B. TECH FINAL YEAR PROJECT REPORT

Submitted by

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in

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Under the guidance of

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Kalyani Government Engineering College

ACKNOWLEDGEMENT

We take this opportunity to express our deep gratitude and sincerest thanks to our project mentor,

Professor Dr. Angsuman Sarkar Sir, for giving his most valuable suggestion, helpful guidance and encouragement in the execution of this project work.

We would like to give a special mention to our classmates for encouraging and helping us in completing the project within the stipulated time frame.

TOPIC

Design and Performance Analysis of sub-circuits/modules of advanced integrated circuits (ICs) using Mentor-based electronic design automation (EDA) software

OBJECTIVE

Our aim is to carry out a literature survey on Flash type Analog to digital converter and then implement a circuit and simulate it in Tanner EDA tools. For this purpose, we have read and understood some research papers available online. Thereafter we have gathered sufficient knowledge regarding the working and performance of a flash type ADC. After that we have designed and simulated a circuit of an Flash-type ADC and shown the outputs here in the report.

INTRODUCTION

In wireless communication world entire signals are analog. But we are surrounded by Digital devices. Everything in the universe measures all signals with analog only. Most of the applications are in digital signal processors only. Like microcontrollers, microprocessors. Analog to Digital converters convert analog signals to digital for processing the information or data. In present days most of the electronic applications are in digital only because digital have finite set of occurrences. Also, another important factor is low power consumption, low operating voltage with a high-speed data transmission. So, we focus on efficient analog to digital converters. We have different types of analog to digital converters like Successive Approximation (SAR), Dual slope ADC, Sigma delta ADC and Flash ADC. Among those, in most cases we prefer only flash type ADC as shown in figure 1.

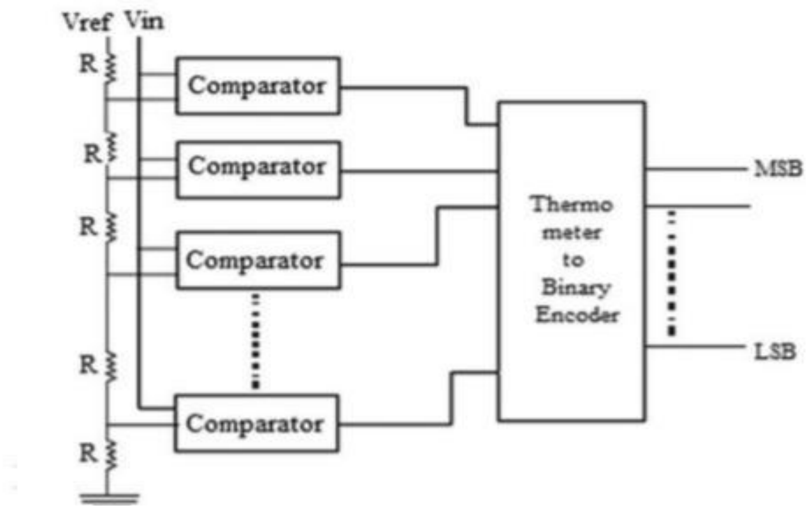


Figure 1: Flash-type Analog to Digital Converter Circuit

Also called the parallel A/D converter, this circuit is the simplest to understand. It is formed of a series of comparators, each one comparing the input signal to a unique reference voltage. The comparator outputs connect to the inputs of a priority encoder circuit, which then produces a binary output. The following illustration shows a 3-bit flash ADC circuit. Basically, an analogue to digital converter takes a snapshot of an analogue voltage at one instant in time and produces a digital output code which represents this analogue voltage. The number of binary digits, or bits used to represent this analogue voltage value depends on the resolution of an A/D converter.

BASIC COMPONENTS OF A FLASH TYPE ADC

1. Comparators: Comparators are one fo the most needed component for the Flash Type ADC. The **Op-amp comparator** (As shown in figure 2) compares one analogue voltage level with another analogue voltage level, or some preset reference voltage, V_{REF} and produces an output signal based on this voltage comparison.

