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**RESEARCH ARTICLE**

# DESIGN OF A LOW POWER FLASH ADC USING THRESHOLD INVERTER QUANTIZATION TECHNIQUE IN 90NM TECHNOLOGY

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**ABSTRACT**

All the signals are analog in nature. An analog to digital converter plays an important and essential role for system-on-chip (SOC) applications because it bridges the gap between the analog physical world and the digital logical world. Now a days low power and low voltage requirements becoming more important issues as the channel length of the MOSFET shrinks so below levels. For improvement of power and speed in an analog to digital converter major building block is a comparator. This paper presents a design of 4-bit low power flash ADC for system-on-chip applications using Threshold Inverter Quantization (TIQ) comparators. The technique threshold inverter quantization uses two cascaded CMOS inverters as a comparator, that eliminates the requirement of resister or capacitor ladder circuit. Threshold inverter quantization provides high speed, low power, and smaller area. TIQ also eliminates the requirement of high gain differential input voltage comparator that are inherently more compound and slower than digital inverters. TIQ based flash ADC also eliminates the need of reference voltages, which require a resister ladder circuit. In the TIQ based flash ADC the reference voltage is internally generated by the circuit that is threshold voltage is used as a reference voltage for comparing the input voltage and produce the thermometer code. An efficient thermometer to binary converter has been designed using transmission gate based on 2*1 multiplexer. Power consumption reduced as per accordance to threshold voltage and for high speed transistor size must kept small. The TIQ based flash ADC requires $2^n$-1 comparators, where n is the number of bits or resolution. To reduce the power consumption of the design, the threshold voltage should not be deviated too much and keep $W_P/W_n < 1$ to reduce power consumption and paracitic capacitance.



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## INTRODUCTION

Analog to digital converter plays important role in design of mixed signal, system on chip and signal processing applications. There are various types of ADCs. Depending on ADC's speed ADC's are classified in three categories; (Shailendra Prakash and Vishal Ramola, 2017). Low speed serial ADC, (Ranam Sireesha and Abhishek Kumar, 2015). Medium speed ADC, and (Pradeep Kumar, 2011). High speed ADC. The serial ADC operates at lower conversion speed but having high resolution. High speed ADC operates at high speed. Now depending upon various topologies the ADCs are classified as; (Shailendra Prakash and Vishal Ramola, 2017). Flash ADC (Ranam Sireesha and Abhishek Kumar, 2015). Sigma delta ADC (Pradeep Kumar, Amit Kolhe, 2011).

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Successive approximation ADC. The speed of ADC is affected by the solid state technology used to implement the converter. There are three types of solid state technologies available for high speed ADC implementation; CMOS technology, the bipolar technology, and the gallium arsenide (GaAs) technology. The CMOS technology allows a high density of logic functions on a chip and also CMOS technology is used technology is widely used technology to be implemented in VLSI. The GaAs technology is fastest of the three technology and the CMOS technology is the slowest of three technology. The ultrafast ADCs are implemented with Flash type using GaAs technology, but the GaAs technology is not compatible with Si CMOS technology, by which it is difficult to realize the SOC Applications. The bipolar technology allows faster operation and it is compatible with CMOS technology but it needed more processing steps and higher cost than the standard CMOS technology. Due to all these reasons here a new technique i.e. TIQ comparator is introduced here which provide higher speed and compatible with current CMOS technology. The main advantage of TIQ techniques is it has simpler speed and eliminates the resister ladder circuit requirement as in conventional ADC which increases its speed and decreases area.

## Flash ADC

The Flash ADC is known as fastest ADC among all the ADC. IT is also known as parallel type ADC because of its parallel architecture. It converts data parallely simultaneously so it has high speed of conversion. The flash ADC comprises of two basic building blocks i.e. comparator and encoder. Comparator block compares the input voltage with reference voltage and generates thermometer code. The encoder block converts the thermometer code into digital output values. The flash ADC requires $2^n$-1 different size comparators for generation of thermocode. Here ‘n’ is the number of bits or resolution. The size of transistor is varied as length or width of transistor is change. One of the most important feature of flash ADC is high power consumption and large chip area. The power dissipation increases with the speed and resolution i.e. higher power is consumed at higher speeds. But it is desirable that to design high speed ADC with less power dissipation.

