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CSE 350: Digital Electronics and Pulse techniques

Exp-01: Flash Analog to Digital converter (ADC)

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Objectives

1. To analyze a 2-bit flash analog to digital converter.

Equipment and component list

Equipment

1. Digital Multimeter
2. Trainer board

Component

- Single Supply Quad Operational Amplifier - LM324 - x1 piece
- 8-to-3 Line Priority Encoder - IC74148 - x1 piece
- Resistors -
    - 10 KΩ - x4 pieces

Task-01: Flash ADC

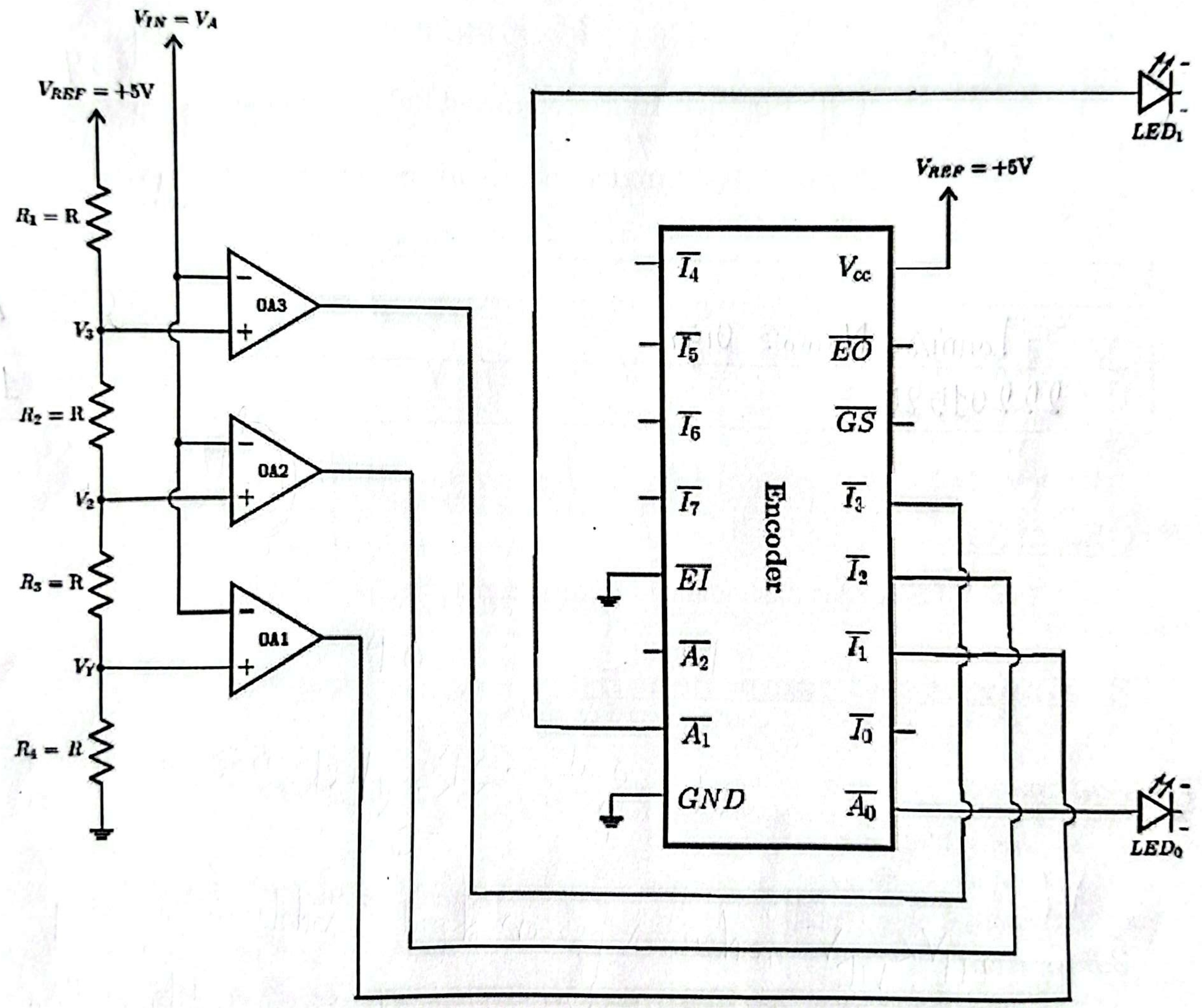
THEORY

Flash ADC is the fastest analog-to-digital converter. You can see the circuit diagram of a 2-bit flash ADC in figure 1. All the op-amps operate as comparators in this circuit. The analog input (V_A) is applied to the 'inverting' input of the three op-amps.

There is a resistive ladder-network with a reference voltage $V_{REF} = 5$ V at the top of the network. We will obtain some fixed voltages at each node of this network. These nodes are denoted as V_1, V_2 and

V_3 . Then, we connected the V_1 node to op-amp 1 (OA1). Similarly, the other two nodes are connected to the corresponding op-amps.

Now, let us calculate the node voltages V_i's of the ladder network. For this, keep in mind that the current towards the op-amp's input terminals are negligible. First, the total resistance of the ladder network is



$$R_{Total} = \Sigma R_i = R_1 + R_2 + R_3 + R_4 \qquad (1)$$

Figure 1: Flash Analog to Digital

So, using Ohm's law, the current through the ladder network will be (same current flows through all the R_i's

