

Design Of Novel Binary Code Encoder Based On Multiplexer for 4 Bit Flash ADC

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Abstract—In this paper, we propose multiplexer based converter which converts the thermometer to binary code Encoder For 4 Bit Flash ADC is proposed. The proposed encoder design uses 2:1 multiplexes (MUX) and 2 input XOR gates for converting thermometer code to binary code. Initially 2:1 MUX are used to convert the thermometer code to equivalent gray code. The resulting gray code is then converted to the binary code using XOR gates. Low power consumption is achieved in the proposed design with the grounding concept and avoiding the additional inverters compared to the conventional encoder design. The proposed encoder is implemented in 180 nm CMOS, N-well technology with 1.8 V supply voltage and was simulated using Cadence Spectra simulator. Simulation results shows reduction in power up to 60% when compared with conventional encoder architectures. The proposed design has a figure-of-merit (FOM) of 12.6fJ with the propagation delay of 0.5098ns.

Keywords— Analog to digital converters, self-re-configurable property, figure of merit, thermometer code, gray code.

I. Introduction

Analog-to-digital converters (ADCs) are the important functional unit in the signal processing, system on chip and mixed signal design applications. ADC form the interface between the analog environment and digital system. Among various ADC architectures [1-4], the flash ADC [5-7] is used for high speed and lower resolution applications. Fig 1 shows the structure of conventional flash ADC. The flash ADC consists of $2^N - 1$ comparators for N-bit resolution, where the analog input is compared with the reference voltage to give the output as „0“ or „1“. The comparator outputs are converted to binary code using thermometer to binary encoder. Since power and delay are the important constraints in IC design, it is important to design ADC with high speed and less power. The encoder in the flash ADC consumes suitable amount of power and delay. Hence, a novel encoder is presented in this paper which consumes less power and delay compared to existing encoder architectures.

The rest of the paper is organized as follows: Section II Literature Review it will be discusses the existing Encoder architectures. In Section III, proposed encoder design is explained. Section IV presents simulation results for the proposed design. Finally, conclusions are drawn in Section V.

II. Literature Review

Different types of encoders [8-9] are used in flash ADC like Wallace tree encoder, fat tree encoder, multiplexer (MUX) based encoders.

A. ROM Based Encoder

ROM based encoder [10] architecture consists of two stages. Initially, the input thermometer code is first converted to one hot code or 1-out of $2^N - 1$ code. In the next stage, the one hot code is the address location for the binary ROM. Binary ROM is a memory location where the equivalent binary code for the thermometer code is present. But this architecture has the disadvantage of high power consumption and large delay because of high static current that flows while pre-setting the ROM encoder.

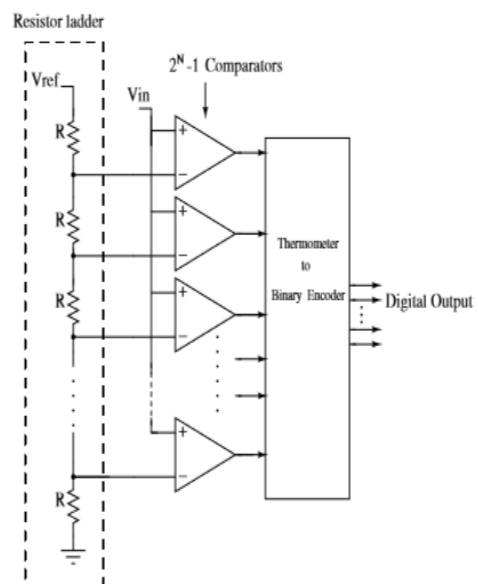


Fig.1 . N bit Flash ADC

B. Wallace Tree Encoder

Wallace tree encoder [11] is basically counts the number of Ones in the input thermometer code. Therefore it is also called “Ones counter”. Fig 2 shows the Wallace tree encoder. The counter topology can be selected based on the speed of ADC. But the architecture has disadvantage of large delay and power.