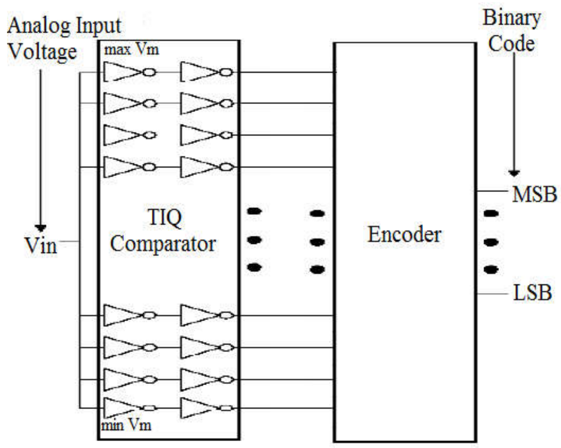


**Fig. 1. Block Diagram of TIQ Flash ADC**

## TIQ Comparator

A comparator is the heart of an ADC circuit. The main work of a comparator is to compare input voltage with reference voltage and generate thermocode. The TIQ comparator is basic CMOS inverter which comprises of two inverter stage, in which first stage works as a comparator and the second inverter stage works as gain booster, which increases the voltage gain of comparator and manages the propagation delay in balance. The second stage is exactly same as first stage to maintain the same DC threshold level and to keep the linearity in balance for voltage variations of high frequency inputs. A TIQ comparator is different from differential comparator only due to its reference voltage. The differential comparator utilizes the external reference voltage ‘$V_r$’ using resistor ladder circuit, however the TIQ comparator sets reference voltage internally on the basis of transistor size.

## TIQ based flash ADC

A conventional ADC consists of $2^n$ resisters in series to generate the reference voltage which requires large chip area and high power consumption. But the TIQ based flash ADC generates reference voltage internally i.e. chip area reduced and also it require low power consumption.

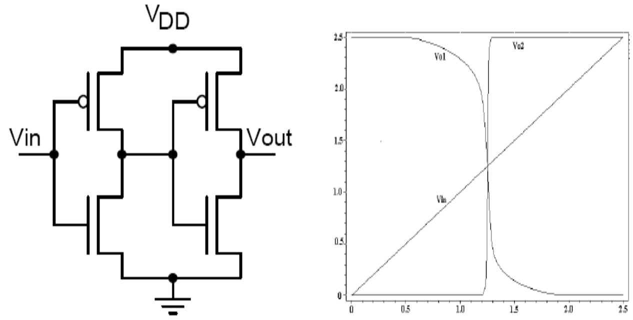


**Fig. 2. TIQ Schematic & VTC**

In the TIQ based ADC all the comparators are of different size where as in conventional ADC all the comparators are of identical size. Advantages of TIQ based flash ADC are;

- Simple comparator design.
- No need of external reference voltage.
- Faster voltage comparison speed.
- Does not require switches, clock signals or coupling capacitors for the voltage comparison.
- No need of resister ladder circuit.
- Suitable for system-on-chip applications.
- Suitable for CMOS technology.

## Encoder

An encoder is a device that converts information from one format to another for purpose of standardization, speed or compressions. A simple encoder assigns a binary code to an active input line. For an ADC an encoder is a circuit that converts the thermometer code into the binary code. Thermometer to binary encoder can be implemented by various approaches e.g. Fat tree, ROM type, logic based, multiplexer based. Among various types of encoders multiplexer based encoder requires less hardware and shorter critical path. A multiplexer is the circuit that gives single output as per accordance to multiple inputs. Here the 2*1 multiplexer based encoder is used. The multiplexers used are designed using transmission gates for better accuracy. A 2*1 multiplexer is the circuit which having 2 input lines and one output line with single select line.