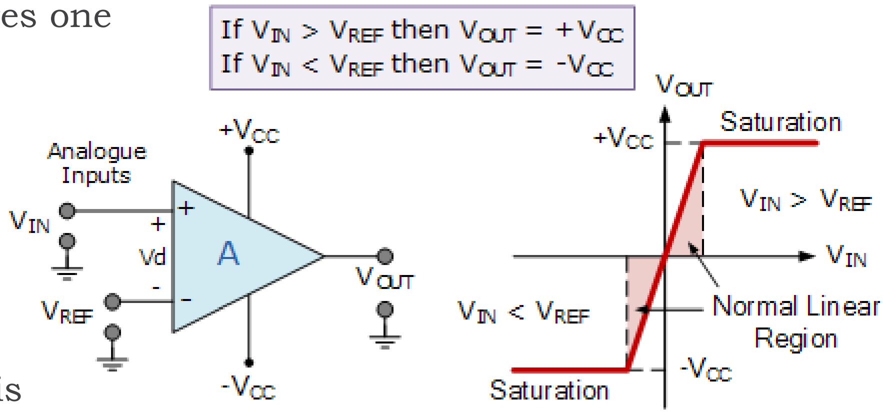


Figure 2: Op-Amp Comparator

In other words, the op-amp voltage comparator compares the magnitudes of two voltage inputs and determines which is the largest of the two.

We have seen in previous tutorials that the operational amplifier can be used with negative feedback to control the magnitude of its output signal in the linear region performing a variety of different functions. We have also seen that the standard operational amplifier is characterised by its open-loop gain A_O and that its output voltage is given by the expression: $V_{OUT} = A_O(V+ - V-)$ where V+ and V- correspond to the voltages at the non-inverting and the inverting terminals respectively.

With reference to the op-amp comparator circuit above, lets first assume that V_{IN} is less than the DC voltage level at V_{REF}, ($V_{IN} < V_{REF}$). As the non-inverting (positive) input of the comparator is less than the inverting (negative) input, the output will be LOW and at the negative supply voltage, -Vcc resulting in a negative saturation of the output.

If we now increase the input voltage, V_{IN} so that its value is greater than the reference voltage V_{REF} on the inverting input, the output voltage rapidly switches HIGH towards the positive supply voltage, +Vcc resulting in a positive saturation of the output. If we reduce again the input voltage V_{IN}, so that it is slightly less than the reference voltage, the op-amp's output switches back to its negative saturation voltage acting as a threshold detector.

Comparator Reference Voltages

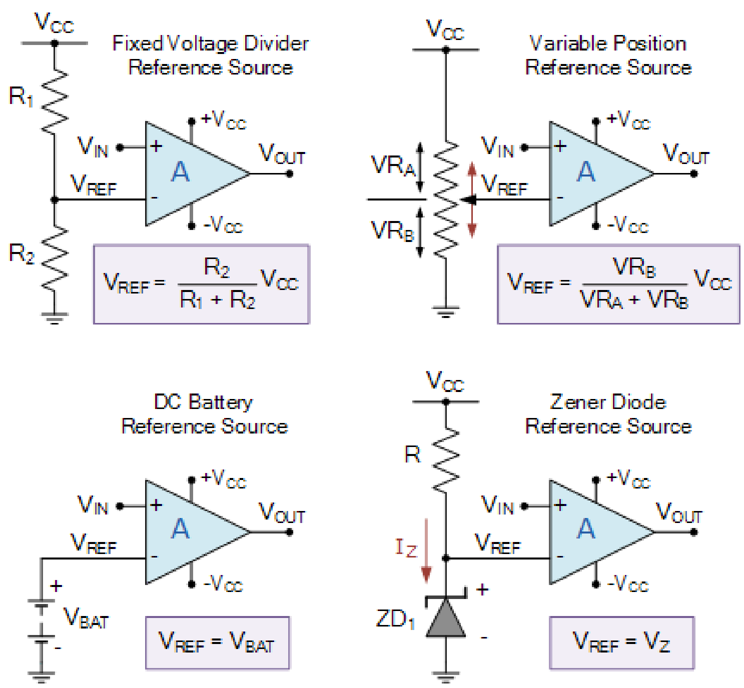


Figure 3: Comparators with reference voltages at their inverting input terminal

In theory the comparators reference voltage can be set to be anywhere between 0v and the supply voltage but there are practical limitations on the actual voltage range depending on the op-amp comparator being device used.

Positive and Negative Voltage Comparators

A basic op-amp comparator circuit can be used to detect either a positive or a negative going input voltage depending upon which input of the operational amplifier we connect the fixed reference voltage source and the input voltage too. In the examples above we have used the inverting input to set the reference voltage with the input voltage connected to the non-inverting input.