$$I_{ladder} = \frac{V_{REF} - 0}{R_{Total}} = \frac{V_{REF}}{4R} \qquad (2)$$

It is now trivial to calculate all the node voltages. The equations for all the node voltages are given below for your convenience.

$$V_1 = IR_4 = \frac{V_{REF}}{4} \qquad (3)$$

$$V_2 = I(R_3 + R_4) = \frac{V_{REF}}{2} \tag{4}$$

$$V_3 = I(R_2 + R_3 + R_4) = \frac{3V_{REF}}{4} \tag{5}$$

Now, closely analyze the operation of all the op-amps. OA1 has input voltage V_A at its '–' input (inverting input) and V_1 at '+' input (non-inverting input). If $V_A < V_1$, OA1 will give a HIGH output. Similarly, OA2 will give HIGH output if $V_A < V_2$ and OA3 if $V_A < V_3$.

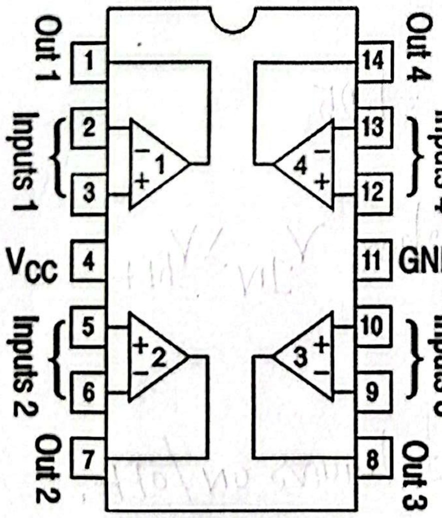
Next, we send the outputs of all the op-amps to a priority encoder. We will then get our desired 2-bit digital signal at the output of this encoder which corresponds to the original analog input signal.

For this flash ADC design, we will need $2^n - 1$ op-amps for implementing an n-bit ADC. This presents a huge disadvantage in terms of practical implementation in the laboratory.

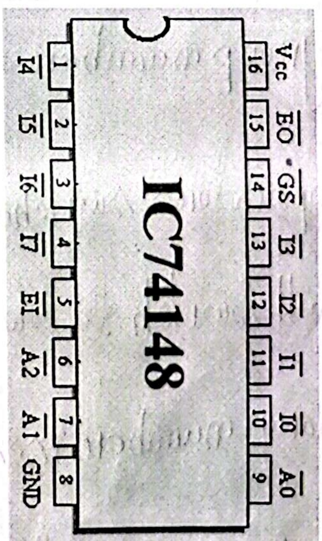
Procedure:

1. Construct the circuit as shown in figure 1. Consider, $R = 10\ K\Omega$.
2. We will not use any external LEDs. Connect the outputs of the encoder to the LEDs of the Trainer Board.
3. Vary the analog input voltage, V_{IN} or V_A from 0V to 5V.
4. Observe when the two LEDs switch ON or OFF and measure the input voltage which causes the transitions. Fill up data table 1 using this data.

