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2, 4 BIT FLASH ADC USING TIQ COMPARATOR

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Abstract: Data converters are fundamental blocks in digital communication systems and storage systems for digital signal processing. A Flash ADC is preferred for high-speed applications. This paper presents the design technique of 2-bit and 4-bit Flash ADC using TIQ comparator. TIQ comparators compare the input signal with internal built threshold, it eliminates the need for power hunger resistor ladder network. An n-bit flash ADC requires 2^n-1 number of TIQ comparators. TIQ output is thus encoded into a binary value using an encoder. A mux based encoding technique has been used in this paper to enhance the conversion speed. The ADC has been designed in CMOS 90nm technology using Cadence virtuoso and cadence specter based simulation result shows that TIQ comparator significantly lowers the power consumption i.e. 1.7 uW and 7.54 uW and conversion speed 342 us and 328 us for 2-bit and 4-bit respectively.

Key Words: Analog to Digital converter, Multiplexer, Threshold Inverter Quantization, Flash ADC, TIQ comparator

1. INTRODUCTION

With the advancement of technology, data converters are widely used in modern communication and digital signal processing. ADCs are basic building blocks in many applications including storage systems, optical communication, radar communication, instrumentation and high-speed serial data links[1]. Different categories of ADC architectures are available based on their speed, resolution and power. Flash ADC is the most appropriate architecture for low power, high speed and medium resolution data converters [3]. In this paper, a Flash ADC is designed using TIQ technique which uses 2^n-1 comparators and high-speed MUX based encoder circuitry for higher efficiency.

2. FLASH ADC

A conventional N-bit Flash ADC uses 2^N resistors in series whereas TIQ technique uses 2^n-1 comparators which eliminate the need for power hungry resistor ladder circuit [2]. The basic difference between conventional and TIQ comparator is the way how the voltage is supplied. The TIQ comparator generates reference voltages internally and compares the input voltage with internally generated switching voltage which is determined by the transistor sizes of inverters and produces thermometer code. In TIQ comparator, threshold voltages are readily available which leads to fast conversion speed. Its role is to convert an input voltage (Vin) into a logic `1' or `0' by comparing a reference voltage (Vref) with the Vin. If Vin is greater than Vref, the output of the

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comparator is '1', otherwise `0'.The thermometer code generated by the TIQ is then converted to 2-bit and 4-bit binary code using a thermometer-binary encoder.

2.1 2 -BIT FLASH ADC

The design of 2-bit Flash ADC is being designed with Cadence Virtuoso and the simulation is done in CMOS 90nm technology. 2-bit Flash ADC uses $\mathbf{2^n}$-1 TIQ comparators which generate reference voltages internally to compare the input voltage and generates thermometer code for each combination of analog input. This thermometer code is then converted to 2-bit binary code using a thermometer-binary encoder.

TIQ Comparator

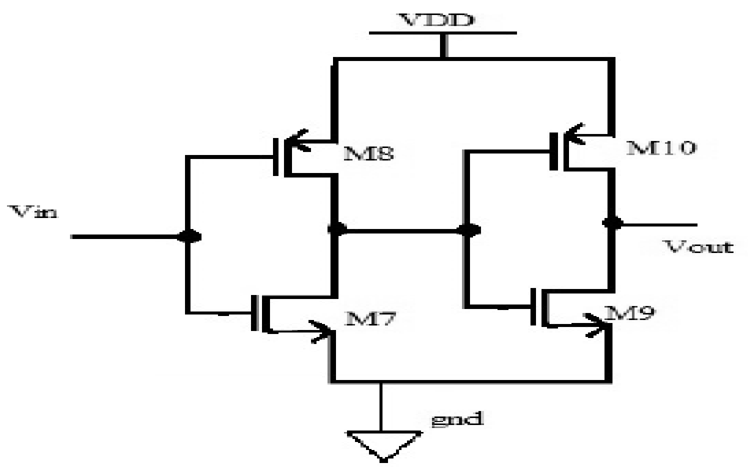

Figure 1: TIQ Comparator

Figure 1 shows that TIQ comparator uses two cascading inverters as a comparator for high speed and low power consumption. The first inverter generates switching voltage internally and the second inverter acts as a gain booster. As we vary the size of CMOS, the cascading inverters generate different switching voltages internally which acts as reference voltages. This happens when the width of transistors is changed, maintaining the length constant [3]. As we vary width of PMOS, the switching voltage Vs [6] obtained can be mathematically expressed as:

$$V_s = \frac{(V_{dd} - |V_{tp}|)\sqrt{K_p/K_n} + V_{tn}}{1 + \sqrt{K_p/K_n}} \tag{1}$$

