University of Dhaka

Computer Science and Engineering

Course Name: Electronic Devices and Circuits Lab

Course Code: EEE-2113

Project Topic: Building a 3-bit Flash Analog to Digital converter

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Introduction:

An ADC (Analog to Digital Converter) produces a digital output (bits) for a specific range of input voltage. The primary purpose of an ADC is to transform continuous analog signals into discrete digital signals. This is essential for interfacing analog real-world phenomena (like temperature, sound, light, etc.) with digital systems such as microcontrollers, computers, and digital signal processors, which can only process digital data. With the advancement of technology, it is a very important device for producing digital signals for digital device as digital devices is much more efficient than analog devices.

From many types of ADC, flash ADCs are the most useful ADC because of their fastest speed than any other ADCs. Flash ADC uses a parallel array of comparators, each comparing the input signal to a different reference voltage and these outputs are fed into priority encoder, which generates the digital output. There are some other types of ADC available like SAR ADC, Sigma-Delta ADC etc. Here will discuss about flash ADC only.

Theory:

Op-Amp (Operational Amplifier): Op-Amp is a widely used electronic circuit because of it’s high gain and stability. It can perform mathematical operation like summing, integration, filtering, amplification. It consists of two input terminal (inverting input and non-inverting input) and an amplified difference between the inverting and non-inverting input, limited by the supplied voltages. Because of high open-loop gain they can produce high output voltage for a small change in input voltage.

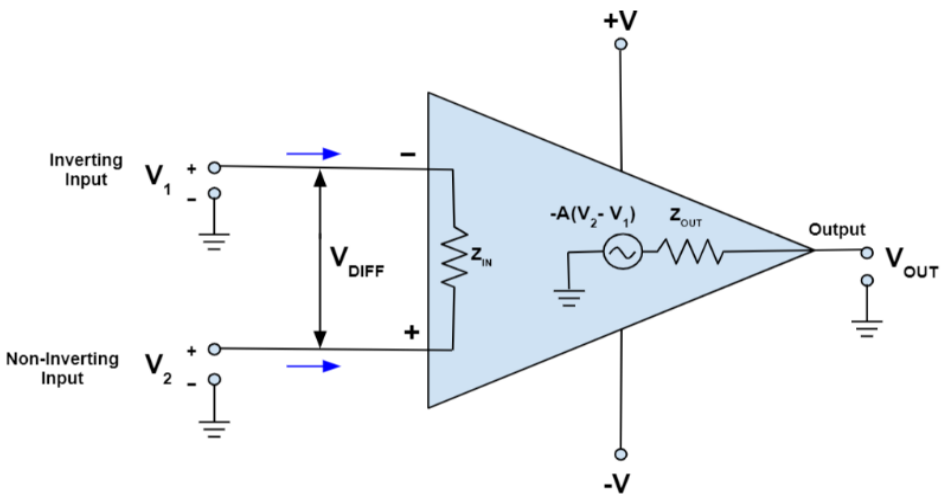

Figure 1: Op-Amp schematic

Comparator: OP-Amp comparators are a type of voltage comparator circuits which compares two voltages and outputs either a 1 or 0 to indicate which is larger. In terms of operation the comparator switches between high and low dependent upon the state of the inputs If the voltage on the non-inverting input is higher than the voltage on the inverting input, the output will create a positive voltage that amplifies the difference in input voltages. Oppositely, if the non-inverting input is lower than the inverting one then the output will saturate to as low of voltage as the op-amp is able to generate. The input voltage connects to the positive end and other connects to the negative end.

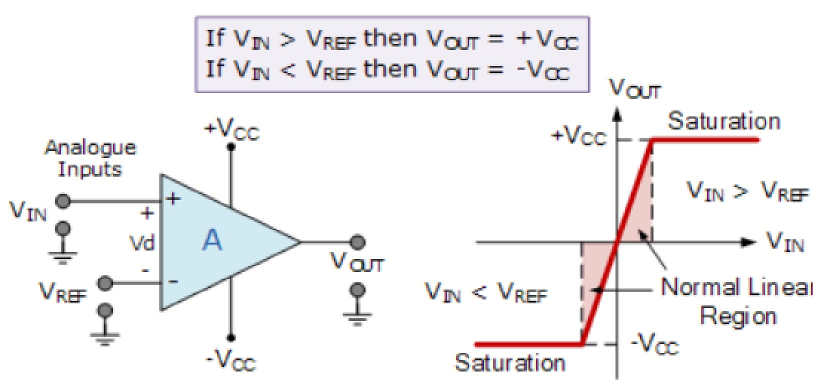

Figure 2: Op-Amp as Comparator

Priority Encoder: Encoder is a combinational circuit which accepts decimal digits and produces digital representation of the inputs. Priority encoder contains 2^n input lines and n output lines. When multiple input lines are active high at the same time, then the input that has the highest priority is considered first to generate the output.