But equally we could connect the inputs of the comparator the other way around inverting the output signal to that shown above. Then an op-amp comparator can be configured to operate in what is called an inverting or a non-inverting configuration.

2. Diodes: Diodes in a flash ADC are used to implement the logic required to convert the input analog signal to digital. The output signals from the comparators pass through the logic circuitry to get converted to equivalent digital data.

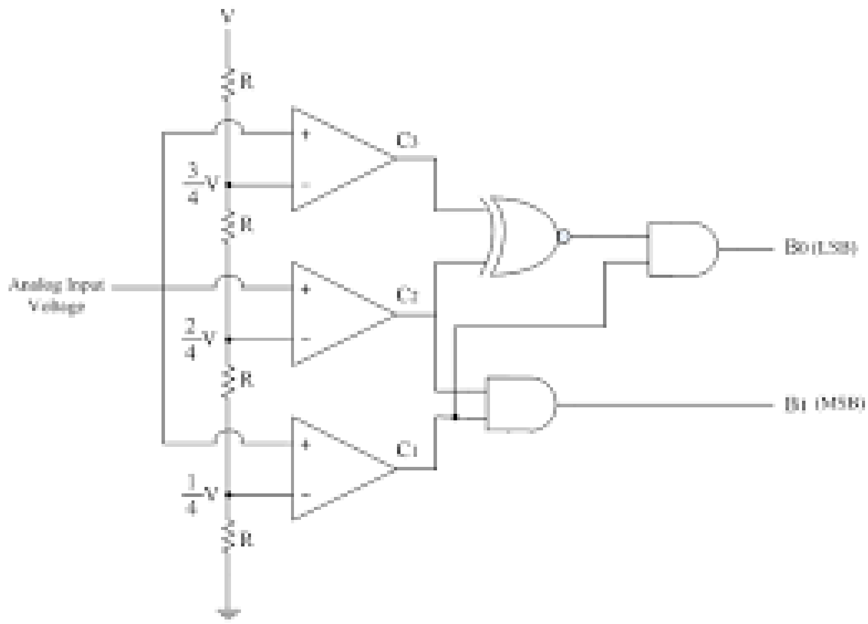


Figure 4: A flash type ADC

3. Resistors: Resistors are used to build the voltage divider essential for the comparator action. The input analog voltage is compared with the divided voltages to find the equivalebt digital value. A **resistor** is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

High-power resistors that can dissipate many watts of electrical power as heat may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors as discrete components can be composed of various compounds and forms. Resistors are also implemented within integrated circuits.

The electrical function of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. The nominal value of the resistance falls within the manufacturing tolerance, indicated on the component.

Types of errors in ADC:

A. Resolution or Step size:

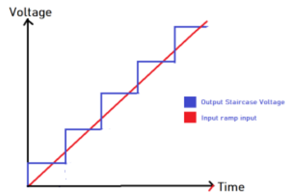
Step size is the minimum change in input voltage which can be resolved by the ADC. The concept of step size is closely associated with the resolution of ADC. Resolution. The resolution of an ADC refers to the number of bits in the digital output code of the ADC.

Resolution =(step size/Vref) *100

B. Offset and Gain Errors:

It is occurs when the slope of the actual output deviates from the slope of the ideal output. Vout=KD,

Height of the slope is changing according to K changes.



A1 is ideal output, if the positive error then goes to upward direction. And for negative error then goes to downward direction.

Offset error: First apply zero volts to the ADC input and perform a conversion; the conversion result represents the bipolar zero offset error. Then perform a gain adjustment by rotating the curve about the negative full-scale point .

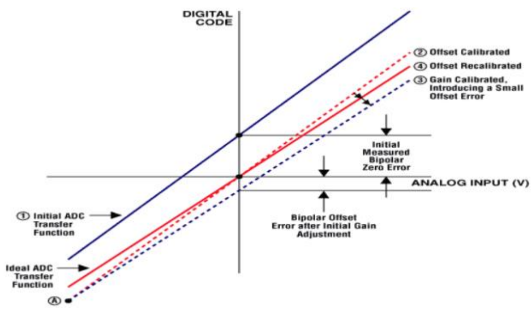


Figure 5: Depicting the offset and gain error

C. Differential Non-Linearity error:

Analog-to-Digital Converter (ADC) Differential Non-Linearity (DNL) is defined as the maximum and minimum difference in the step width between the actual transfer function and the perfect transfer function. Non-linearity produces quantization steps with varying widths, some narrower and some wider.

