



# **Design and Analysis of Low Power Temperature Sensor using Static Latch D Flip-Flop**

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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 and which is autonomous of the amount of material that means temperature have the intensive property. This dissertation shows a CMOS temperature sensor which is designed using self-bias differential voltage controlled ring oscillator at 180 nm TSMC CMOS technology to achieve low jitter operation. In this paper focuses on simulation, design and performance analysis for temperature sensor and its different components. The VCRO has limit with maximum voltage controllability along with a wide tuning range from 185 MHz to 810 MHz, and 93 MHz (free running frequency). The Power dissipation of Voltage controlled ring oscillator with power supply 313.91 $\mu$ W at 1.8V.

## **I.INTRODUCTION**

Through the scaling down of present VLSI technologies, and it makes difficult to digital circuits have been implemented with lower supply voltage and a clock rate that introduces more constraints to analog circuits for this design of minimum voltage, analog circuitry with low-power has become important that the supply voltage is limited because of powered by batteries, the life moment of the battery is of great significance for the devices, factors address the necessities of low-power system building blocks and decrement in supply voltage restricts the signal swing in circuits and brings difficulties for analog circuit design. In a low-voltage environment, the transistor characteristics degrade and some circuit techniques can no longer be used, therefore the low-voltage is unlike from the traditional circuit design system.

## **II.BASICS OF TEMPERATURE SENSOR**

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 situations.

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 over lapping sensing areas. Smart sensors with signal conditioning and embedded function are more adopted in the market.

### **Types of smart sensor**

There are different types of smart sensors used in many fields of the industry like, biomedical application, control systems, security systems etc. These Microsystems combine sensing, accuracy and signal processing in a microscopic scale. Examples of smart sensors include [X]

- Temperature sensors
- Pressure sensors
- Accelerometer sensors
- Optical sensors

### **Temperature sensor**

Temperature is one of the most significant physical quantity that is a use to determine hotness n coldness on a numerical scale. Temperature sensors are widely used in measurement, instrumentation, and control systems. In many

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applications, it would be striking to use temperature sensors that produce a ready interpretable temperature reading in a digital format. Such “smart” temperature sensors combine a sensor and interface electronics on a single chip, and are preferably manufactured in a low-cost standard CMOS process.

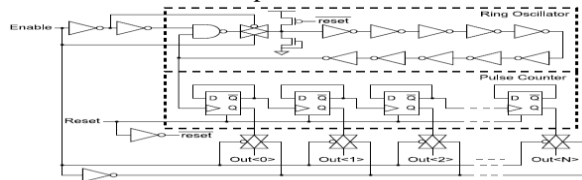


Fig : Schematic of temperature sensor component

The reset circuit is used to ensure that the oscillator is in the correct state when re-enabled for the next sample. It also reduces short circuit power dissipation resulting from the floating output node of the transmission gate. Complete circuit for temperature sensor shown below in fig . In this two temperature

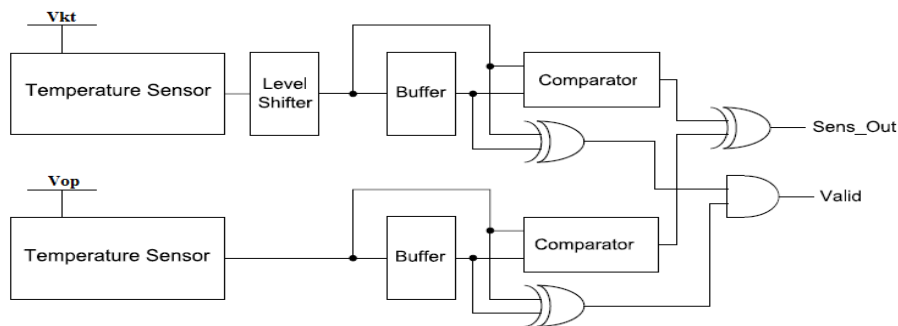


Fig : Complete circuit of Temperature Sensor

sensors component are used which simultaneously take readings at the chosen  $V_{KT}$  and the operating voltage of the system  $V_{OP}$  (these temperature readings are referred to as  $T_{KT,t}$  and  $T_{OP,t}$ , respectively). Low-voltage level shifters are used to convert the lower voltage output to the higher voltage to perform comparison. Each reading is compared with its previous reading sample,  $T_{KT,t-1}$  and  $T_{OP,t-1}$ , stored in buffers. The comparators circuits are used for comparison. The comparator outputs are then passed into an XOR gate, which determines if the temperature at VOP is the known or if it is the opposite.