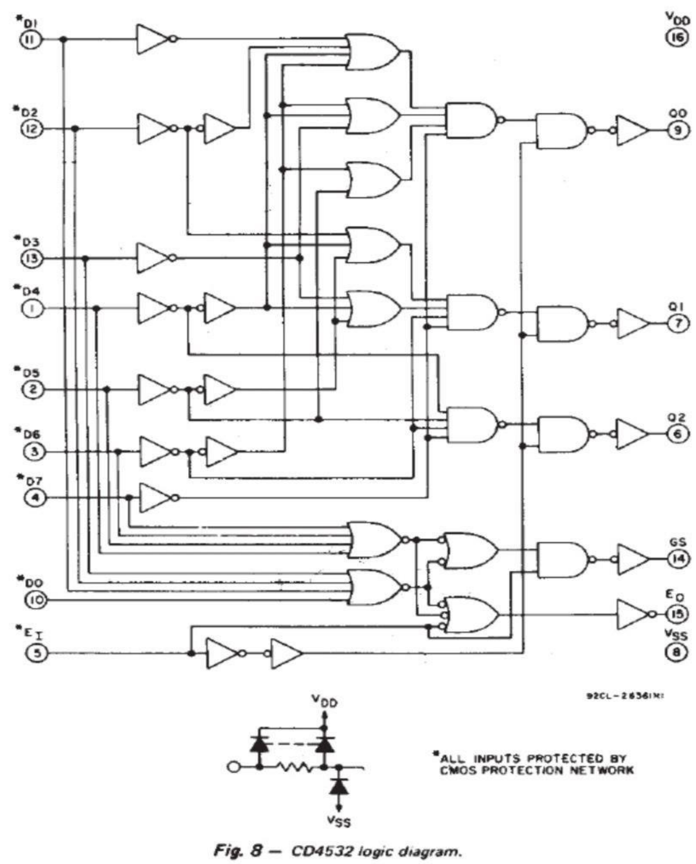

Figure 3: 8 to 3 priority encoder

FLASH ADC: Flash ADC is formed of a series of comparators, each one comparing the input signal to a unique reference voltage. There is a voltage divider network used to establish these reference voltages and divide them into multiple levels. The comparator outputs are connect to the inputs of a priority encoder circuit, which then produces a binary output.

Equipments:

- Operational Amplifier (Op-Amp) (LM-324 X 2)
- Analog Input Signal
- Breadboard
- Resistors Jumper Wires
- DC Power Supply
- LEDs (3)
- Multimeter
- Priority Encoder (CD4532)

Circuit Description:

