A current mode bandgap reference circuit has been designed in a 65nm CMOS technology for a possible application in high energy physics experiments. The prototype has been characterized as a function of temperature (from -30°C to +140°C) and voltage supply (from -0.78V to 1.32V) variation. Without trimming, the temperature variation effect is approximately 55 ppm/°C.

**Characterization of Bandgap Reference Circuits designed for High Energy Physics Applications**

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**Temperature variation**

![Temperature variation graph](image)

- **BANDGAP**
- **STARTUP CIRCUIT**
- **STARTUP CIRCUIT**

- VREF
- VDD
- MNOS
- Q2
- Q1
- Diode
- C1
- Rz
- R1
- Rh
- M1
- M2
- M3
- M10
- M11
- M12
- M13
- M14
- M15

**Voltage supply effect**

![Voltage supply effect graph](image)
Due to the harsh environment foreseen for this circuit, different devices (BJT, Diodes, MOSFETs) have been considered and implemented in the prototype.

BGRs have been irradiated up to 230Mrad (SiO\(_2\)) with X-rays:

- BGR based on BJT devices shows an increase of the output voltage from 690mV to 737mV: variation of 47mV. Recovers 6mV with Annealing (7 days at room temperature);
- BGR based on diode devices shows an increase of the output voltage from 706mV to 756mV: variation of 50mV. Recovers 6mV with Annealing (7 days at room temperature);
- BGR based on MOS in weak inversion region shows a decrease of the output voltage from 674.8mV to 667.2mV: variation of 7.6mV, degradation. Increase 0.7mV with Annealing (7 days at room temperature).

Conclusions and future activities:

- A voltage shift around 0.6% was measured after irradiation up to about 100 Mrad (SiO\(_2\))
- Irradiation with a monochromatic neutron source is being planned to study BGR sensitivity to bulk damage
- A different bias point of the circuit, featuring higher static currents, has to be used in order to improve the radiation hardness up to 1 Grad (RD53 requirement)
- A new design with trimmable resistance in order to reduce the temperature coefficient was designed

Promising result, but it has to be improved for some application (e.g. HL-LHC)