A Current-Controlled Oscillator with Temperature, Voltage and Process Compensation

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Abstract

This paper presents a current-controlled oscillator (CCO) circuit design with temperature, voltage and process compensation. The current reference biasing circuit was composed of complementary-to-absolute-temperature (CTAT) and a proportional-to-absolute-temperature (PTAT) to compensated temperature variation. And output current adjustment circuit is used to overcome process variation. The voltage variation is compensated by the connecting structure between current reference and oscillator. The CCO is fabricated in a 0.18-µm CMOS technology. The measured temperature variation coefficient is 48.8 ppm/°C across a temperature range of 0 °C to 100 °C, and voltage variation coefficient is 0.13% for a supply voltage range from 1.62V to 1.98V. Power consumption is 64µW.

Key words: compensation, PVT, current-controlled-oscillator

Introduction

The current reference is indispensable circuit in analog, digital and power electronic systems. Since it is easy to implement a voltage reference by bandgap circuit. The current references can be derived from voltage references by voltage to current conversion. However, the bipolar transistors most used to the bandgap circuits of current reference. This circuits may take more silicon area since it contains some bipolar transistors, operational amplifier, and resistors. These should be designed stable as possible, the current reference with temperature, supply voltage, and process variations immunity for proper operation. They are usually used to determine current reference of analog circuits, for example amplifiers, oscillators, phase-locked loops (PLLs). Many current reference circuits of the temperature, supply voltage and process Compensation have been designed for oscillators reference citcuits without bipolar transistors [1]-[6].

In this research work, we present a controlled system of current reference circuits. The proposed current reference consists of two components. The first circuit is a current reference generator circuit with temperature variation [7]. This current reference generator circuit could produce proportional-to-absolute-temperature (PTAT) current and complementary-to-absolute-temperature (CTAT) current. The second circuits used the PTAT current and CTAT current of current reference generator circuit to compensate each other such that it provides a current insensitive to temperature, supply voltage and process. We apply the proposed current reference circuit to the current-controlled oscillator (CCO) and make the CCO have low sensitivity to temperature, supply voltage and process variations.

In this paper, the proposed a circuit introduces all CMOS current reference utilizing MOS transistors operating in the sub- threshold region and the CCO is compensated by the current reference. The rest of this paper is organized as follows. Analysis for the proposed CMOS current reference circuit and CCO are both described in section II. Section III presents CCO simulation of temperature, supply voltage and process variation to assess the performance. Finally, conclusions are given in Section IV.

Current-Controlled Oscillator Architectures

In this section, the circuit architectures and operating principles of system architecture are analyzed and discussed. The Current-Controlled Oscillator (CCO) system block diagram is shown in Fig. 1. The block diagram included of reference current biasing, ring oscillator, and differential to single output buffer.

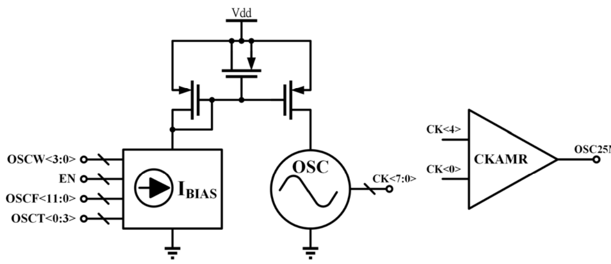

Fig. 1 Block diagram of the current-controlled oscillator

A. Reference Current Biasing

This current reference block diagram included of Current Generator, trimming current slope with temperature variation, trimming current slope with supply voltage variation, trimming current slope with process variation, and trimming output current for CCO frequency, shown in Fig. 2. The current generator circuit produced Proportional-to-Absolute-Temperature (PTAT) and Complementary-to-Absolute-Temperature (CTAT), shown in Fig. 3 [7]. The current reference used TRIM1 and TRIM2 to adjustment PTAT current and CTAT current. And the TRIM1 output current and TRIM2 output current were integrated into one current to TRIM3 circuit. The CCO current reference used the TRIM3 circuit to adjustment. The TRIM3 output current could adjustment the CCO output frequency.