C. Fat-Tree Based Encoder

Fat tree encoder [12] over the other encoder is high encoding speed .also the fat tree encoder consumes less power compared with the ROM and Wallace tree encoders Fig 3 shows the 15 to 4 bit fat tree encoder. Fat tree encoder comprises of 2 stages. The one hot code is obtained in the first

stage from the input thermometer code. The output of this first stage is converted to equivalent binary code using multiple trees of OR gates.

D. Existing MUX Based Encoder

In this design [13-14] 2:1 MUX are used to achieve low power and less delay when compared to Wallace tree and Wallace encoder. Fig 4 shows the existing MUX based encoder design. The MUX based encoder design have the advantage of self re-configurable property [15] in which the same encoder can be used for low resolution ADC by keeping the higher order inputs to „0“.

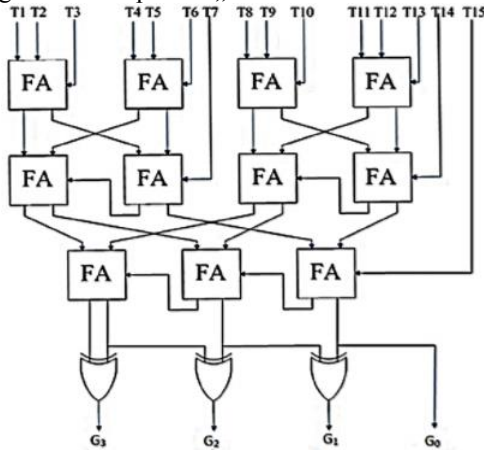


Fig. 2 . Wallace Tree Encoder

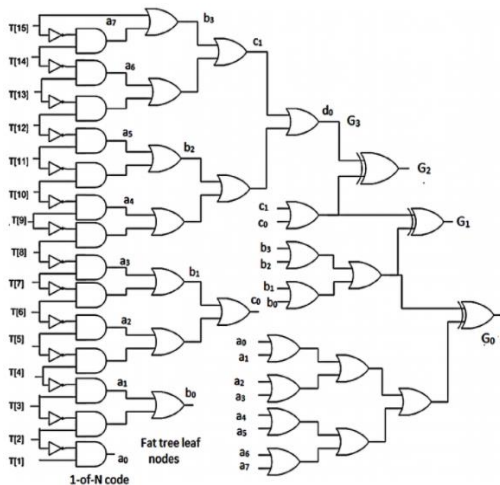


Fig. 3 . Fat Tree Encoder

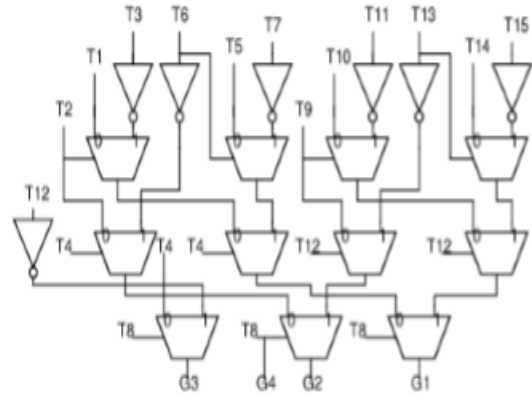


Fig. 4. Existing MUX Based Encoder

III. Proposed Architecture

The architecture for the proposed design is analyzed first for the 7-bit encoder. Truth table for 7: 3 thermometer to gray code converter is shown in table I. From the table I, it is possible to write the following expressions for the gray code G2, G1, G0.

