



Smart Temperature Sensor Design Using Voltage Controlled Ring Oscillator

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ABSTRACT: Temperature is unique of the supreme significant important physical quantities and is almost common in our day-to-day life. With the scaling down of modern VLSI technologies, more complicate digital circuits have been implemented with a higher clock rate and lower supply voltage, which introduces more constraints for the analog circuits. Therefore, the design of low voltage, low-power analog circuitries has become more important. Because of powered by batteries, the supply voltage is often limited, and the life time of the battery is of great importance for these devices, and all these factors basically address the needs of low-power system building blocks. However, decreased supply voltage restricts signal swing in the circuits and brings difficulties for analog circuit design. In the low-voltage environments, transistor characteristics degrade and the some circuit techniques cannot be used longer thus the low-voltage design is different from the traditional circuit design technique. Ring Oscillator generates the clock signal which is proportional to change in the temperature. A current-starved inverter along with 4-digit adjustable inputs makes ring oscillator frequency-tenable. Voltage level shifter ensures that the counter counts number of its rising edge. The register saves counter output at the very positive edge of external clock. The main difference between two successive outputs of register indicates the temperature.

KEYWORDS: Temperature, VLSI, CMOS, Ring Oscillator

I. INTRODUCTION

Market trends today show devices becoming smaller, mobile, and more battery efficient. This was made possible by the shrinking die sizes and high frequencies achievable due to what we all know as scaling of the transistor. But scaling also means increased power densities that lead to unusual temperature gradients across the chip [2]. In certain areas of the chip high switching activity combined with fast speeds of processing can generate a localized high temperature area on the chip called a “hotspot”. Moreover, current power supply delivery networks, clock gating schemes and dynamic nature of circuits may cause these hotspots to change dynamically. This proves a significant threat to reliability and robustness of the product as well as increases the power consumption of the chip. Hence in addition to external cooling and heat sinks provided by the chip packaging, today there is a need for on-chip thermal monitoring and management of these localized hotspots through use of adaptive systems. All sensors feed information to core control logic which provides a temperature-reducing feedback to very heated circuits. It manipulates the circuit operations performed by parts of the chip; for example it reduces the number of execution operations and increases the number of stall, fetch or completion operations in the overheated part of the circuit and on the other hand increases the number of execution of computational operations in cooler part of the chip.

II. BASICS OF TEMPERATURE SENSOR

TEMPERATURE sensors are widely applied in measurement, instrumentation, and control systems. In many applications, it would be attractive to use the temperature sensors which generate a readily interpretable temperature reading in the digital format. Such “smart” temperature sensors combine a sensor and interface electronics on the single chip, and are preferably manufactured in a low-cost standard CMOS process [5]. Smart sensors are Micro-Electromechanical System (MEMs) devices that have more embedded features than ordinary sensors. They are smaller in size, cost effective and consume less power, and are aimed to detect and report information in unusual and extreme



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situations. Nevertheless, most of the temperature sensors applied nowadays are usually the conventional sensors, for example, the thermostats or the platinum resistors, that require the separate readout circuitry. The limited use of the smart sensors can also be attributed to restricted operating range (which is typically limited to military range from 55 C to 125 C). The information received from smart sensor is shared with an end user. One of the main properties of a smart sensor is sharing information among neighbours with overlapping sensing areas. Smart sensors with signal conditioning and embedded function are more adopted in the market. More importantly, they were relatively inaccurate as compared to the conventional sensors. Typical inaccuracy in mentioned temperature range is 2 C, while the inaccuracy which can be obtained with, such as, a class-A platinum resistor in which range is 0.5 C. The higher accuracy can be achieved by calibration at the multiple temperatures, but this could undo much of the cost advantage of the CMOS smart temperature sensors. Most of the CMOS smart temperature sensors are based on the temperature characteristics of parasitic bipolar transistors.