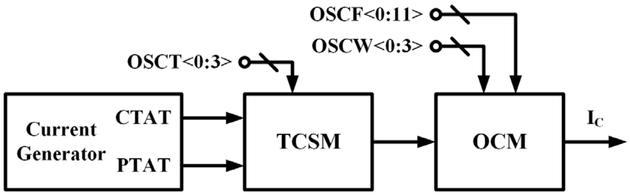

Fig. 2 Block diagram of the current reference

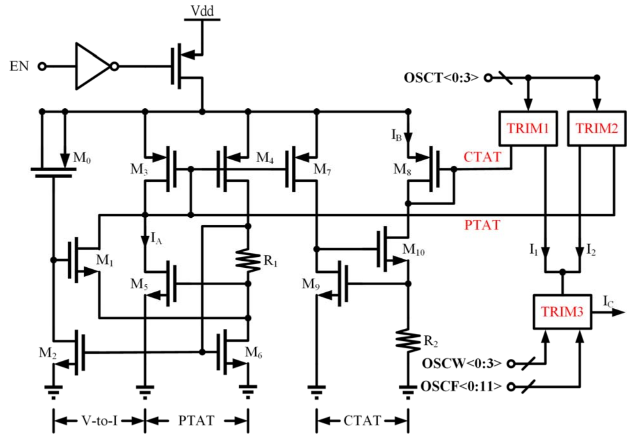

Fig. 3 Schematic of current reference

B. Ring Oscillator

The four-stage ring oscillator used the TRIM3 output current to controlled the output frequency, and the four-stage ring oscillator shown in Fig. 4. The Fig. 5 was the delay cell circuit of four-stage ring oscillator [5].

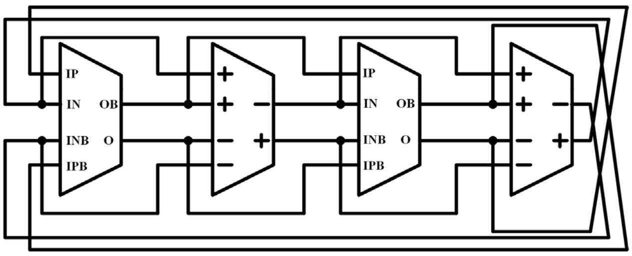

Fig. 4 Schematic of the four-stage ring oscillator

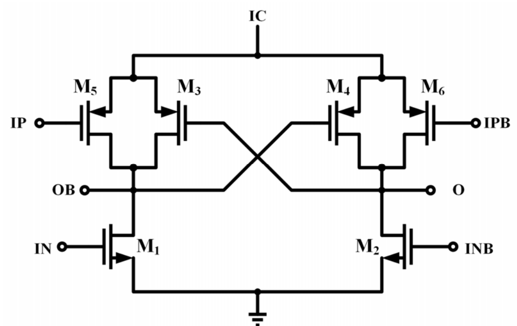

Fig. 5 Delay cell of ring oscillator

C. Differential to Single Output Buffer

The CCO output differential signal used the differential to single output buffer. The differential to single output buffer could let CCO output signal swing to full swing and adjustment the duty cycle to 50%.

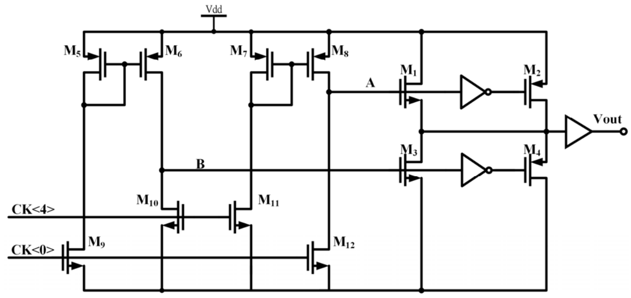

Fig. 6 Schematic of the differential to single output buffer

Simulation and Measurement Results

The CCO is fabricated in a standard 0.18-μm CMOS process. The simulation of frequency versus temperature variation is shown in Fig. 7. The simulation of temperature variation coefficient is 36 ppm/°C across a temperature range of 0 °C to 100 °C with process typical- typical (TT) corner. The simulation of frequency versus supply voltage variation is shown in Fig. 8. The voltage variation coefficient is 0.08% for a supply voltage range from 1.62V to 1.98V with process typical- typical (TT) corner. The total power consumption is 37.2μW.

Fig. 9 shows the die photo of the current-controlled oscillator. The total area of the proposed CCO is 356 μm × 200 μm. The measurement of frequency versus temperature variation is shown in Fig. 10. The simulation of temperature variation coefficient is 48.8 ppm/°C across a temperature range of 0 °C to 100 °C. The measurement of frequency versus supply voltage variation is shown in Fig. 11. The voltage variation coefficient is 0.13% for a supply voltage range from 1.62V to 1.98V. The total power consumption is 64μW. The performance summary and comparisons with other research works of the CCO are shown in TABLE 1.