V_{ref} is a stable reference voltage provided by a precision voltage regulator

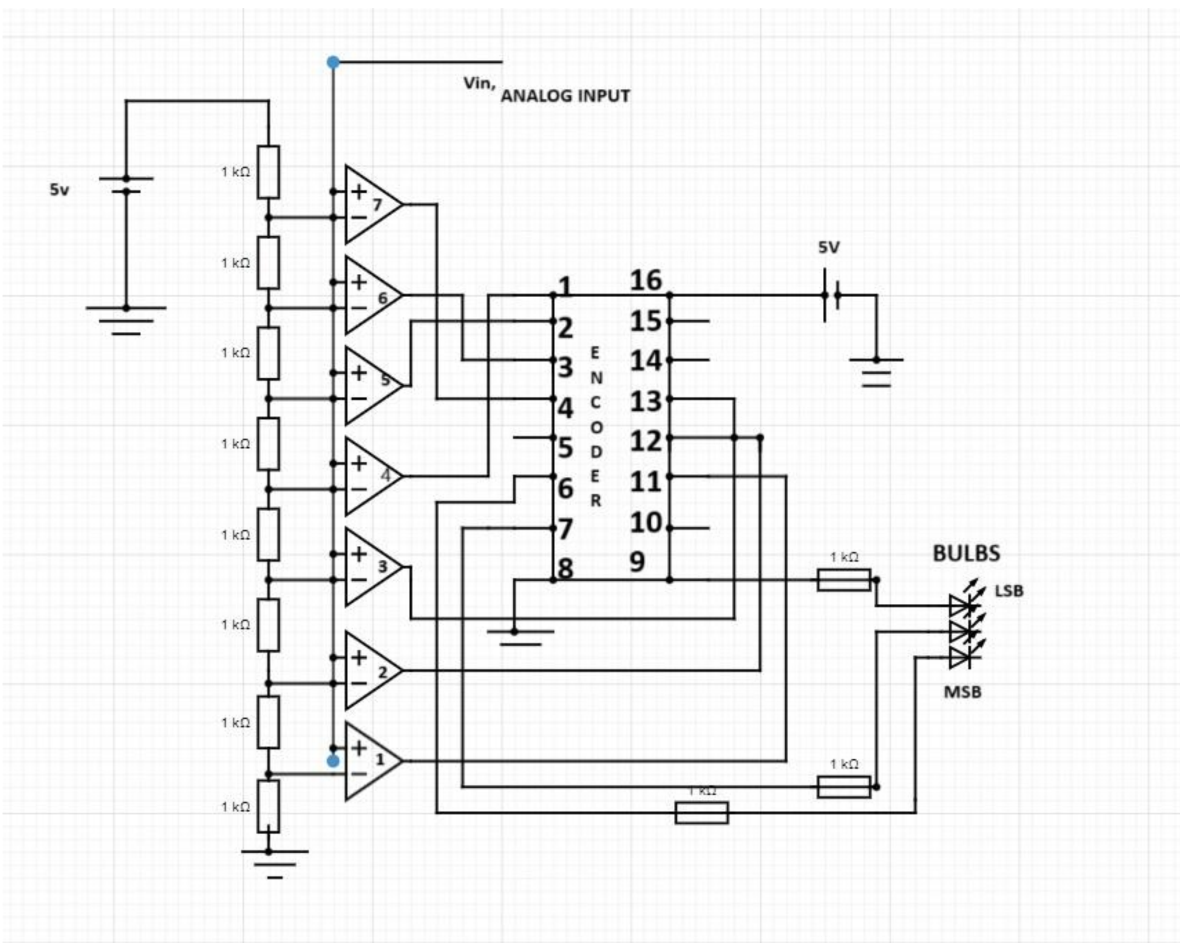

Figure 4: Flash ADC circuit design

as part of the converter circuit. As the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state. The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs. Finally, the 3-bit digital output was connected to three LEDs, with each LED representing a single bit (Not shown in the schematic. LEDs will be placed in binary output with resistors).

Working Procedure:

- **Setting Reference Voltages:** The first step involves setting up reference voltages for each comparator. These reference voltages divide the input voltage range into several levels. We used 5V as reference voltage. So, the voltages in our inverting terminal of our comparator will be – (with respect of ground)
    - Comparator 1: 0.625V
    - Comparator 2: 1.25V
    - Comparator 3: 1.875V
    - Comparator 4: 2.5V
    - Comparator 5: 3.125V
    - Comparator 6: 3.75V
    - Comparator 7: 4.375V

- **Setting and Comparing input Voltage:** Now we will give input voltage to the circuit from 0. Each comparator compares the input voltage with its corresponding reference voltage. If the input voltage is greater than the reference voltage, the comparator output goes high; otherwise, it remains low.
- **Priority Encoding:** The outputs of all comparators are connected to a priority encoder. The priority encoder determines the highest order active input and produces a binary output corresponding to its position. All other comparator outputs are ignored. Suppose if

converter 5 is high than it will show output ‘101’ and the lower binary output will be ignored.

- **LED Display:** If we add three LED with resistors connected with the output of priority encoder than we can see the binary bits properly from 0 to 7. With increasing of input voltages the output will be goes from 0 to 7.

Table: This table shows the input voltage range and corresponding unique binary output.

Input Voltage Range (V)	Binary Output
0-0.625	000
0.625-1.25	001
1.25-1.875	010
1.875-2.5	011
2.5-3.125	100
3.125-3.75	101
3.75-4.375	110
4.375-5	111

Problems: At first we faced problem setting up two of our voltage sources. That’s why we got some problems in our result. After fixing this problem we faced a problem with our priority encoder. We used a TTL encoder first. When we connect our LEDs with this it was showing error results though we checked the output of our comparator outputs manually. This was not working properly. Then we bring this CMOS type priority encoder and the problem was solved.

