by 12mV.

Summary

Analog blocks are mandatory parts of today's CMOS ASICs used in high energy physics experiments. Such the blocks like supply voltage regulators, high quality ADCs and DACs include a reference circuit. The common way to implement reference circuit with a low temperature sensitivity and high power supply ripple rejection is the bandgap reference circuit.
With steadily decreasing power supply voltages (Vdd) in present and future deep sub-micron CMOS technologies a design of any bandgap voltage/current reference on-chip becomes a non-trivial task.
The classical voltage summing bandgap reference circuit (BGR) featuring parasitic diodes (p-diffusion in N-well) is not suited for a 0.13μm CMOS technology with a maximum Vdd of 1.2V. It is so because the value of bandgap voltage (Vgap) in silicon (1.12V) turns out to be very close to the nominal supply voltage of the process.
This causes the circuit to fail.
We use a new structure called a dynamic-threshold MOS transistor (DTMOST) in place of conventional diodes in the circuit. Such a combination constitutes a high-quality reference circuit able to fit into the reduced supply voltage range of a 0.13μm CMOS technology.
In order to construct a model of the DTMOST device suitable to run simulations, pre-design characterizations have been carried out.
The circuit has been submitted in CuTe2 MPW submit in May 2004.
Testing has shown that the measured performance of the circuit is in good agreement with the performance predicted by simulations.
The circuit is able to operate at supply voltage in range from 1.4V down to 0.85V.
Sensitivity of the reference voltage to the power supple voltage variation is 3.3mV/V.
The circuit can be externally trimmed in order to reach the operating point where the reference voltage has the lowest temperature coefficient (less than 1mV in the range from 0ºC up to 80ºC). However, due to statistical variation the trimming is dedicated to the chip. With no trimming the temperature coefficient is typical 0.05mV/ºC.
The circuit will operate in the radiation environment of high energy physics experiments and therefore radiation tolerance is an issue for the design. We used the CERN's in-house X-ray facility for the irradiation of the chips. The effect caused by irradiation consists in the shift of the reference voltage while the circuit remains fully operational.
The change of the reference voltage has been monitored in the time of the irradiation. We tested 5 chips and have seen that the reference voltage does not demonstrate an identical behaviour. The only thing to conclude is that the reference

voltage deviates in the range of ± 12mV. It indicates that the irradiation is the dominant factor of instability of the reference voltage.
In some applications not only stability of the reference voltage is important but its absolute value as well. The absolute value differs from chip to chip and is caused by fabrication process variation. With few samples available we can roughly estimates chip-to-chip spread of the value of the reference voltage. It turned out to be confined in the range of ± 15mV.
A commercial 0.13um CMOS technology is suitable to design a high quality bandgap voltage reference circuit in spite of a low power supply voltage.
Redesign of the circuit is needed in order to improve chip-to-chip spread of absolute value of the reference voltage as well as its sensitivity to irradiation.

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