General Purpose Bandgap Implementation on Skywater's Open-Source 130nm Process Node

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Abstract—An example of a CMOS bandgap reference circuit implementation on Skywater's open-source process design kit (pdk) is proposed. A simple reference voltage source topology will be evaluated with a set of simulations and then implemented in open-source EDA tools. In the design, a current mirror without an operational amplifier will be used to keep the topology simple.

Index Terms—CMOS, voltage reference, bandgap.

1 Introduction

VOLTAGE reference circuit is one of the most important building blocks of mixed-signal systems and its output is used at different parts in the design, for example, in signal converters like ADC to avoid signal degradation. The bandgap voltage reference circuit (BGR) typically provides a stable and accurate output voltage that is insensitive to temperature, power supply, and production process variations [1] [2]. A bandgap voltage source outputs a voltage proportional to the bandgap voltage of semiconductor material. Although silicon based voltage references which outputs 1.2V are common, other semiconductor materials such as GaAs which outputs 1.42V can also be used [3].

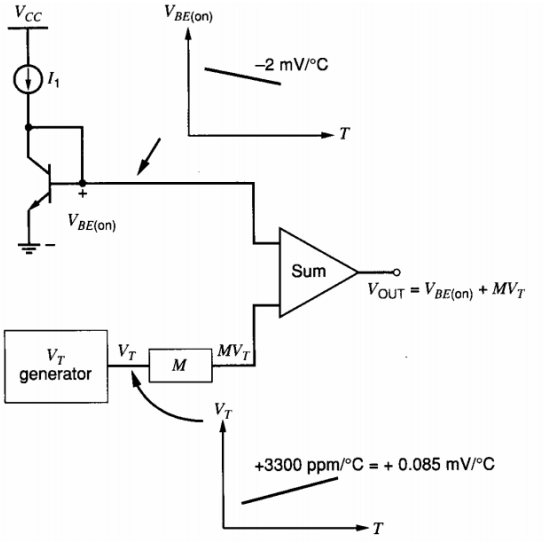

Fig. 1. Concept of bangap reference circuit [4].

1.1 Working Principle

A combination of outputs of the circuit elements that exhibit opposing temperature characteristics, namely PTAT and CTAT, is used to deliver a stable BGR output. Proportional to absolute temperature (PTAT) property refers to the devices that show increased current flow with increased temperature, whereas complementary to absolute temperature (CTAT) property refers to the devices that show decreased current flow with increased temperature.

A conceptual design in Figure 1 shows that the forward bias voltage of a PN junction which has a negative temperature coefficient is added to weighted thermal voltage V_T which has a positive temperature coefficient and has comparatively low dependency on the temperature. This addition cancels out temperature-dependent terms and provides stable reference output.

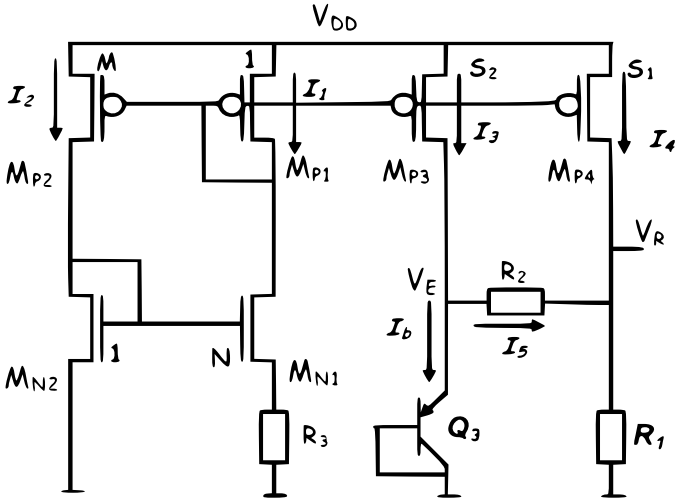

Fig. 2. Reference voltage source topology [5].

1.2 Reference Source Topology

A simple design in Figure 2 that provides satisfactory stability, power consumption and area is proposed in [5]. This design uses a current summation approach contrary to the traditional voltage summation approach used in bandgap voltage sources to provide a stable output voltage.

1.3 Next Steps

- Detailed analysis of reference topology according to the design specifications (analytical step)
- Check design implementation feasibility in Sky130 pdk
- Based on the analysis, addition of a start-up circuit to provide sufficient gate voltage and cascode transistors in the current mirror
- Simulate design in ngspice to verify circuit operation

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