$$G3 = T4$$

$$G2 = T2 T6$$

$$G1 = T1 T3 + T3(T7 T5)$$

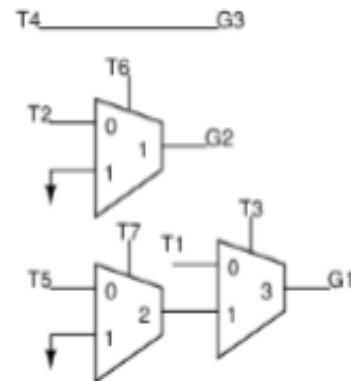


Fig. 5. Proposed 3-bit Encoder

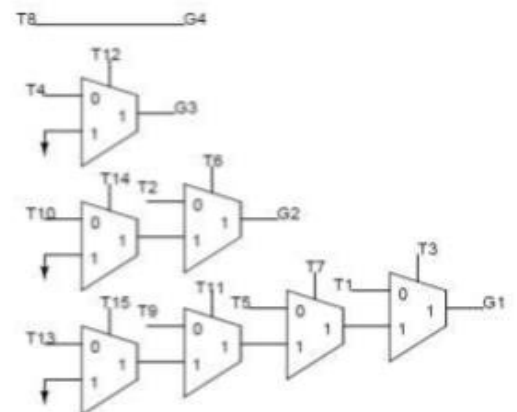


Fig. 6. Proposed 3-bit Encoder.

Similarly the expressions for the output of 4-bit encoder can

be written as

$$G4 = T8$$

$$G3 = T4T12$$

$$G2 = T2T6 + T6(T10T14)$$

$$G1 = T13T1 + T3(T7T5 + T7(T11T9 + T11(T15T13)))$$

TABLE I

TRUTH TABLE FOR 3- BIT ENCODER

THERMOMETER CODE							GRAY CODE		
T7	T6	T5	T4	T3	T2	T1	G3	G2	G1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	1
0	0	0	0	0	1	1	0	1	1
0	0	0	0	1	1	1	0	1	0
0	0	0	1	1	1	1	1	1	0
0	0	1	1	1	1	1	1	1	1
0	1	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	0	0

The architecture for the proposed design of 3-bit and 4-bit encoder is shown in fig 5, 6 respectively. 2:1 MUX and 2-input XOR gate forms the basic elements for the proposed design. The output gray codes are implemented using 2:1 MUX and the equivalent binary code from the gray code is obtained using 2-input XOR gates as shown in fig 7. Here the input line „1“ of some of the MUXs are connected to ground terminal, to reduce the number of MUXs and avoid the need of additional inverters when compared to the existing MUX based design. The 2:1 MUX and 2 input XOR gates are implemented in the transmission gate logic style [16] to achieve low power consumption as shown in fig 8,9.

The output gray code G4 is equivalent to the input thermometer code T8. Hence G3 is directly connected to T8. The output code G3 is obtained from the input codes T12, T4. The input codes T4, T12 are used to obtain the equivalent gray code G1. T12 is used as selection line and T4 as the inputs to MUX 1. The input codes T6, T2, T14, T10 are used to obtain the equivalent gray code G2. T14, T6 are used as selection lines and T10, T2 are the inputs to MUX 2, 3 respectively. The output code G1 is obtained from input codes T13, T15, T9, T11, T5, T7, T1 and T3 using MUX 4,5,6,7. Using the 2 input XOR gates the output binary code is obtained from the gray code.

The proposed design also has the advantage of self-reconfigurable property. The 4-bit encoder can be converted 3-bit encoder by assigning the higher order inputs T8-T15 to „0“. Similarly it can be converted to 2-bit encoder by assigning the inputs T4- T15 to „0“. Thus the same encoder can be used for the lower resolution flash ADC. Fig.4 shows how the self-reconfigurable property is used to design 3-bit encoder from the 4-bit encoder.