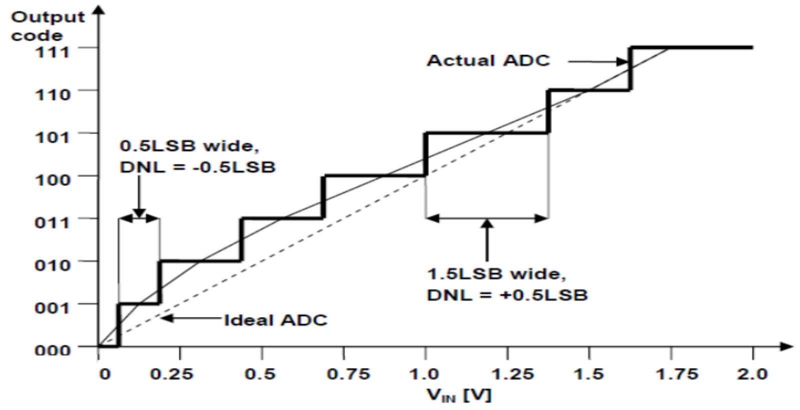


Figure 6: Depicting the differential nonlinearity error

D. Monotonicity error:

Monotonic behaviour is an especially important characteristic for ADCs used in feedback control loops since non-monotonic response can cause oscillations in the system. Monotonicity is a critical specification with automatic control applications. It does not, however, mean no missing codes. A non-monotonic ADC transfer function will miss a lower code until after the higher code is converted (assuming linearly increasing input voltage). The figure below shows a 3-bit ADC with a missing code:

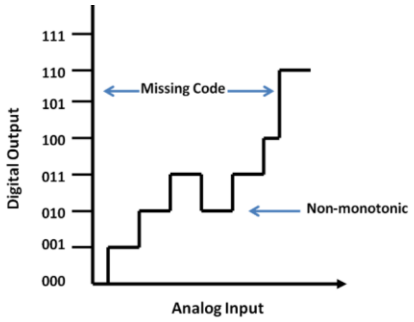


Figure 7: Depicting the monotonicity error

LITERATURE SURVEY

1. Title: Low Voltage Low Power High Speed Flash ADC with Multiplexer based code converter

Author: Prasadh Teppala, K. Praveen Kumar, Ch. Praveen Kumar

[International Journal of Scientific & Engineering Research]

Volume 3, Issue 11, November 2012

Summary:

In this article, the author has emphasized on increasing the speed and performance of the ADC while reducing its power consumption and working voltage. The major challenge faced by the author is achieving the speed greater than 2 giga samples per second. The ADC was designed at 130nm node. The Flash ADC conventionally contains resistor ladder circuit, comparator and code converter. Resistor ladder circuit is mainly to generate reference voltages. Because of high power consumption of resistors, TIQ comparator and QV comparator are introduced to generate reference voltages and to generate the thermometer code by comparing the input voltage with the reference voltages. Code converter is used for converting the thermometer code to binary code.

2. Title: DESIGN, IMPLEMEN DESIGN, IMPLEMENTATION AND AN TION AND ANALYSIS OF FL SIS OF FLASH ADC ASH ADC ARCHITECTURE WI TURE WITH DIFFEREN TH DIFFERENTIAL AMPLIFIER AS AL AMPLIFIER AS COMPARATOR USING CUST OR USING CUSTOM DESIGN APPRO OM DESIGN APPROACH

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Volume 2, Issue 1, July 2012

Summary:

In this paper, the authors have described a completely different type of ADC that is a variable-power and variable-resolution ADC. It can operate on high frequencies and consume low power by working at a lower resolution, while it can also operate on low frequencies with higher resolution. Such features are highly desirable in many wireless and mobile applications. For example, the strength of a radio frequency (RF) signal varies greatly depending on geographic location. Optimally, the ADC resolution can be reduced upon the reception of strong signal and can be increased upon the reception of weak signal.

