Process Voltage Temperature Analysis of Bandgap Reference Circuit at 180nm

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Abstract- *Many applications in analog circuits require a stable current or voltage. Systems like A/D or D/A converters require a reference which defines the input or output full scale range and a reference circuit is very useful for such applications. A voltage reference is a circuit which is used to generate a fixed voltage reference that is independent of the temperature, power supply voltage and process variations. Also the term reference is used when the current or voltage value have more precision and stability than an ordinarily found in a source.*

The basic idea to implement a Bandgap Reference is to add a positive temperature coefficient voltage and a negative temperature coefficient voltage, and the output voltage can be made temperature independent by selecting proper value of two voltages. The output voltage of conventional voltage reference is 1.24 V which is nearby the same voltage as the bandgap of silicon.

Keywords- Bandgap reference voltage, current mirror circuit

I. INTRODUCTION

The Voltage reference circuits are usually used as a parts of analog to digital converters (ADCs) or digital to analog converters (DACs) to design the input voltage or output voltage ranges. The main goal of this design is to produce a fixed reference voltage V_{ref}. The V_{ref} shows a very small dependence on power supply voltage VDD, temperature and as well the process parameters for example different corners (slow-slow, fast-fast, typical, fast-slow and slow-fast). In this proposed design short-channel bandgap reference voltage was implemented with a power voltage supply VDD set to 1.8 V and a desired Vref kept at 500 mV. The circuitry of discussed design was divided into three vital components, a start–up circuit that allows avoiding the situation where zero current. A self-biased differential amplifier and finally a combination of PMOS, NMOS, BJTs and resistors that forced current in every branch to be equal, and made the Vref much less sensitive to changes in VDD and temperature. This last part of the circuit block was implemented by using two essential circuits. The first component was formed of two parasitic BJT diodes D1 and D2, whose temperature coefficient was determined through simulations, and pooled with a resistor R which will force Vref to be proportional to absolute temperature (PTAT). The second part was made of a pn junction diode determined through simulations and parameter calculations, and that will make V_{ref} to complementary to absolute temperature (CTAT). The combination of these two circuits yields an overall design which formed a Vref relatively independent of temperature (in a certain range), and voltage supply VDD depending on the process corners. Temperature was swept from -50˚C to 125˚C to observe temperature dependence of the bandgap reference voltage, while VDD was swept from 0V to 5 V to observe voltage supply dependence.

II. SYSTEM MODAL

II.I Voltage Reference

A voltage reference is a circuit used to generate a fixed voltage, V_{REF} that is independent of power supply voltage, temperature and process variation. A very simple voltage reference can be made from a voltage divider between the power supply and ground. Passive or active elements can be used as a divider element, but the problem with passive circuits is that their V_{REF} is directly proportional to power supply. Also, the resistance must be large in order to reduce the power dissipation (current through the resistor).The active elements have the advantage of smaller layout and less power dissipation.

II.II Temperature Independent References

In some cases we want to design a reference that varies with temperature. If the reference voltage, V_{REF}, increases with temperature, we say that the reference is proportional to absolute temperature or PTAT. If the reference voltage, V_{REF}, decreases with increasing temperature, the reference is said to be complementary to CTAT or absolute temperature.

In order to realize zero temperature coefficients we can add a CTAT (Complimentary to Absolute Temperature) & a PTAT (Proportional to Absolute Temperature) voltage mutually. Although the Bandgap reference that changes very slight with the temperature that can be implemented with a PTAT and a CTAT reference as shown in Figure II.I