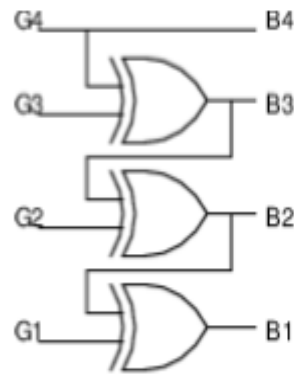


Fig. 7. Gray to binary conversion

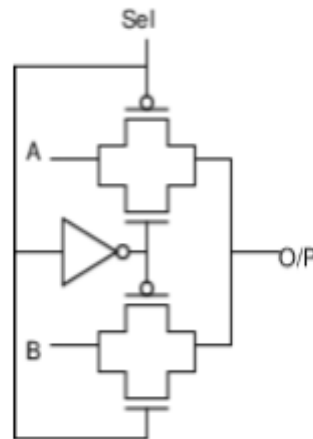


Fig. 8. 2:1 MUX using transmission gate logic.

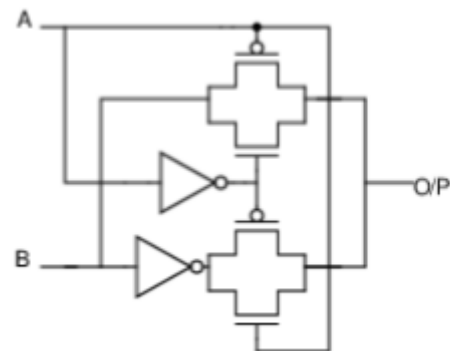


Fig. 9. XOR gate using transmission gate logic

IV. Simulation Results

The proposed MUX based architecture, Wallace tree encoder and the existing MUX based architecture are simulated in Cadence Spectre Simulator at 180 nm technology. The performance is evaluated with all the possible input logic states and results are tabulated in Table II.

TABLE II
COMPARISON OF PROPOSED MUX BASED ENCODERS WITH THE EXISTING ENCODER ARCHITECTURES.

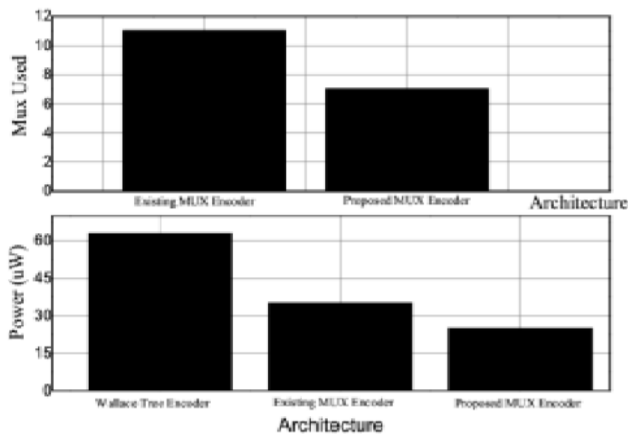


Fig. 10. Comparison with the existing architectures.

The proposed encoder design consumes power of 24.75µw, which reduces power up to 60% compared to Wallace tree encoder. The supply voltage is kept at 1.8 V for the simulation of proposed and existing designs. The proposed MUX based design consumes less power compared to the existing MUX based architecture. The number of MUX is reduced from 11 to 7 as seen in fig 10. The proposed design also has less delay compared to existing MUX based architecture and Wallace tree encoder with a good FOM of 12.61fJ

V. Conclusion

A MUX based Thermometer to Binary code encoder is proposed in this paper. The grounding concept is used to reduce the number of MUX from 11 to 7 when compared to existing MUX based design. Also the needs for additional inverters are avoided in this design. The thermometer code is first encoded to its equivalent gray code and then the gray code is converted to binary code using XOR gates. The proposed encoder design has a power consumption of 24.75µW with the FOM of 12.6fJ. The proposed encoder can be used for low resolution flash ADC with the self-reconfigurable property.

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Architecture	Power Consumption (µw)	Delay (ns)	FOM (fJ)
Wallace Tree	62.94	0.9666	60.81
Existing MUX Encoder	31.31	0.5299	16.59
Proposed MUX Encoder	24.75	0.5098	12.617

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