## Temperature Sensor component

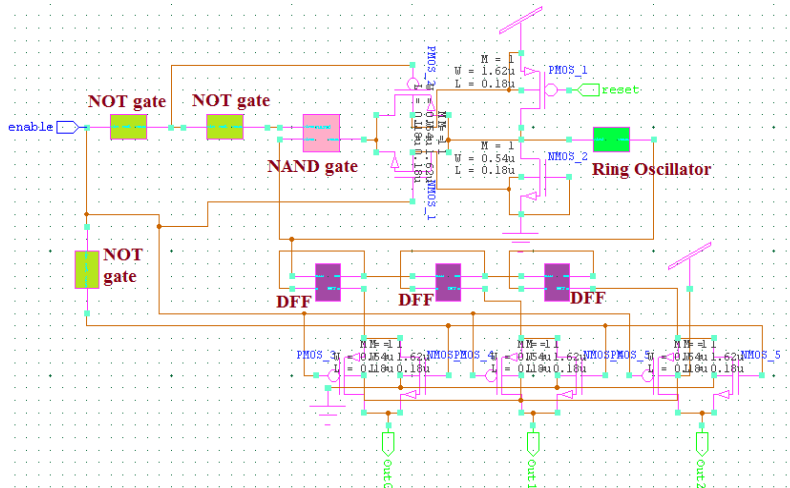
The temperature sensor component is shown in fig . It consists of ring oscillator and a pulse counter circuit. Oscillation period ( $1/f$ ) of voltage controlled ring counter is converted to a number of oscillations by applying enable signal of fixed pulse width, and the number of oscillations is stored in the counter to produce the digital output. Additional circuitry between enable input and the ring oscillator is used to remove synchronization problem, and the sensor outputs are connected to transmission gates to avoid unnecessary toggling. The reason of synchronization problem is the oscillator frequency which is temperature-dependent.

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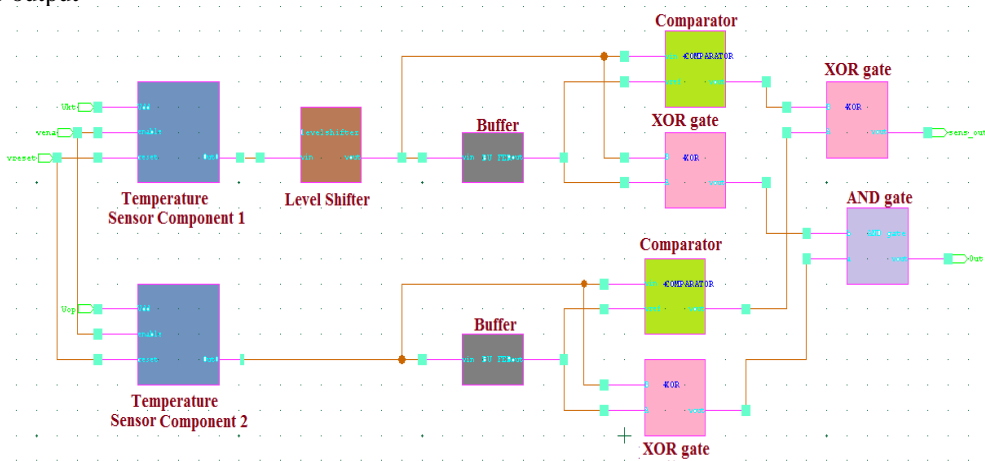
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**Fig : Temperature Sensor component**

## Temperature Sensor

The complete diagram of temperature sensor contains two temperature sensor component, level shifter, 2 buffers, 2 comparator circuit, three XOR gate, one AND gate. Temperature sensor component is used to take readings simultaneously at given temperature readings VKT and operating voltage (VOP) of system. The readings (TKT, t and VOP, t) is taken at time t. Low-voltage up level shifter 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



**Fig: Temperature Sensor**

## III.RESULT AND ANALYSIS

Simulation result and analysis of individual component used to design temperature sensor is discussed below. Temperature sensor is designed by means of 180nm TSMC technology.

### Temperature Sensor Component

Voltage controlled ring oscillator (VCRO) sense the temperature and give output, which is then passed to register where reset signal is used to reset data of VCRO and register. When clock signal (clk) input of register becomes logic '1' then data stored in register passes to output through transmission gate. Here temperature sensor component contains 3-bit register. Simulated waveform of temperature sensor component is shown in fig 5.14.

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**Fig 5.14: Waveform of Temperature sensor component**

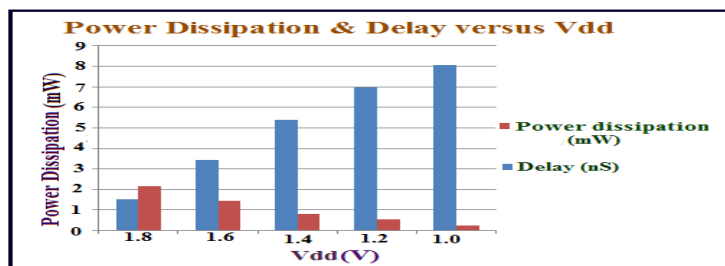
Delay and power dissipation of temperature sensor component is given in table 5.6.

Table 5.6: Delay & Power Dissipation at different  $V_{DD}$  of Temperature sensor Component

Vdd(V)	Delay (nS)	Power Dissipation (mW)
1.8	1.528	2.1465
1.6	3.442	1.437
1.4	5.379	0.810
1.2	6.962	0.548
1.0	8.047	0.263

At 1.8 V

power supply delay and power dissipation of temperature sensor component is also calculated at different temperature and different threshold voltage  $V_{TH}$ , shown in table .