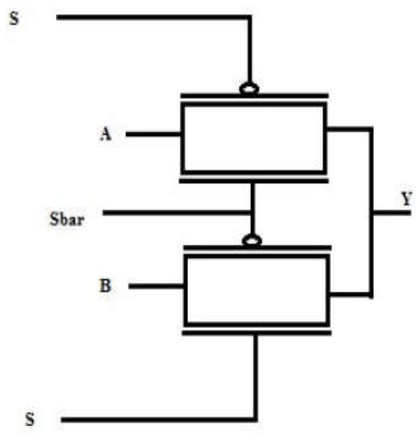


**Fig. 3. Multiplexer Schematic**

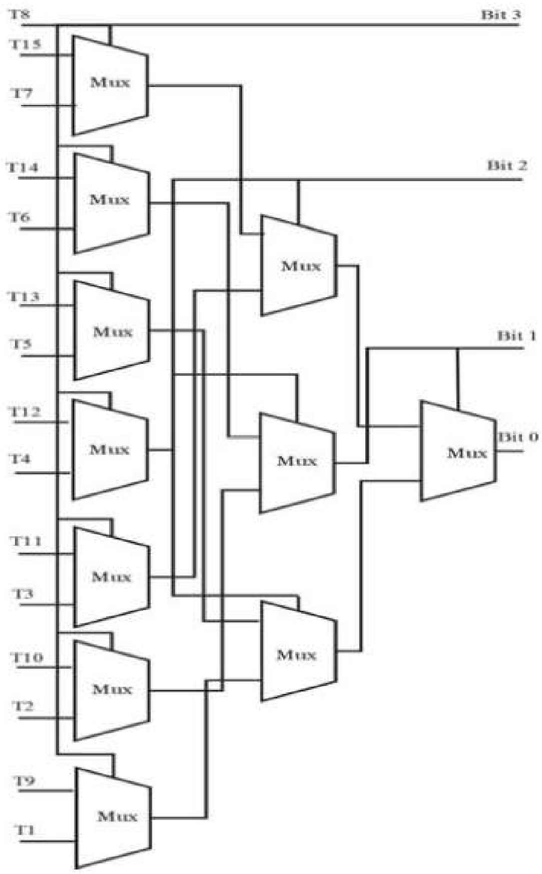


Fig. 4. 2*1 Multiplexer Based Encoder

## Proposed Work

In our work we are designing a low power Analog to Digital converter which operates at low voltage. The implementation is carried out on Symica DE tool. The process technology used is 90nm. For n-bit Flash ADC,$2^n$-1 comparators are required. Here 04-bit ADC is designed for which 15-comparators are designed. In this design we take constant n-mos length-width and constant p-mos length, with varying the width of p-mos to calculate the switching voltage and can be mathematically calculated as;

$$V_m = \frac{\left( \left( V_{dd} - \left| V_{tp} \right| + V_{tn} \right) \sqrt{\frac{K_p}{K_n}} \right)}{\left( 1 + \sqrt{\frac{K_p}{K_n}} \right)} \qquad \text{............(01)}$$

Where; $V_{dd}$ = supply voltage.
$V_{tp}$ = pmos threshold voltage.
$V_{tn}$ = nmos threshold voltage.
$K_p = (W/L)_p \cdot \mu_p \cdot Cox$.
$K_n = (W/L)_n \cdot \mu_n \cdot Cox$.
$\mu_p$ = mobility of holes.
$\mu_n$ = mobility of electrons.
$W_p$ = width of pmos.
$W_n$ = width of nmos.
Cox = gate oxide thickness.

Switching voltage is calculated by equation (01) with varying pmos width and maintaining transistor length. All the calculated switching voltages are noted in table [01] (from ref.02).

**Table 1. Switching Voltages for Different PMOS width**

| Wn(µm) | $W_p$(µm) | $V_s$(v) |
|---|---|---|
| 0.120 | 0.120 | 0.336 |
| 0.120 | 0.215 | 0.358 |
| 0.120 | 0.285 | 0.371 |
| 0.120 | 0.385 | 0.384 |
| 0.120 | 0.685 | 0.410 |
| 0.120 | 0.920 | 0.421 |
| 0.120 | 1.225 | 0.430 |
| 0.120 | 1.640 | 0.442 |
| 0.120 | 2.195 | 0.455 |
| 0.120 | 2.935 | 0.467 |
| 0.120 | 3.925 | 0.473 |
| 0.120 | 7.015 | 0.497 |
| 0.120 | 12.545 | 0.513 |
| 0.120 | 22.435 | 0.530 |
| 0.120 | 30 | 0.542 |