Generations of Smart Sensor

New type of sensors comes out when older types of sensors fail in unfavourable conditions like weather and temperature conditions. The strategy of implementing expert knowledge from previous technology to a framework of new architecture that supports smaller and smarter sensor was used. The intention is to enable sensor manufacturing to be more flexible and dynamically configurable. In recent years, the increase in the area of nanotechnology has produced interesting materials which provides more opportunity for the development of sensing transduction technology. Older generations of sensors are built on to produce improved performance and extension of its functional capabilities. The technology behind this improvement makes use of advanced calculation, algorithm and signal processing. Example of these includes characteristic functions, weight functions, and inferential calculation of soft sensors its own advanced self-adaptive method for frequency-to-digital conversion. The generation of smart sensor can be categorized into three generations.

First generation: The first generation can be classified according to its receptor. The sensor receptor is trapped in the base sensor. The electronics part of the sensor is usually fused with the transducer.

Second generation: This generation is based on the individuality of component making up the sensor. The electronic element and the sensor node of the sensor are separate in the sensor.

Third generation: In this generation, the electronic element and the sensing node of the sensors are fused together on a single chip, and are relatively small and portable.

III. TEMPERATURE SENSOR

Temperature is most-measured process variable in the industrial automation. The most commonly, temperature sensor was used to convert the temperature value to the electrical value. The temperature sensors are the key to read the temperatures correctly and to control the temperature in the industrial applications.

A large distinction can be made among the temperature sensor types. The sensors differ a lot in the properties such as temperature range, calibrating method, sensing element and contact-way. Temperature sensors consist of a sensing element enclosed in the housings of metal or plastic. With help of the conditioning circuits, sensor will reflect the change of the environmental temperature.

In the developed temperature functional module, we use LM34 series of the temperature sensors. The LM34 series are the precision integrated-circuit temperature sensors and its output voltage is linearly proportional to Fahrenheit temperature. LM34 thus has an advantage over the linear temperature sensors calibrated in the degrees Kelvin, as user is not required to subtract the large constant voltage by its output to obtain the convenient Fahrenheit scaling. LM34 does not need any external calibration or the trimming to provide the typical accuracies of the $\pm 1.2^\circ\text{F}$ at room temperature and $\pm 11.2^\circ\text{F}$ over the full -50 to $+300^\circ\text{F}$ temperature range. LM34 is rated to function over the -50° to $+300^\circ\text{F}$ temperature range.

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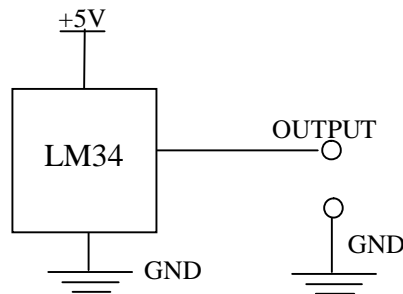


Figure 3.1: The Circuit diagram for LM34 temperature sensor functional module

It is easy to include LM34 series in the temperature measuring application. Output voltage of the LM34 is linearly proportional to Fahrenheit temperature, and it has the Linear $+10.0 \text{ mV}/^\circ\text{F}$ scale factor that means you will get $n \times 10.0 \text{ mV}$ output voltage if environment temperature is $n^\circ\text{F}$.

In the hermetic TO-46 transistor packages, the LM34 series is available packaged, while the LM34C, LM34CA and the LM34D are also available in plastic TO-92 transistor package. LM34D is also available in the 8-lead surface mount small outline package. Now, in our functional module, the LM34H in the metal can package (TO-46) was used in functional module so, it is very important to know that wiring of the sensor should be based on positions of leading pins in the different packages.

Temperature is one of the most important fundamental physical quantity that is a measure of hotness and coldness on a numerical scale. Temperature sensors are widely used in measurement, instrumentation, and control systems. In many applications, it would be attractive to use the temperature sensors which produce readily interpretable temperature reading in the digital format. Such “smart” temperature sensors combine a sensor and interface electronics on the single chip, and are preferably manufactured in a low-cost standard CMOS process. Temperature sensor consist ring oscillator, transmission gate and pulse counter circuit [3]. Pulse counter circuit is designed using d flip flop. The oscillation period ($1/f$) is converted in to a number of oscillations by applying enable signal of fixed pulse width (PW), and the number of oscillations is stored in the counter to produce the digital output.

IV. DESIGN OF TEMPERATURE SENSOR

4.1. Voltage Controlled Ring Oscillator

The voltage controlled ring oscillator [1] is used to generate a signal of specific frequency. This VCO is designed using self-bias differential ring oscillator as shown in figure 4.1. A ring oscillator device is composed of odd number of NOT gates and whose output is oscillates between the two voltage levels, representing logic ‘1’ and logic ‘0’.