**Fig : Power Dissipation and Delay versus  $V_{DD}$**

Table : Delay & Power Dissipation of Temperature sensor Component at different Temperature

Temperature (°C)	Delay (nS)	Power Dissipation (mW)
-27	0.0	1.560
27	1.028	1.146
37	0.553	1.036
47	0.307	0.954
57	0.101	0.697

Simulated waveform of temperature sensor component which is used for calculation of average power dissipation of circuit is shown in fig 5.16. Formula for average power dissipation is

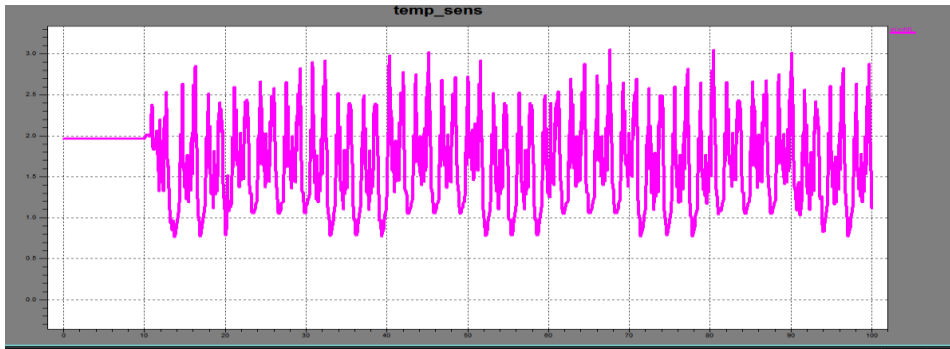
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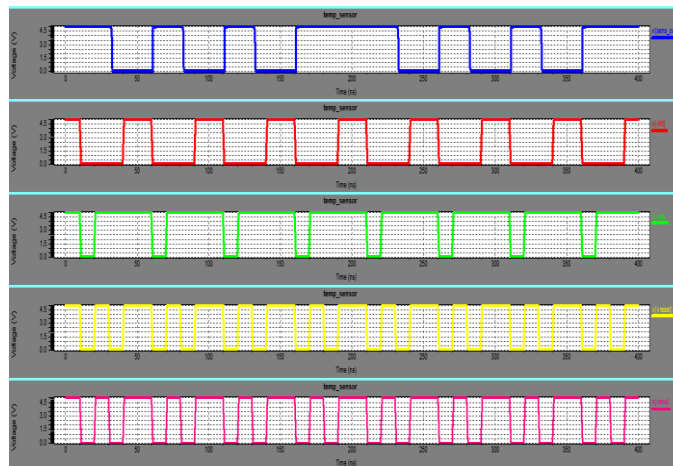
$$\text{Average Power Dissipation} = \frac{P_{\max} + P_{\min}}{2}$$



**Fig Waveform of power dissipation of Temperature sensor component**

## Temperature Sensor

Simulated waveform of temperature sensor component is shown in fig 5.17. Here input  $V_{KT}$  is the temperature reading of temperature sensor component 1 where  $V_{OP}$  is the operating voltage of temperature sensor component 2 and  $sens\_out$  is the output of temperature sensor. When temperature reading  $V_{KT}$  sense by temperature sensor component 1 is different with operating voltage ( $V_{OP}$ ) of temperature sensor component 2, output is logic high otherwise logic low as shown in fig . Delay and power dissipation of temperature sensor component is calculated at by varying various parameters like power supply voltage temperature, threshold voltage and as shown in table .



**Fig Waveform of Temperature sensor**

Table : Delay and Power Dissipation of Temperature sensor at different  $V_{DD}$

$V_{DD}$ (V)	Delay (nS)	Power Dissipation (mW)
5	4.656	76.88
4	5.454	25.1
3	6.717	03.47
2	8.967	0.58

At constant 5V power supply voltage delay and power dissipation at different temperature and threshold voltage ( $V_{TH}$ ) is also calculated which is listed below in table



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Table Delay and Power Dissipation of Temperature sensor at different Temperature

Temperature (°C)	Delay (nS)	Power Dissipation (mW)
27	5.656	70.88
37	4.923	80.235
47	3.357	89.56
57	2.514	98.35

## IV.CONCLUSION

A voltage controlled ring oscillator-based CMOS temperature sensor has been designed at 180 nm CMOS TSMC technology in Tanner Tool 13.1. smaller silicon area occupies by the proposed temperature sensor with higher resolution than the conventional temperature sensor based on band gap . The characteristic of VCRO is drawn between its control voltage and frequency. The frequency range of VCRO is calculated as 185 MHz to 810 MHz by its characteristic, with frequency of 93 MHz. Power dissipation of Voltage controlled ring oscillator at 1.8 V power is 313.91 $\mu$ W.

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