Where V_{dd} = Supply Voltage

V_{tp} = PMOS Threshold Voltage

V_{tn} = NMOS Threshold Voltage

$K_p = u_p W_p$

$K_n = u_n W_n$

u_p = Mobility of hole and W_p is width of PMOS

u_n = Mobility of electron and W_n is width of NMOS

Table 1
Switching voltages for different PMOS widths

Wn(um)	*Wp(um)*	*Switching Voltage(mv)*
0.120	0.350	715.280
0.120	0.215	448.173
0.120	30	485.972

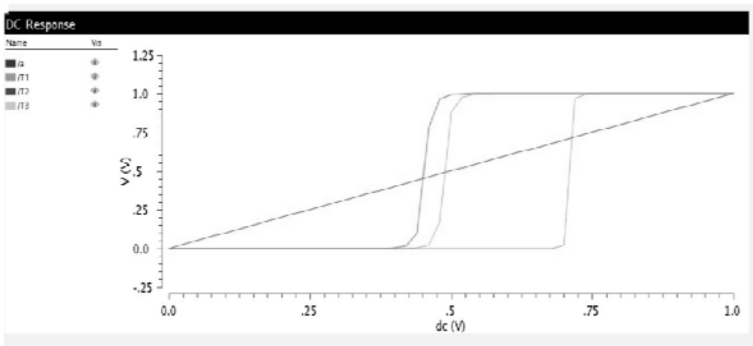

Figure 3. Parametric Analysis of TIQ Comparator

Figure 3 shows the different switching voltages are obtained by changing various PMOS width keeping NMOS width constant.

Encoder: The next stage of the comparator is an encoder. The output of the comparator stage is thermometer code which is converted to a binary code using the thermometer to a binary encoder.The Thermometer code generated by the TIQ is the unary code that represents a natural number n, with n followed by zero or (n-1) ones followed by a zero. Some representations use n or (n-1) zeroes followed by 1. As the analog input increases the number of 1's simultaneously increases. For example, if the thermometer code is 111 then the encoder converts it in the binary form as 11. There are several methods for thermometer-binary code conversion out of which MUX based encoder is more accurate and efficient.[4]

Table 2
Thermometer to Binary code conversion

T3	*T2*	*T1*	*B1*	*B0*
0	0	0	0	0
1	0	0	0	1
1	1	0	1	0
1	1	1	1	1

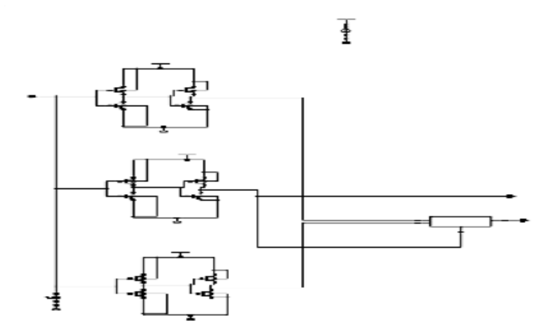

Figure 4. 2-bit Flash ADC

Figure 4 presents the interfaced circuit of comparator and encoder. Thermometer code generated by the TIQ is directly converted to the binary code using 2:1 MUX. From the truth table of table 2, it is clear that bit B1 is equivalent to thermometer code T2. Bit B0 can be obtained from T1 and T3 by keeping T2 the select line for the multiplexer. The combination of digital output B1 and B0 is obtained in the simulation result of 2-bit Flash ADC shown in fig5.

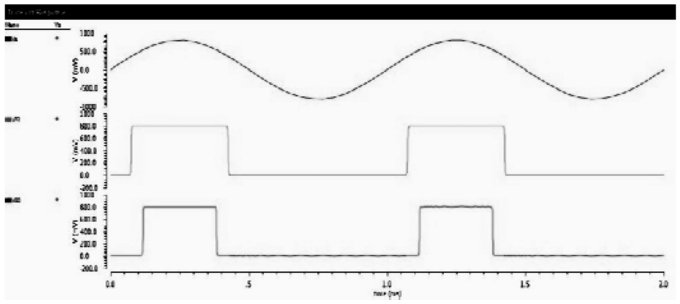

Figure 5. Output of 2-bit Flash ADC

2.2 4 -BIT FLASH ADC

4-bit Flash ADC uses the similar concept as that of 2-bit ADC. It requires 15 TIQ comparators for its operation; these comparators are arranged in parallel, generates different switching voltages which are fixed to that level.