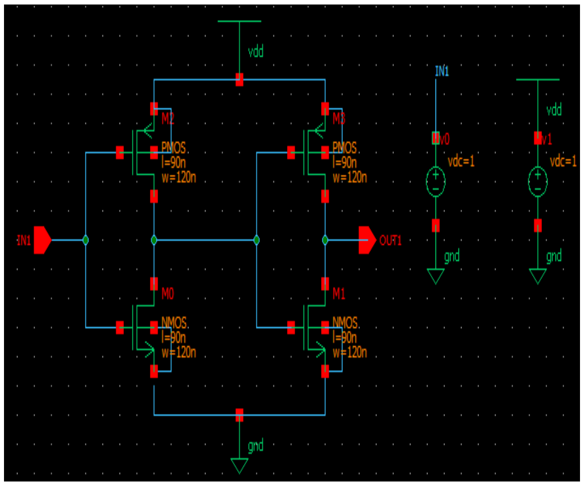


Fig. 5. TIQ Shematic

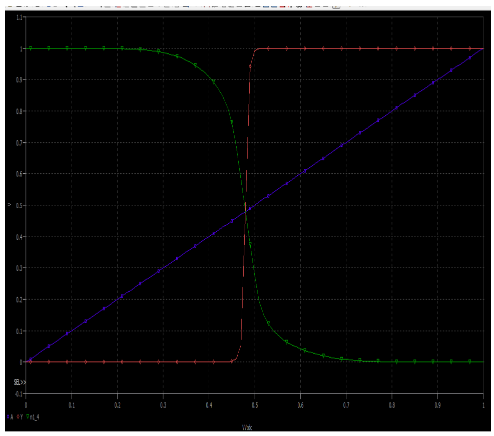

Fig. 6. VTC of TIQ Comparator

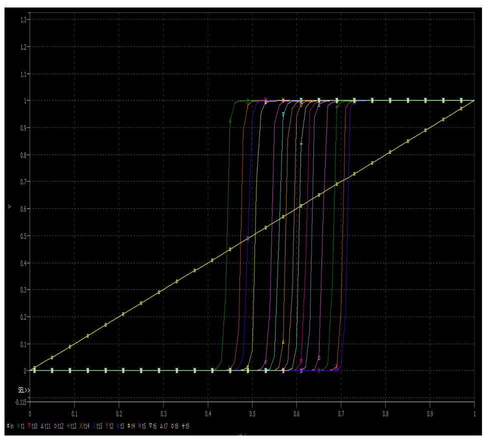

Fig. 7. Parametric Analysis of TIQ Comparator

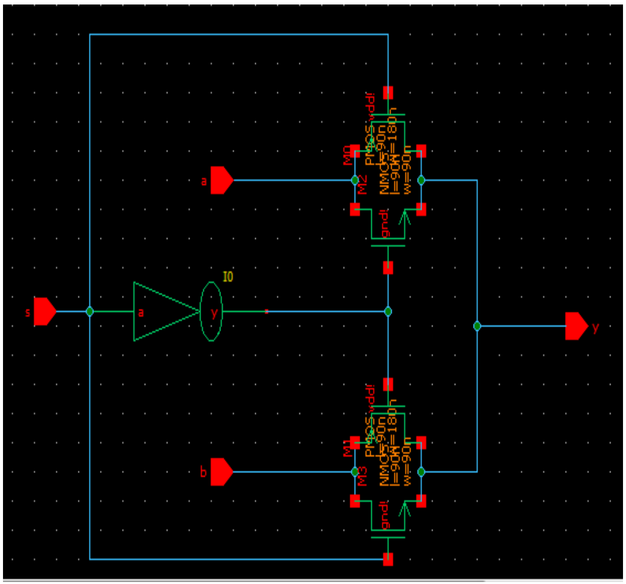

**Fig. 8. Multiplexer Schematic**

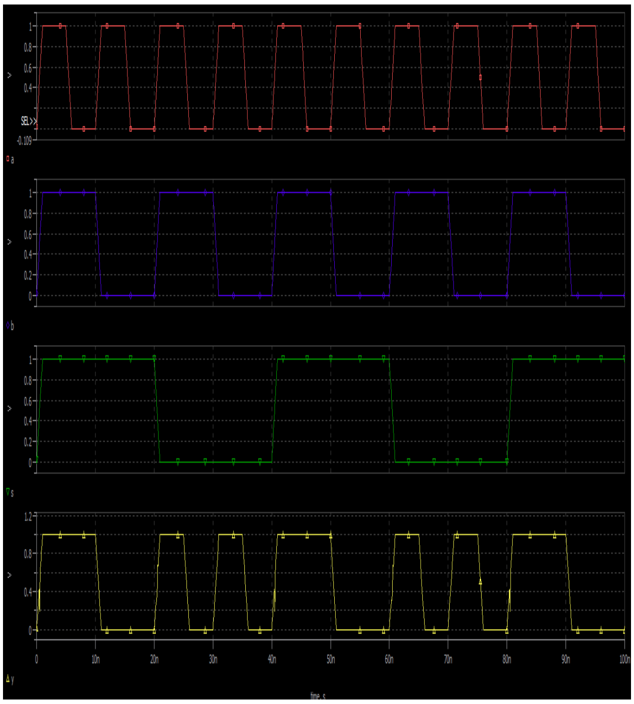

**Fig. 9. Multiplexer Output**

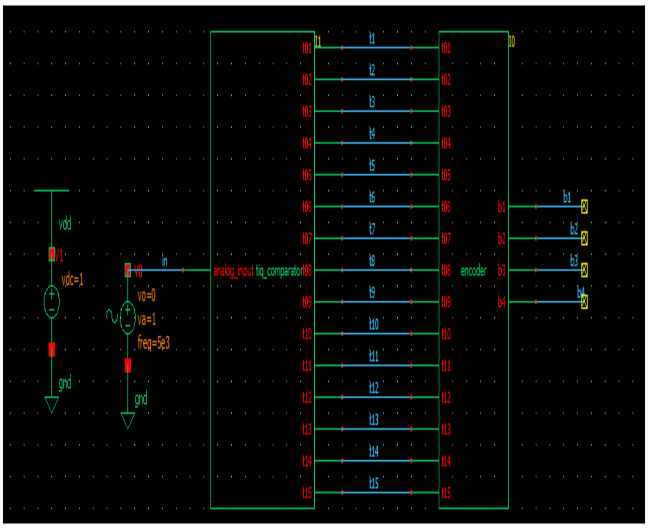

**Fig. 10. 04-Bit Flash ADC**

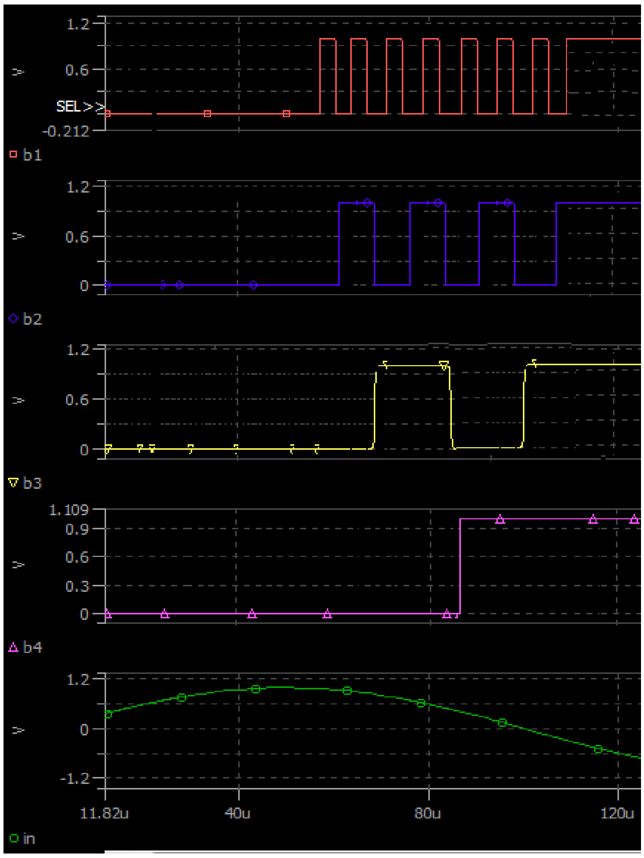


**Fig. 11. Output of 04-Bit Flash ADC**

The comparator compares the voltage with internally generated reference voltage. Comparator gives output as logic high (i.e. 1) when input voltage ($V_{in}$) is greater than the reference voltage and the comparator gives output as logic low (i.e. 0) when input voltage ($V_{in}$) is less than the reference voltage. An input sine wave with frequency 5KHZ and amplitude 1v has been applied to 15 different TIQ.

**Conclusion**

Here a simple and fast 04-bit flash ADC architecture has been implemented with new comparator style that uses two cascaded inverters i.e. known as Threshold Inverter Quantization (TIQ) and 2*1 multiplexer logic based encoder. Flash ADC provides higher data sampling rate and operates at low voltage and also low power consumption. This design is suitable for System-On-chip (SOC) applications. All the simulations are carried out by Symica DE with 90nm process technology.

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