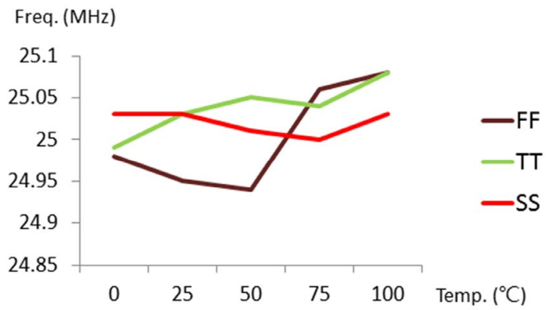

Fig. 7 The simulation of frequency versus temperature variation

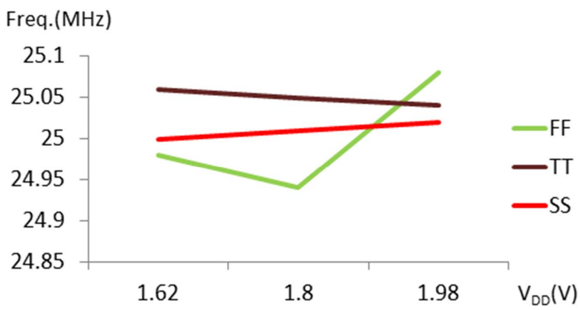

Fig. 8 The simulation of frequency versus supply voltage variation

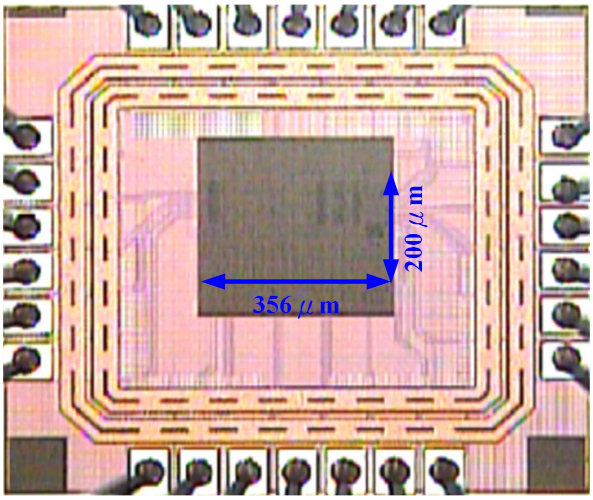

Fig. 9 The die photo of CCO

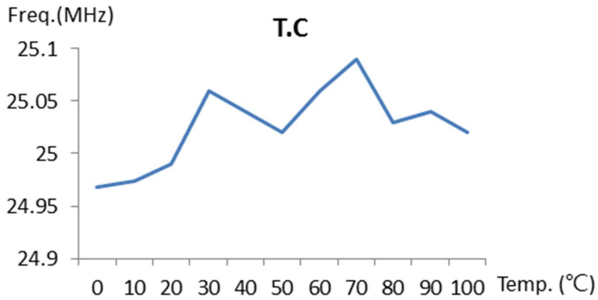

Fig. 10 The measurement of frequency versus temperature variation

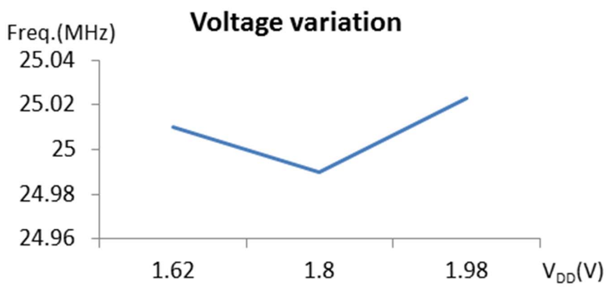

Fig. 11 The measurement of frequency versus supply voltages variation

TABLE I
Performance summary and comparisons

	[1]	This work
Technology (μm)	0.25	0.18
Supply Voltage(V)	2.4	1.8
Frequency(MHz)	7	24.99
Variation with temperature (ppm/℃)	1300	48.8
Temperature range(℃)	-40~125	0~100
Variation with supply voltage (%)	0.31	0.13
Supply voltage range (V)	2.4~2.75	1.62~1.98
Jitter (ps)	N/A	39.04
Duty cycle (%)	49.6	49.5
Power dissipation(μW)	1500	64

Conclusions

The current-controlled oscillator (CCO) circuit design with temperature, voltage and process compensation. The CCO controlled the current slope of current reference biasing to adjustment variation of temperature, voltage and process. The CCO is fabricated in a 0.18-μm CMOS technology. The measured temperature variation coefficient is 48.8 ppm/°C across a temperature range of 0 °C to 100 °C. The voltage variation coefficient is 0.13% for a supply voltage range from 1.62V to 1.98V. The total power consumption is 64μW.

Acknowledgement

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