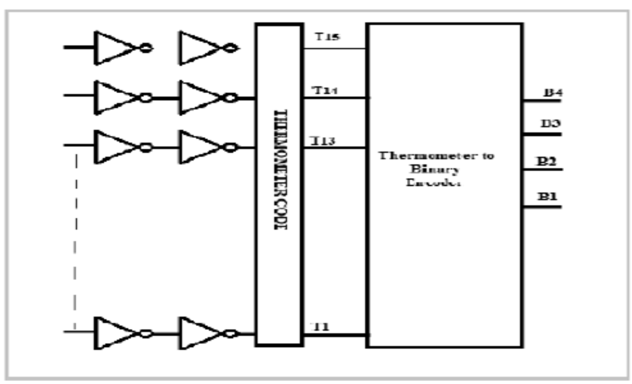

Figure 5. 4-bit Flash ADC Schematic

TIQ Comparator: Table 3. gives the different switching voltages generated by changing width of PMOS keeping the length constant. Parametric analysis has been performed to obtained different switching voltage. The results obtained by the simulation are 99% accurate as calculated by the mathematical equation given by (1).

Table 3
Switchingvoltages for different PMOS widths

W_p(um)	W_n(um)	Switching Voltage(mv)
0.120	0.120	144.69
0.169	0.120	336.69
0.239	0.120	348.39
0.338	0.120	375.92
0.477	0.120	391.32
0.673	0.120	406.38
0.950	0.120	422.54

Table 3 Contd…

1.34	0.120	436.46
1.89	0.120	448.69
2.67	0.120	457.62
3.78	0.120	472.77
5.33	0.120	488
7.53	0.120	497.38
10.62	0.120	505.30
15	0.120	521.46

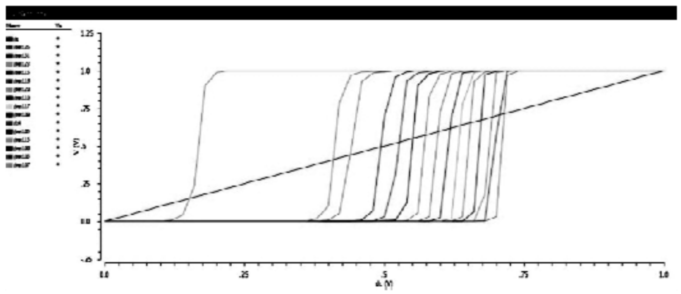

Figure 6. Parametric Analysis of TIQ comparator for different PMOS widths

Encoder: The next block of TIQ comparator is an encoder. The encoder converts the thermometer code generated in the first stage to 4-bit binary code. There are many encoding techniques available for thermometer-binary conversion out of which the more efficient is MUX based encoder as it consumes less power[5].

Table 4
Thermometer to Binary code conversion

T15	T14	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	B4	B3	B2	B1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0
1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1
1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0
1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	1
1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	0	1	0
1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1
1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

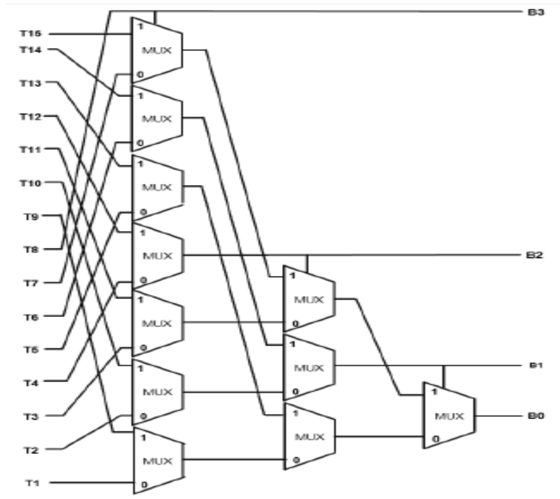

Figure 6. Encoder using 2:1 MUX

There are many encoding techniques available for thermometer-binary conversion out of which the more efficient is MUX based encoder. It is designed using 11 numbers of 2:1 multiplexers. From the truth table of table 4, it is clear that bit B4 is directly equivalent to T8. Bit B3 can be obtained from T12 and T4 keeping T8 as a select line for the MUX. Similarly, all the bits can be obtained from the truth table.

