Sub 1-V Bandgap Reference Circuit

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***Abstract*— Bandgap references (BGR), which are an integral part of analog and mixed signal integrated circuits, are circuits that provide temperature, supply and process independent output voltage. The main challenge in this domain is to ensure correct operation in sub 1V supply voltages as we proceed to smaller technology nodes.**

***Keywords*— Bandgap reference circuit, Analog integrated circuit, Operational amplifier, low voltage, Curvature Compensation,**

I. Introduction

Bandgap references (BGR) are circuits that provide a temperature and supply independent output voltage. Voltage references are among the most important building blocks in current analog and mixed signal circuits and are a critical component of any SoC. This calls for low voltage operation, while simultaneously ensuring that the generated output voltage is insensitive to temperature and power supply variations. A general concept is to generate a signal with positive temperature coefficient (PTAT), and another with negative temperature coefficient (CTAT), and add them after suitable scaling.

II. Reference Circuit Details

The bandgap architecture [1] based on 80 nm BiCMOS shown in Fig. 1 uses current mode principle for temperature compensation and add currents proportional to $VBE1$and VT. The operational amplifier is used to make the two voltages VA and VB equal thus producing a CTAT current in the nominally equal resistors R1 and R2 proportional to VBE. PTAT current proportional to $VBE1 - VBE2 = VT\, lnN$ flows through transistors Q1 and Q2. Thus, the current in the PMOS transistors M1, M2 and M3 ($I1 = I2 = I3$) and the output voltage is thus given by,

$$Vref = \frac{R3}{R1}\left[VBE + \frac{R1ln(N)}{R0}VT\right] \quad (1)$$

TABLE I

PERFORMANCE SUMMARY OF THE BANDGAP CIRCUIT [1]

Parameter	*Value*
Power Supply Voltage	1 V
Technology	0.8 μm BiCMOS
Bandgap Cell Area	
Without Curvature Compensation	0.20 mm^2
With Curvature Compensation	0.25 mm^2
Power Consumption @ T = 25° C	92 μW
Reference Voltage @ T = 25° C	536 mV
Temperature Variation (0° C ≤ T ≤ 80 ° C)	
Without Curvature Compensation	800 μV → 20 ppm / K
With Curvature Compensation	300 μV → 7.5 ppm / K
Dependence on the Supply Voltage	114 μV / V→ 212 ppm / V

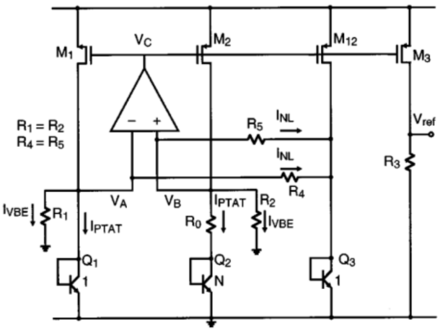

Fig. 1. Schematic of the bandgap circuit with curvature compensation [1].

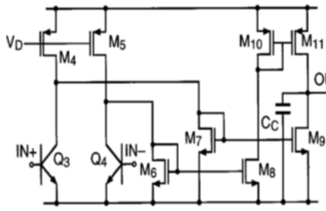

Fig. 2. Schematic of the two-stage operational amplifier [1]

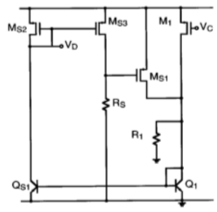

Fig. 3. Schematic of the startup circuit [1]

III. Reference Waveforms

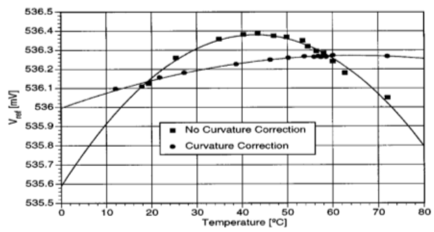

Fig. 4. Measured bandgap voltage as a function of temperature with and without curvature compensation [1]

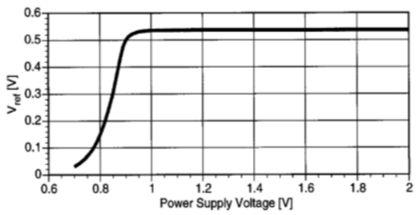

Fig. 5. Measured bandgap voltage as a function of the power supply [1]

References

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