Some other Surveys

- The paper entitled “The CMOS Inverter as a Comparator in ADC Designs”, spinger Analog Integrated Circuits and Signal Processing, Vol.39, pp.147-155, 2004 by Tangel A. Choi K discussed about the advancement of technology, digital signal processing has progressed dramatically in recent years. The main emphasis of this paper is that the digital signal processing (DSP) in the digital domain gives a high rate of accuracy, lower power consumption and small silicon area besides the flexibility in design. The design process is also quite faster and cost effective. Furthermore, their implementation makes them suitable for integration with complex digital signal processing blocks in a compatible low-cost technology, particularly CMOS.
- P. Rajeswari, Dr.A.R.Aswatha and Dr.R.Ramesh et al proposed the low power design system for flash ADC. With the assistance of this technique, we can reduce the power utilization of flash analog to digital converters when reduced the quantity of comparators by half. This paper proposed the precision of the flash ADC by using the T/H circuit. Their proposed technique spared 35% of power consumption when contrasted with the conventional one.
- The demanding issue in this paper was to design a low power latched comparator using 90nm technology with 0.8V DC supply. This technique consumes low power of 7.67mW, which consumes a low power of around half for a sampling frequency upto 1.2GHz. This configuration can be extended to high-speed applications because comparator utilized as a part of this plan can work upto 5GS/s.

Result

After going through some of the research papers, first we have implemented a basic simple CMOS Inverter circuit (as shown in figure 8) using the Tanned EDA tool, and simulated it. We have used Generic 250 nm devices package from Tanner EDA to implement this. The main purpose of this basic circuit building was to verify and be familiar with the software Tanner EDA tool.