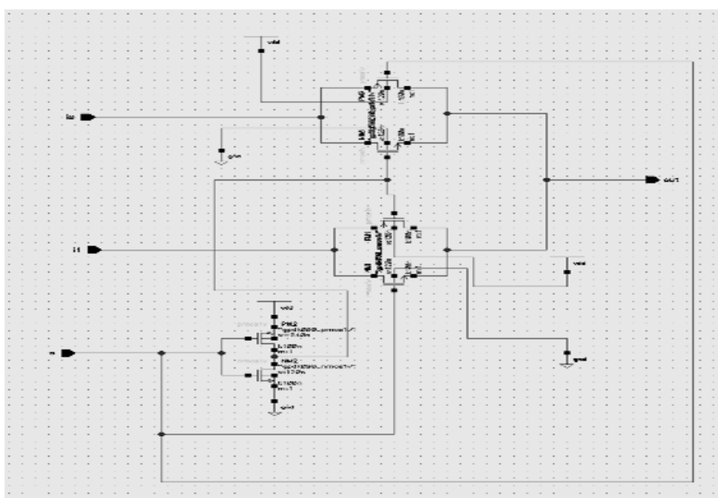

Figure 8. MUX using transmission gates schematic

MUX acts as an interface between thermometer-binary conversions. It uses less number of transistors thereby reducing the power and making the circuit more efficient.

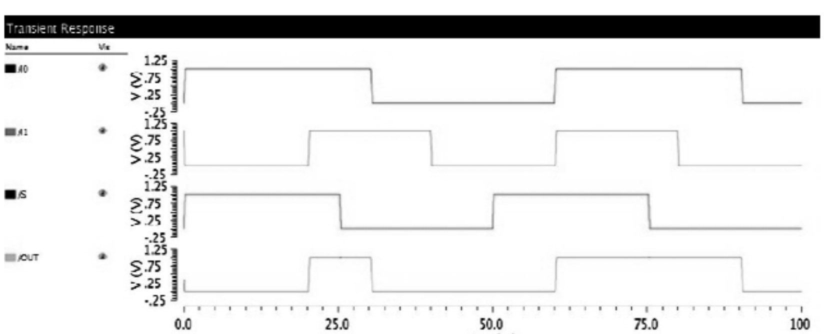

Figure 9. MUX output

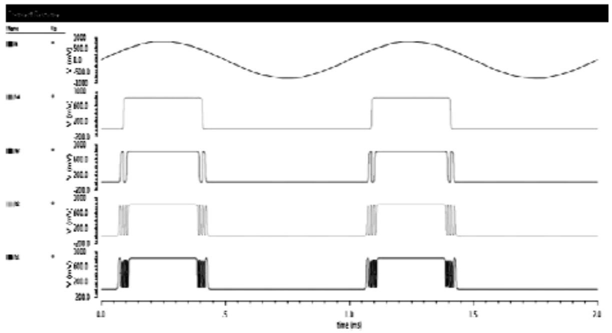

Figure 10. 4-bit Flash ADC output

Figure 11 shows complete working circuitry of 4 bit flash ADC, 15 TIQ comparators generate different thermometer code for individual voltage level. Mux based encoder converts thermometer code to 4 bit binary. Fig 10 presents that simulated result of 4 bit flash ADC. MSB B3 switches one for half of supply voltage while B0 LSB switches alternately. Table5 represents optimized result of flash ADC.

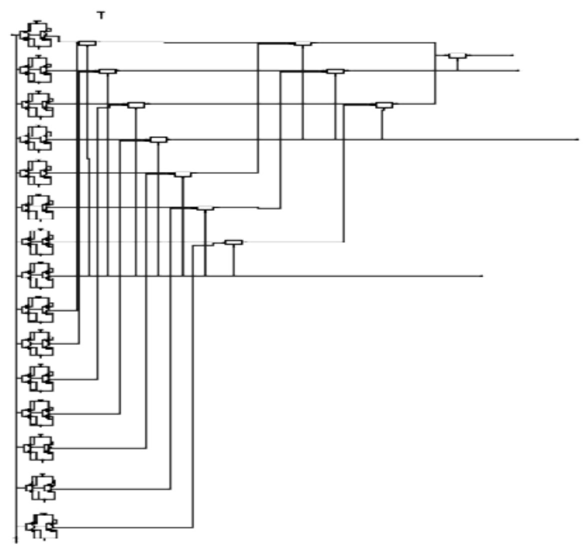

Figure 11. 4-bit Flash ADC

Table 5
Different parameter of 2,4 bit flash ADC

Parameter	*2-bit ADC*	*4-bit ADC*
Voltage	700mv	700mv
Frequency	1KHz	1KHz
Power	1.709uW	7.54uW
Delay	342.5us	328.4us
PDP	585.33J	2476.13J

3. CONCLUSION

In this paper the design of 2 bit and 4 bit Flash ADC based on TIQ comparator has been explored. Conventional ADC requires an extra number of comparators and resistors, in this work TIQ comparator is used to minimize power consumption. TIQ comparator compares the input voltage with the in-built reference voltage thereby providing the fast conversion speed. The design and simulation is carried in cadence environment using spectre simulator under 90nm technology.

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