Status of LED in different voltage:

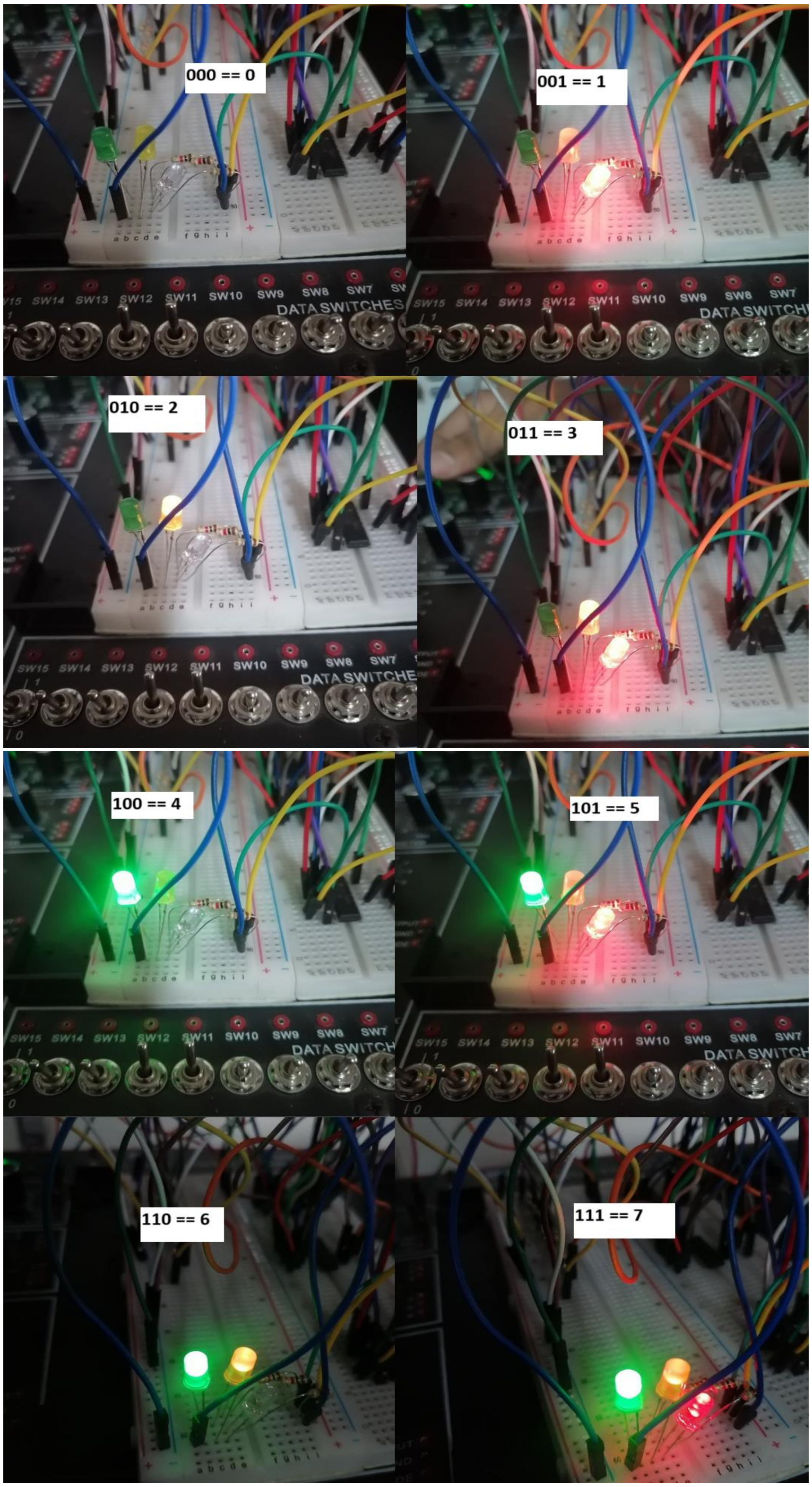

Figure 5 status

Discussion: Flash ADC is the fastest ADC and very most frequently used in electronics industry nowadays. Using op-amps, we were able to successfully build a 3-bit flash A/D converter. The analog input voltage's equivalent digital output was rendered visually visible by the LEDs. ADCs play a crucial role in various electronic systems, including communication devices, instrumentation, consumer electronics and digital signal processing. It has some limitations. It consumes high power, cost is high because we need many comparators, and including of priority encoder make this more complex.

Some Useful Reference:

OP-Amp Basics (monolithic power)

electronics-tutorials_op-amp-comparator

allaboutcircuits_flash-adc

electronics-lab_priority-encoder

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