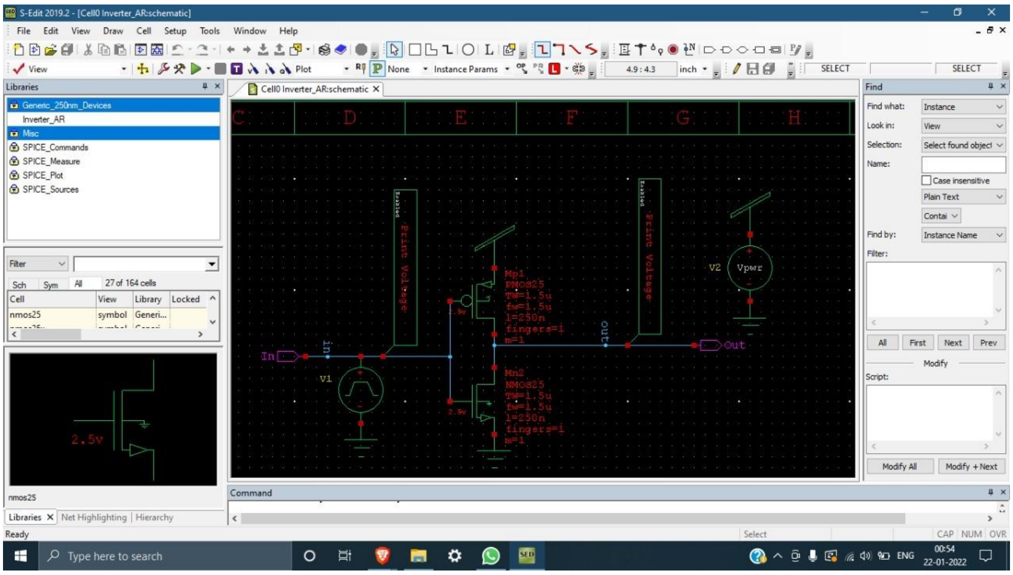


Figure 8: CMOS Inverter

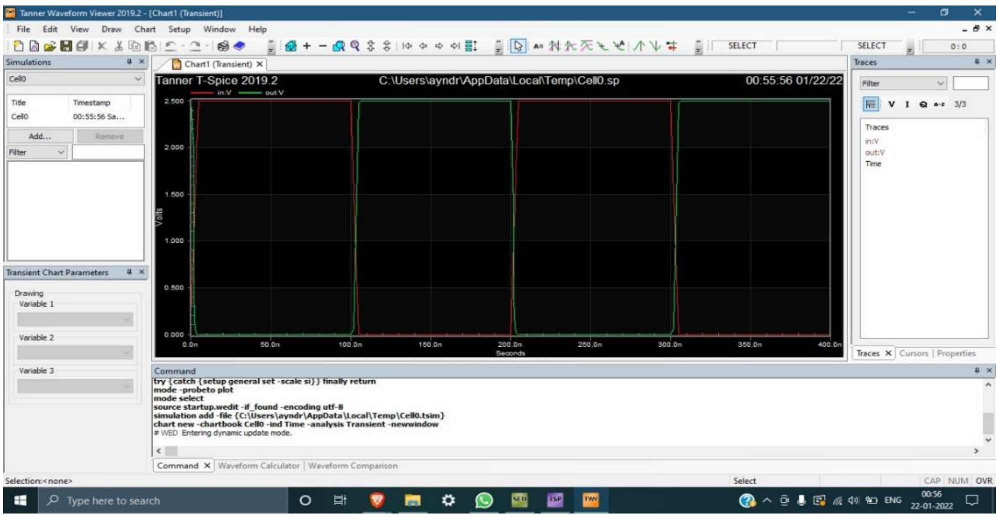


Figure 9: Transient analysis of CMOS Inverter

After that the main task was to build the circuit of 2-bit ADC (as shown in figure 10). For that, a number of digital electronics books were consulted. Finally, a circuit was built that is given below-

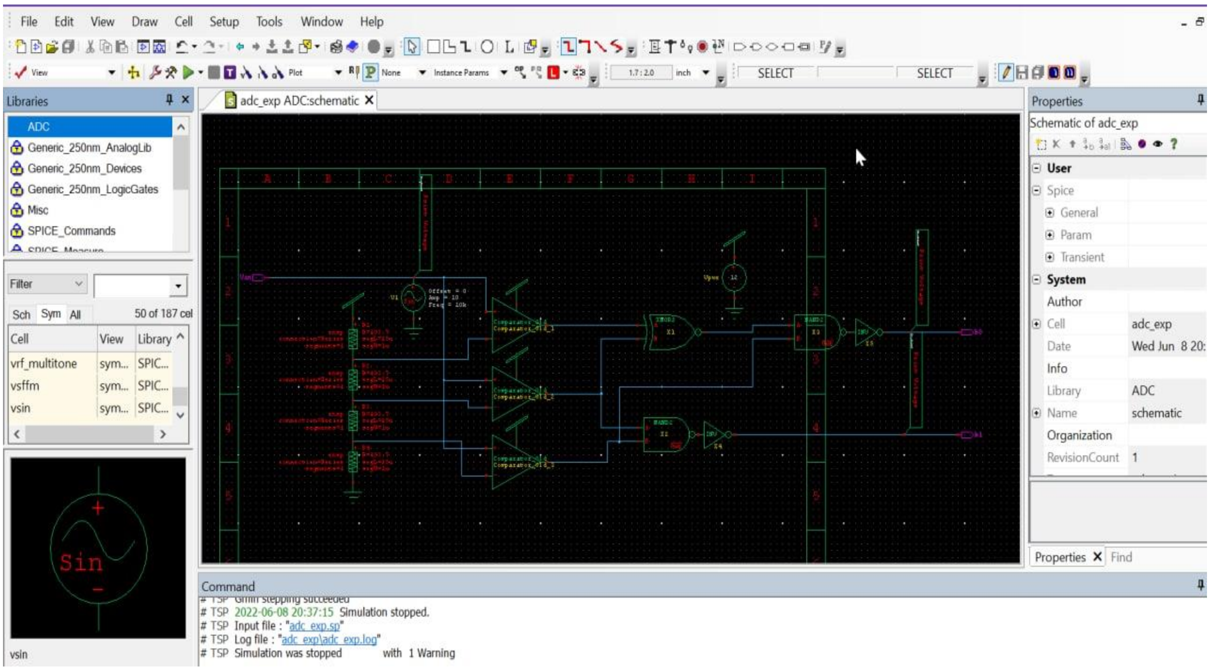


Figure 10: Flash ADC designed in Tanner S Edit

Software Used

The softwares used for this project are-

a) Tanner EDA Tools

b) MATLAB

Circuit Description

In this circuit, the reference voltage that is used at the inverting terminal is of 12v, and all the non-inverting terminals are connected to the input voltage that has to be converted to digital output. The input voltage is termed as “Vin” and the two output terminals are termed as “b0” and “b1”. A voltage divider circuit containing four resistors is used to divide the 12v reference voltage to 9v, 6v and 3v. Each of the inputs from 9v, 6v and 3v are connected to the inverting terminals of the op-amps. After the op-amp stage, an encoding logic containing one XOR gate and two AND gates are used to convert the input voltage to equivalent digital output. The input voltage is a sinusoidal voltage that has an amplitude of 10v and 0v offset. The output voltages is measured by a tool named "VVoltagePrint". The device package used for this purpose is the 250nm generic devices package.