In this figure 4.1, the MOSFETs M7 and M13 operate as inverter while MOSFETs M2 and M18 operate as current sources. The current sources are used to limit the current available to the inverter or it can be said that the inverter is starved for the current. So this type of oscillator is called current starved voltage controlled oscillator. Here the drain currents of MOSFETs M1 and M12 are the same and are set by the input control voltage. The other transistors are added just to form the 5-stages of ring oscillator because the 5-stage ring oscillator gives better VCO characteristic and frequency range.

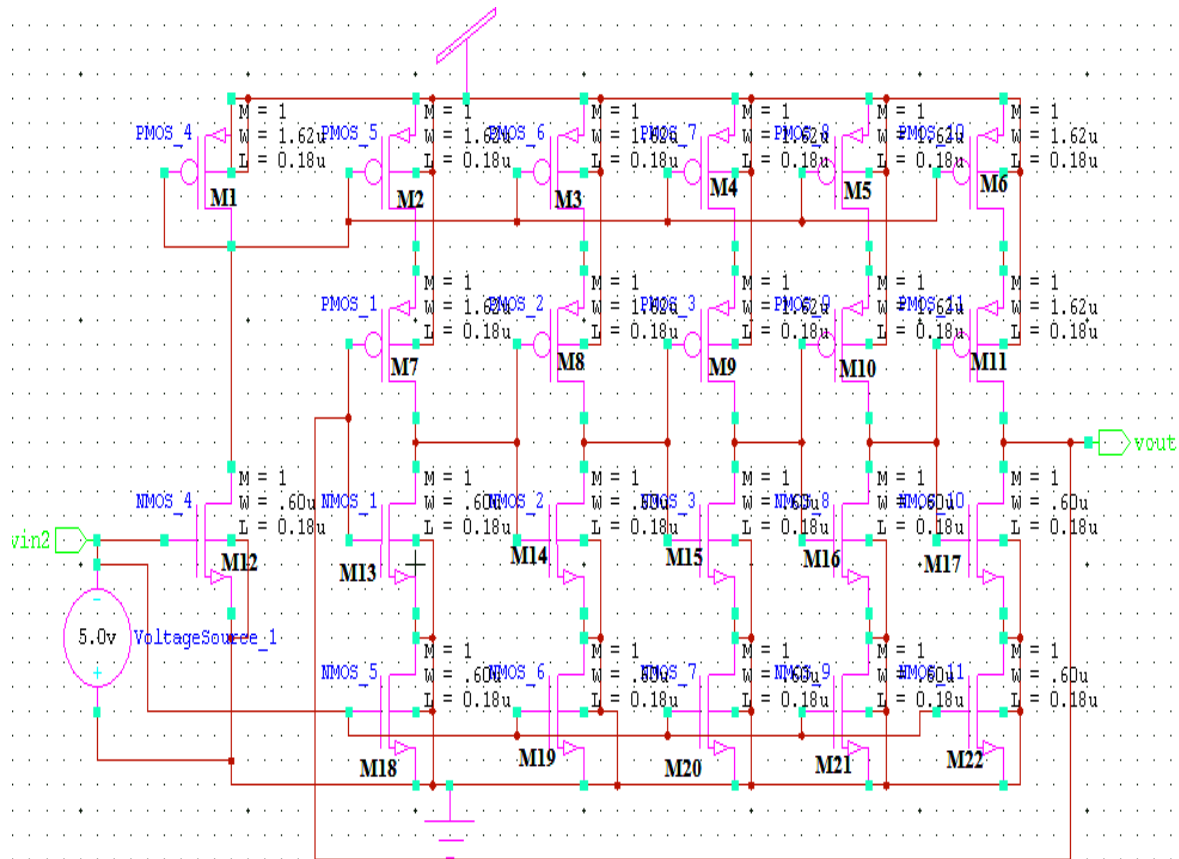


Fig 4.1: Voltage Controlled Ring Oscillator

This VCO characteristic also depends on the width and length parameters. So the width and length of each MOSFET is chosen very carefully according to the used technology. Length and width of MOS transistor is set according to technology [6].