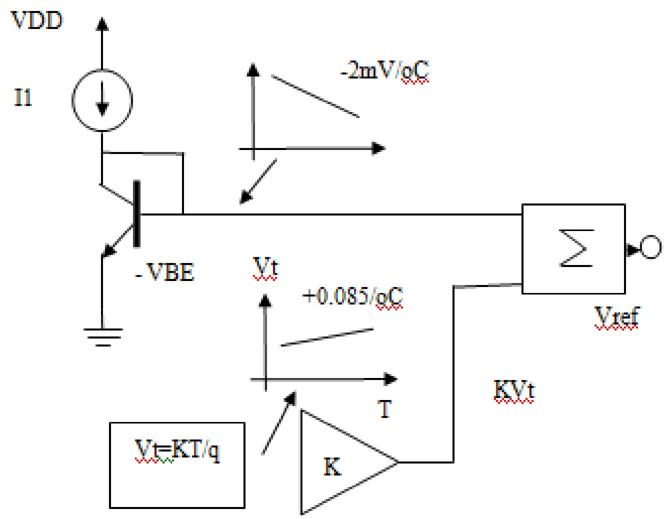

Figure II.I General Principal of Bandgap Reference

We know that f or a forward biased PN junction diode VBE is having negative temperature coefficient. In figure 2.1 voltage across the base emitter junction of a transistor will be decreasing with increasing temperature at a rate of -2mV/ºC and thus represents CTAT behavior, while a thermally generated voltage is having positive temperature coefficient in figure 2.1 V_T is the thermally generated voltage. V_T increases with temperature at a rate of +0.085mV/ºC. To obtain a zero TC voltage reference we can multiply PTAT voltage generator with a constant K and then add the two quantities as shown in figure 2.1 then we will get an output voltage which is independent of temperature variations and the magnitude of V_{REF} is equal to 1.25V which is nearby same voltage as the bandgap of silicon

III. PROPOSED DESIGN FOR BANDGAP REFERENCE

III.I Start-up Circuit

In every self biased reference there may be a problem of existence of degenerate bias point, in this case the operating point lies on zero current or we can say all the transistors carry zero current when supply is turned on, in this situation transistors may remain off indefinitely, this is called start-up problem. The start-up problem can be avoided by adding some mechanism that ensures that the circuit will not operate in degenerate region of operation, when supply is turned on.

III.II Bandgap Reference Design

We can design a bandgap reference with a PTAT and a CTAT references. We know that base to emitter voltage of a bipolar transistor shows CTAT behavior as temperature increases base emitter voltage decreases, so we can use a bipolar transistor as CTAT reference. As in PTAT current generation we have seen that two transistors will hold current of unlike densities then the difference of their base-emitter voltages is directly proportional to absolute temperature. PTAT concept can be implemented in the circuit shown in figure III.I here we are using thermal voltage referenced self biasing circuit. In this circuit voltage drop across Q1 must be equal to the drop across Q2 and the resistor R. To make equal voltage drop we can make Q2 larger than Q1 so that voltage drops across Q2 will be smaller for the same current through each branch. Alternatively we can increase the current flowing in left branch by making MOSFETs K times wider and keep the size of two transistors equal. The current flowing in left branch would be K times more than the current flowing in the right branch of the reference. The reference voltage is the sum of CTAT and PTAT voltage references

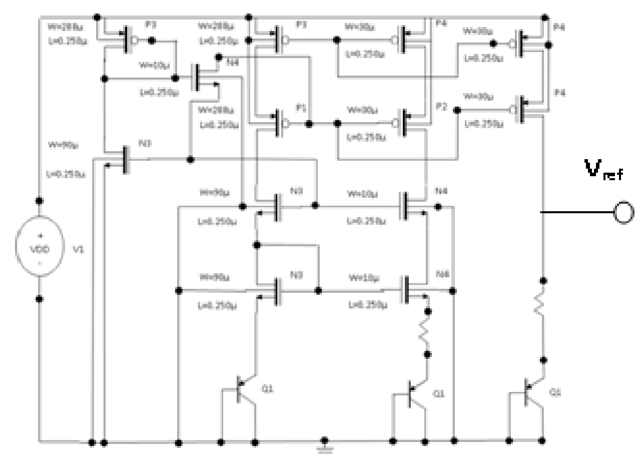

Figure III.I Bandgap voltage reference circuits

IV. SIMULATION RESULTS

To achieve desired results in bandgap reference circuit EDA Tool was required. Simulation is performed using Tanner EDA tool and 0.18µm technology. The results and waveforms for the bandgap reference circuit are as follows.

IV.I Output voltage variation (Vref) with supply voltage

For any bandgap reference circuit output voltage variation characteristic play very important role. Variation should be as low as possible for the entire range of supply voltage. In our design we provided variation in supply voltage and observed its effects on output voltage. From the result we come to know that bandgap reference voltage has been generated only when our supply voltage is more than 3.3V and the variation was also negligible in the range of supply voltage from 3.3V to 5V. The simulation result is shown in figure IV.I