Simulation Settings

For simulation of the mentioned circuit, transient analysis method is chosen. The stop time is set to 200 us and maximum step size is taken as 400 ns. The Generic 250nm devices library file is chosen as the library. The value of the reference voltage is 12v.

Simulating the circuit

After all the mentioned settings are done, the circuit is simulated and the following waveforms are obtained at the **Tanner Waveform Viewer**-

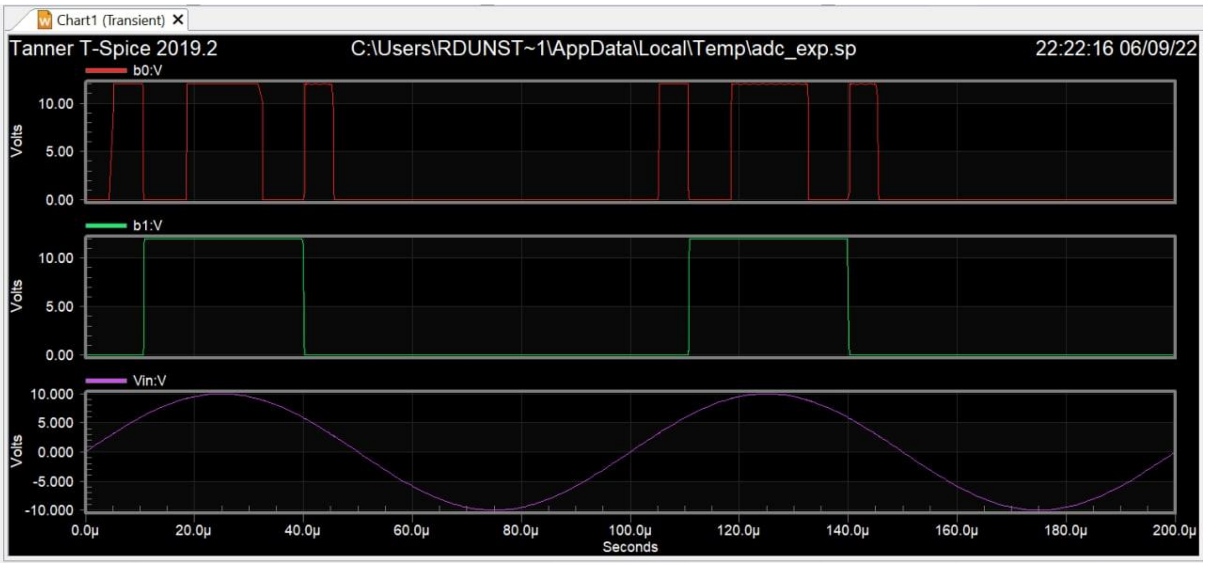


Figure 11: Transient analysis of the ADC circuit and plot of the input voltage, MSB and LSB

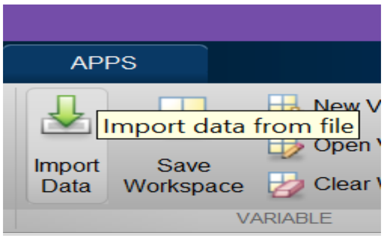
Here, the corresponding output for the sinusoidal input is shown. The lower purple waveform is for **Vin**, green one is for the MSB **b1** and the red one is for the LSB **b0** (as shown in figure 11).

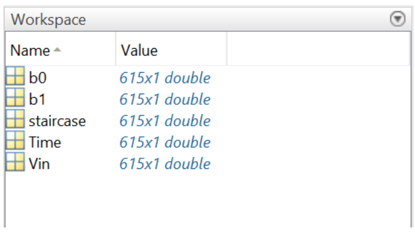
Plotting Graphs in MATLAB and obtaining the staircase output

Now the next task is to export the graph data to an excel file and plot the corresponding graphs in MATLAB software. For that purpose, the chart data is exported to an excel file named as "adc data.csv". After that the data is imported to MATLAB and all the variables are renamed as "b0", "b1", "Vin" and "Time". Now using the "subplot" and "plot" commands, the same graphs are plotted in MATLAB. A new variable named "staircase" is defined as

```
>> staircase = 2*b1 + b0;
>>
```

This variable will be used for the staircase type waveform for the ADC output.