4.2. Temperature Sensor

The complete diagram of temperature sensor contains two temperature sensor component, level shifter, two buffers, two comparator circuit, three XOR gate and one AND gate. Temperature sensor component is used to take readings simultaneously at given temperature readings V_{KT} and operating voltage (V_{OP}) of system. These readings ($T_{KT,t}$ and $V_{OP,t}$) is taken at time t . Low-voltage up level shifters convert the lower voltage, taken from output of temperature sensor component 1 to higher voltage. Comparator compares each temperature reading with previous temperature reading to produce output. Previous temperature readings are stored in buffer circuit. The two comparator outputs are then passed into an XOR gate circuit, which determines if the temperature (V_{KT}) sense by temperature sensor component 1, depends at operating voltage V_{OP} (same as V_{OP}) of temperature sensor component 2 or not. If both V_{KT} and V_{OP} are same then XOR gate gives logic zero output and if different then gives logic '1' output. Circuit diagram of temperature sensor is shown in fig 4.2.

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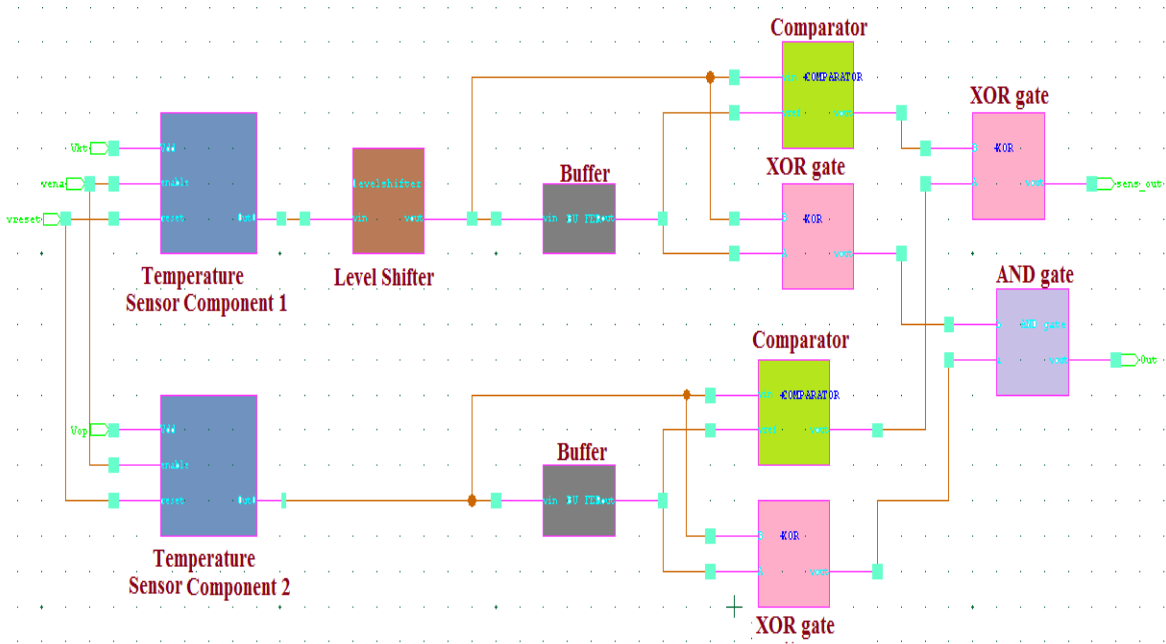


Fig 4.2: Temperature Sensor

V. RESULT AND ANALYSIS

Simulation result and analysis of individual component used to design temperature sensor is discussed below. Temperature sensor is designed using 180nm TSMC technology. Simulated waveform of temperature sensor component is shown in fig 5.1. Here input V_{KT} is the temperature reading of temperature sensor component 1, V_{OP} is the operating voltage of temperature sensor component 2 and sensor out is the output of temperature sensor.