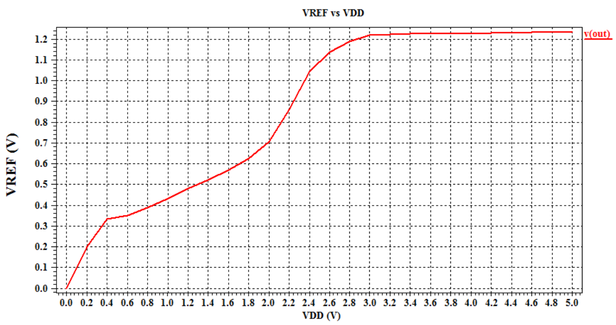

Figure IV.I Output voltage v/s Supply voltage curve

IV.II Reference Voltage (Vref) variation with temperature

As we have changed temperature from -40°C to +125°C the output voltage variation is obtained as 5 mV and the supply voltage provided is 5V figure IV.II shows this simulation result.

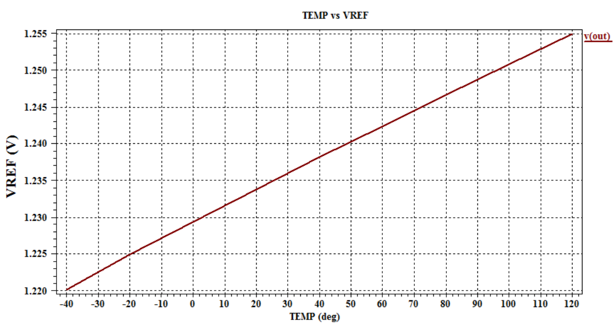

Figure IV.II Reference Voltage (Vref) variation v/s Temperature curve

V.III Reference Voltage (Vref) variation with temperature for different values of supply voltage

For different values of supply voltage if we vary temperature from -40°C to +125°C and observe the output voltage then we found that for supply voltage more than 3.5 volt the variation in output voltage is almost negligible, which gives us a very stable reference voltage. This result is shown in figure 4.3.

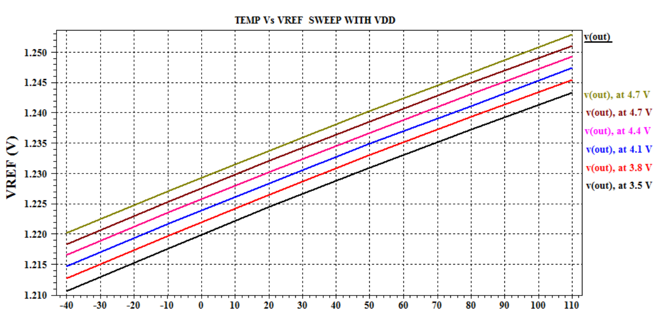

Figure IV.III Reference Voltage (Vref) variation v/s Temperatures for different values of Supply Voltage (Vdd) curve

V.IV Reference Voltage (Vref) variation with supply voltage for different values of temperature

For different values of temperature if we vary supply voltage and observe the output voltage then we found that for different temperature values the output voltage variation is as shown in figure IV.IV.

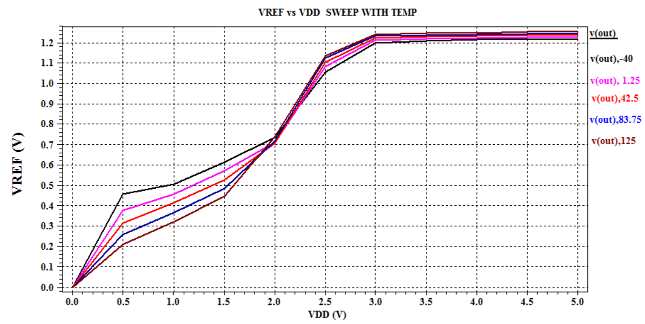

Figure IV.IV Reference Voltage (Vref) variation v/s Supply Voltage(Vdd) for different values of Temperature curve

V. CONCLUSION

To design a bandgap reference circuit our primary requirements was to obtain a reference voltage which is independent of temperature variation and supply voltage variation. Simulation results show that our output voltage is almost independent of temperature variation. The temperature coefficient is 10.8 ppm /°C is obtained in the range of temperature between -40°C to +150°C. The Supply independency has been achieved by the use of cascode current mirror circuit which increases our supply voltage requirement. The output voltage is immune to change in supply variation for supply voltage between 3.3V to 5V.

This voltage reference is based on bandgap reference technique so we require supply voltage greater than 1.25V. With the advancement of CMOS process reference voltage with low supply voltage is required. In future the supply voltage requirement can be reduced.

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