General Purpose Band-Gap Reference with N-Well Resistors

Sheryl Corina Serrao

Department of Electronics Engineering, Fr. Conceicao Rodrigues College of Engineering
Mumbai, Maharashtra 400050, India

sherylcorina@gmail.com

***Abstract*— This paper discusses the generation and the design considerations of a general purpose band-gap reference circuit with N-well resistors as per the specification of V_{DD}=3.3V and V_{bgp}=1.2V. A general purpose band-gap reference circuit should generate a reference voltage, ideally independent of temperature, power supply, load, and process variations. An on-chip band-gap reference is a crucial block in the design of analog integrated circuits as the accuracy and precision of these circuits can be limited by the reference voltage.**

***Keywords*—** band-gap reference; PTAT; CTAT; start-up; PSRR; Temperature coefficient

I. INTRODUCTION

A reference voltage, generated by the band-gap reference (BGR) circuit, that has little to no dependence on the process, temperature, power supply variation is imperative for correct operation and performance of several analog and mixed-signal systems. BGR blocks are used in data converters-ADCs & DACs, LDOs, DRAMs, encoders & decoders, signal processing blocks, sensor interfaces, and several other applications. Therefore, a designer should take care to design a BGR circuit with a high power supply rejection ratio and an extremely low temperature coefficient. Since, the output reference voltage is approximately equal to the intrinsic band-gap voltage (1.2eV) of the semiconductor material used, silicon, it acquires the name of band-gap reference.[4] The principle of generation, Implementation, Issues & Improvements, Conclusion, and Future Scope will be discussed further.

II. PRINCIPLE OF GENERATION

The reference voltage that is insensitive to temperature can be produced by the combined effect of two blocks that have opposite and equal temperature coefficients, that compensate for the variation in voltage produced by each other due to varying temperatures, thereby producing a constant voltage, independent of temperature. The BGR circuit is the summation of a CTAT circuit, with a negative temperature coefficient and a PTAT circuit with a positive temperature coefficient equal in magnitude to that of CTAT. As the V_T in the PTAT is a weak function of temperature compared to the CTAT, scaling of the PTAT circuit is necessitated to achieve a constant voltage.

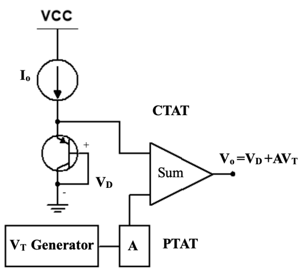

Fig. 1 Block Diagram of band-gap reference voltage circuit

III. IMPLEMENTATION

Two fundamental band-gap reference circuits have been presented:

a. Current Mirror based band-gap reference circuit:

$$V_{ref} = V_{EB3} + (R_2/R_1)V_T \ln(N) \quad [2]$$

b. Op-Amp based band-gap reference circuit:

$$V_{ref} = V_{EB1} + (V_{EB1} - V_{EB2})(R_2/R_1) \quad [1]$$

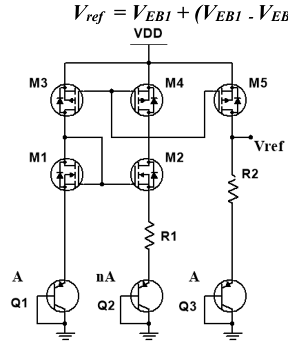

Fig. 2 Current Mirror based BGR

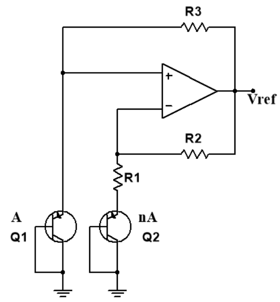

Fig. 3 Op-Amp based BGR

To improve the PSRR, making the BGR circuit (a) resilient to power supply variations a cascode current mirror can be implemented. Care should be taken to eliminate the effect of the output offset voltage in BGR circuit (b), as it varies with temperature, thereby introducing an error in V_{ref}. Due to transients in the supply, the BGR circuit could enter the zero current stable state, to disturb it from this state and for it to return to normal operation, a Start-up circuit needs to be incorporated in the design. Owing to non-linearities, a finite curvature is observed in V_{ref} with respect to temperature. As per the specification, N-well resistors are to be used in the BGR circuit, they have higher resistance per square, lower leakage currents, better substrate isolation; however, they have a positive temperature coefficient and large positive voltage coefficient.

IV. ISSUES & IMPROVEMENTS

Process and Mismatch variations cause a sizeable amount of variation in V_{ref}. Therefore, the layout and matching of BJTs and resistors should be done such that performance is not deteriorated. The effect of offset voltage of op-amp in the BGR can limited by employing auto-zero amplifiers which have ultra-low offset voltages. Due to the dependence of temperature of the resistor, it will cause a change in the output current's temperature dependence, thereby, changing the reference voltage.

V. CONCLUSION & FUTURE SCOPE

Hence, the significance, principle of generation of V_{ref}, and design of a BGR circuit was studied. Several architectures of the BGR circuit were studied for a potential design and implementation a circuit with better performance and least trade offs. There are several other circuits that were proposed to improve PSRR, temperature coefficient, temperature range, curvature compensation, etc.

VI. REFERENCES

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