Note: The encoder is "Active LOW". This means that whenever the output (A_0, A_1) is supposed to be "Logical 1", they are at a LOW voltage. Hence, the corresponding LED will turn OFF!



LM324 IC (Quad Op-Amp) pin diagram



74148 IC (Encoder) pin diagram

Data Tables

Table 1: Flash AD Converter.

Input Voltage $V_{IN} = V_A$	State of LED_1	State of LED_0	Digital Binary Output
0.6	ON	ON	00
1.8	ON	OFF	01
3.1	OFF	ON	10
4.2	OFF	OFF	11

Table 1: Data Table for Flash AD Converter

Lab Task 1

Use your "group number" as input voltage V_A and observe the binary digital output using LEDs. Then, measure the output voltages using a multimeter. If the group number is greater than 5, divide it by 2 and use the resultant value as input. Explain the reason for obtaining the binary output using the voltages you have measured.

Input Voltage $V_{IN} = V_A$	Digital Binary Output
4.0	11

group number $= 12/3 \Rightarrow 4$, $\frac{5-0}{4} = 1.25$

The comparators switches to high voltages, when $V_{IN} > V_{REF}$ and it will switch to low, when $V_{IN} > V_{REF}$

The binary number is sent in the LED's, that turns ON/OFF.

V_{IN} Range	Binary output
0-1.25	00
1.25-2.5	01
2.5-3.75	10
3.75-5	11

∴ 4 is in range of (3.75-5), binary output 11.

Lab Task 2

Adjust the input voltage such that we get Binary output 00 and 01. For each case, measure the output voltages of the encoder. Explain why the LEDs turn on or off. (Note: disconnect the LEDs when measuring the output voltages)

The LED will turns 'ON', when it gets a high signal and turns 'OFF', when it get's a low signal. The encoder outputs either 0/1, depending on analog input voltage.

Output bits. A_1A_0	Output voltage (V)	
00	2.4	2.4
01	3.1	3.2

Lab Task 3

Measure the voltages of points V_3, V_2 and V_1. Do the values match with the theory?

$V_1 = 1.25V$, $V_2 = 2.5V$, $V_3 = 3.75V$

Yes, the values almost exactly matches with our theoratical value, which we had calculated.

V_1 (V)	V_2 (V)	V_3 (V)
1.2	2.4	3.7

Signature

Report

1. Write down an advantage and a disadvantage of a Flash AD converter.

Ans. Writing down the advantage and disadvantage of a flash AD converter:

advantages: (i) It has very fast conversion speed, and it is use as the fastest ADC

(ii) It has low laterate or minimal delay

(iii) It is used for high application of frequency

disadvantages: (i) This setup is expensive compared with others.

(ii) Requires too much components

(iii) only practical for low resolution conversions.

2. If we wanted to build a 3-bit Flash AD converter, how many resistors and comparators (op-amps) would we need?

Ans. Given, 3 bit Flash AD converter,

$n = 3$

resistors need $\Rightarrow 2^n = 2^3 = 8$

comparators need $\Rightarrow 2^n - 1 = 2^3 - 1 = 8 - 1 = 7$

3. Write a discussion and include the following: your overall experience, accuracy of the measured data, difficulties experienced, and your thoughts on those.

→ while doing the experiment, my overall experience was pretty good. I got to learn many more things practically, which we had learned theoratically. While measuring the data, one of our resistor was faulty, but after the change of that perticular resistor, we started getting mostly accurate values. The circuit seems to be complex. But the making and step, made that easy at the end. We almost got, similar values, with the theoratical values. That matched pretty well. We got to learn about ADC converter more practically, while completing this lab physically.