Study of general purpose band-gap reference with N-well resistors

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***Abstract*—This paper is on study of Bandgap Reference Circuits (BGR) basics which involves circuits that shows temperature dependent output voltages. The BGR is an imperative circuit in today's modern VLSI chips. Various applications of BGR in other basic building blocks are discussed briefly.**

I. Introduction

ICs needs a constant reference voltage. The Bandgap Reference (BGR) is a circuit which provides a stable voltage output which is independent of factors like temperature, supply voltage. The idea to develop a constant reference voltage independent on mainly temperature is done by using two types of circuits which changes voltages/current (V/I) complementary to each other. The first type would be where the V/I varies proportionally to temperature or PTAT (Proportional To Absolute Temperature voltage). The second one where the V/I is inversely proportional to temperature or CTAT (complementary to absolute temperature voltage). So the final form of BGR will be addition of two circuits with addition to constant multipliers so that the net effect is a constant w.r.t temperature. Similarly we can eliminate the effect of supply voltage. While adding the CTAT and PTAT, the higher order terms are not compensated resulting in some curvature in actual practice.

II. CTAT and PTAT

A. CTAT

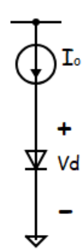

Fig. 1. Simple CTAT implementation

When a diode is operated at a constant current as in Fig. 1, the voltage across the diode is CTAT with a temperature coefficient of approximately -2 mV/K [1].

B. PTAT

When diodes are operated at same current as shown in Fig. 2, and the voltages V1 and V2 are made equal, the voltage developed across the resistor is a PTAT voltage which will be equal to $V_T \ln(N)$ [2]. This resistor used can be implemented using N-well resistor which is compatible with CMOS circuits and is preferred over other type of resistances in CMOS technology due to its high value for its voltage coefficient.

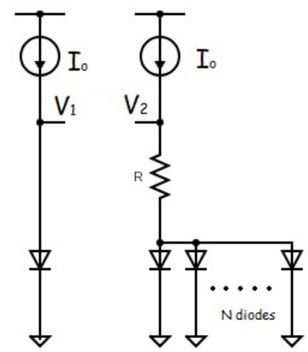

Fig. 2. Simple PTAT circuit

C. Bandgap Reference

In the summation of two circuits, we can choose the resistor values such that the first order effects of temperature gets cancelled out. The final output voltage will be about 1.2V-1.3V which is close to Silicon bandgap 1.22V at 0K [1]. Hence the name bandgap.

III. Applications in VLSI

Analog circuits use voltage and current references substantially. These references provide dc quantities which is made not to depend much on supply and process parameters with clear-cut dependence on temperature. We see some applications which deploy BGR.

A. Low drop out voltage regulators

Low drop out voltage regulators or LDO is essential component of on-chip power management systems to provide constant voltage supply rails, which can regulate voltage at the output even when supply voltage is very close to output voltage [5]. Recent LDOs have been developed for automotive, cellular phones, pagers, desk and lap tops, and medical applications, where the main unregulated supply voltage is very close to the regulated one. [6]

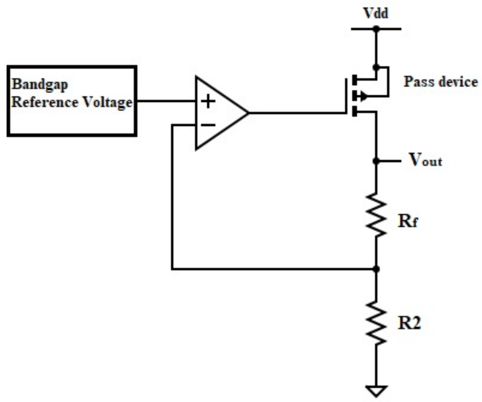

Fig. 3. Typical LDO

A typical LDO circuits consists of bandgap reference voltage, pass device ususally PMOS in CMOS implementation, error amplifier. The output voltage is sensed via series resistors and feedback to error amplifier which amplifies the error and controls the pass device to meet the needs of high current in output load device.

B. ADC

Analog to digital converters take input from outside environment using some built in embedded system which is analog in nature. This analog input is compared to different reference levels to determine the corresponding digital value. The precision of ADC depends on the number of valid input levels it can distinguish which is also given by the number of bits in digital format it gives output. If the output is of 12 bits which will translate to 2^{12} or 4096 levels. The conversions is done by successive approximation, dual slope converters etc where the analog input is compared to the reference voltage from BGR as shown in Fig. 4 [3]. The final output is reached by successive comparisons made by circuit inside ADC.

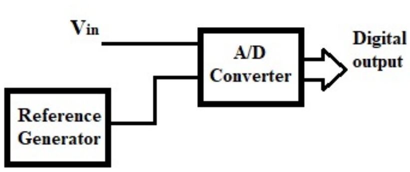

Fig. 4. A/D converter using reference generator

C. VCO

VCO or Voltage controlled oscillators take input as dc voltage and produce oscillations which is a function of input voltage. The same voltage input can be taken from the BGR circuit to make is temperature sensitive. One such implementation is shown in Fig. 5

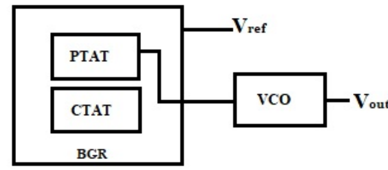

Fig. 5. Temperature sensed VCO and BGR

The PTAT circuit in BGR produce a voltage with a positive temperature coefficient, which is applied to VCO which makes it temperature sensing which can be applied to multivariate sensors, sensing overheated chip, and reference voltage to variety of low-power management systems. [4]

IV. Conclusion

The BGR concept is explained briefly. The various applications of BGR in VLSI domain is discussed. The BGR is thus of a paramount importance for a system on chip (SoC), which meets the need of various other functional components.

References

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