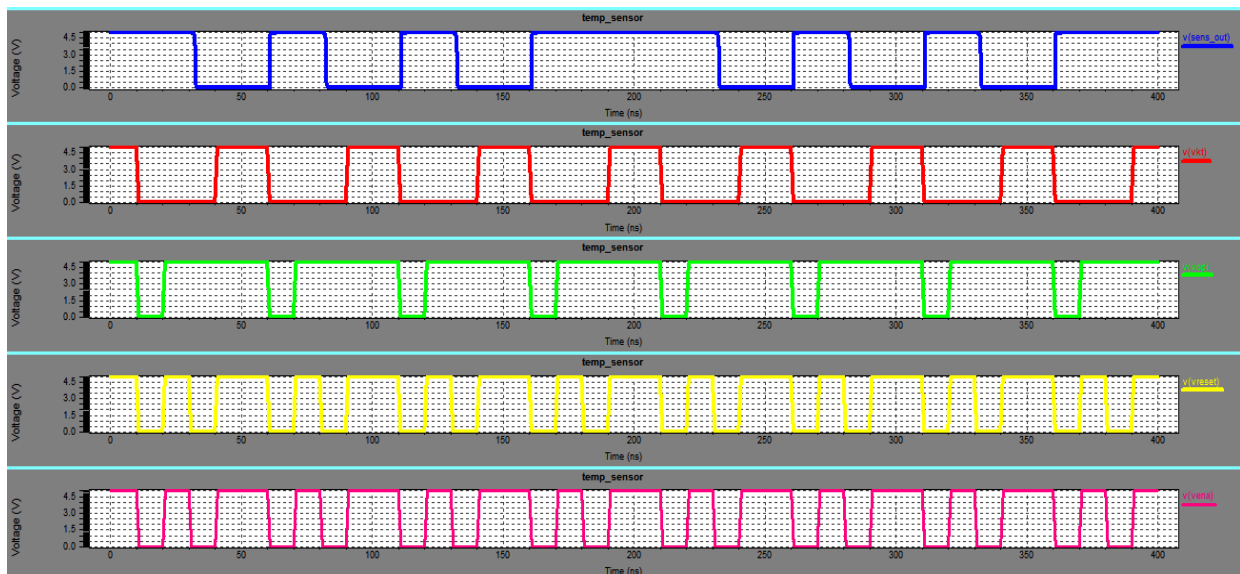


Fig 5.1: Waveform of Temperature sensor



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VI. CONCLUSION

A voltage controlled ring oscillator-based CMOS temperature sensor has been designed at 180 nm CMOS TSMC technology in Tanner Tool 13.1. The proposed temperature sensor occupies smaller silicon area with higher resolution than the conventional temperature sensor based on band gap reference. The characteristic of VCRO is drawn between its control voltage and frequency. The frequency range of VCO is calculated as 185 MHz to 810 MHz by its characteristic, with free running frequency of 93 MHz. Power dissipation of Voltage controlled ring oscillator at 1.8V power supply is 438.91 μ W.

REFERENCES

- [1] Shruti Suman, Prof. B.P. Singh, "Ring Oscillator Based Cmos Temperature Sensor Design", International Journal of Scientific & Technology, ISSN 2277-8616, Volume 1, Issue 4, May 2012.
- [2] David Wolpert, And Paul Ampadu, "Exploiting Programmable Temperature Compensation Devices To Manage Temperature-Induced Delay Uncertainty", IEEE Transactions On Circuits And Systems—I Regular Papers, Vol. 59, No. 4, April 2012.
- [3] Sunghyun Park, Changwook Min and Seong Hwan Cho, "A 95nW Ring Oscillator-based Temperature Sensor for RFID Tags in 0.13 μ m CMOS", IEEE International Symposium on Circuits and Systems, 2009.
- [4] Poorvi Jain and Pramod Kumar Jain, "Design and Implementation of CMOS Temperature Sensor", International Journal of Current Engineering and Technology, Vol.4, No.2 (April 2014).
- [5] Eran Socher, Salomon Michel Beer, and Yael Nemirovsky, "Temperature Sensitivity of SOI-CMOS Transistors for Use in Uncooled Thermal Sensing", IEEE Transactions on Electron Devices, Vol. 52, No. 12, December 2005.
- [6] Xuan Zhang and Alyssa B. Apsel, "A Low-Power, Process-and-Temperature-Compensated Ring Oscillator with Addition-Based Current Source", IEEE Transactions on Circuits and Systems, 2010.