The finally obtained waveform is as follows-

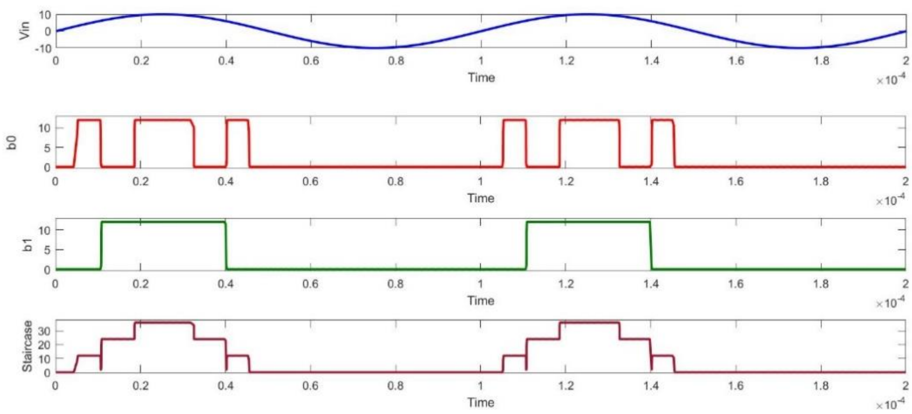


Figure 12: Plot of the input voltage, MSB and LSB and obtaining the staircase waveform

The digital output of the ADC follows the following logic-

Voltage range	Output Voltage	
9v – 12v	b1 – 12v (1)	b0 – 12v (1)
6v – 9v	b1 – 12v (1)	b0 – 0v (0)
3v – 6v	b1 – 0v (0)	b0 – 12v (1)
0v – 3v	b1 – 0v (0)	b0 – 0v (0)

Table 1: Truth table for the flash ADC at different voltage ranges

Approximation: The low output voltage of 40 uv is considered to be logic zero in this case.

The exported data from Tanner waveform viewer

Time[Seconds]	b0:V[Volts]	b1:V[Volts]	Vin:V[Volts]
0.00E+00	3.70E-06	2.44E-06	0.00E+00
2.50E-08	3.70E-06	2.44E-06	1.57E-02
2.75E-07	3.69E-06	2.44E-06	1.73E-01
1.08E-06	3.68E-06	2.44E-06	6.75E-01
1.88E-06	3.67E-06	2.44E-06	1.18E+00
2.68E-06	3.65E-06	2.44E-06	1.67E+00
3.48E-06	3.63E-06	2.44E-06	2.17E+00
4.28E-06	3.57E-06	2.44E-06	2.65E+00
5.08E-06	8.06E+00	5.56E-06	3.13E+00
5.16E-06	1.00E+01	5.91E-06	3.19E+00
5.20E-06	1.08E+01	5.11E-06	3.21E+00
5.22E-06	1.13E+01	5.91E-06	3.22E+00
5.23E-06	1.17E+01	5.29E-06	3.23E+00
5.25E-06	1.20E+01	6.97E-06	3.24E+00
5.27E-06	1.20E+01	1.16E-05	3.25E+00
5.29E-06	1.20E+01	1.64E-05	3.26E+00
5.30E-06	1.20E+01	1.17E-05	3.27E+00
5.33E-06	1.20E+01	1.64E-05	3.28E+00
5.34E-06	1.20E+01	1.17E-05	3.29E+00
5.42E-06	1.20E+01	1.63E-05	3.34E+00

Conclusion

Comparators and encoders are the two principle and vital parts of flash ADC. The comparator is a device for designing the mixed signal system and speed, area furthermore accuracy which is essentially characterized by its energy dispersal and speed is primary variables for high-speed applications. The encoder is a device that changes over the data starting with one arrangement then onto the next for the purpose of speed and compressions. After surveying the literature in details, we infer that the power utilization and speed assumes a vital part in the design of flash ADC.

Future Work

In future, we will concentrate on the work of the designing of the flash ADC to execute a high-speed ADC with high exactness, reduced size and low offset comparator to furthermore actualize the enhanced flash ADC with low power and high speed. We will import lower technology PTM files in Tanner EDA (7nm – 45nm Node) and redesign the existing circuit with that.

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