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CSE 350: Digital Electronics and Pulse techniques

Exp-05: Flash Analog to Digital converter (ADC)

Name: Tasnia Jannat Ayesha	Section: 11
ID: 21301611	Group: 2

Objectives

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

Equipment and component list

Equipment

1. 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 - x7 pieces ♦ 1 KΩ - x2 piece

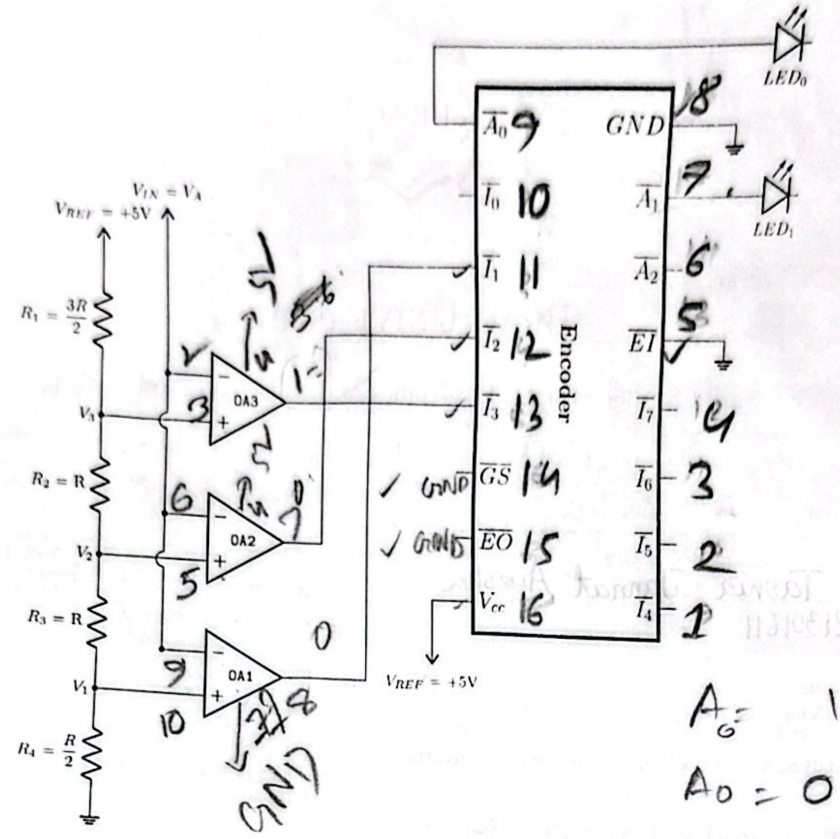


Figure 1: Flash Analog to Digital Converter (ADC)

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 comparator in this circuit. The analog input (V_A) is applied to the 'non-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 these network. These nodes are denoted as V_1, V_2 and V_3. Then, we have 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 op-amp's input terminals are negligible. First, the total resistance of the ladder network is

$$R_{total} = \sum R_i = R_1 + R_2 + R_3 + R_4 = 4R. \tag{1}$$

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

$$I_{ladder} = \frac{V_{REF} - 0}{R_{total}} = \frac{V_{REF}}{4R}. \tag{2}$$

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

$$V_1 = IR_4 = \frac{V_{REF}}{4R} \times \frac{R}{2} = \frac{V_{REF}}{8} \tag{3}$$

$$V_2 = I(R_3 + R_4) = \frac{V_{REF}}{4R} \times \frac{3R}{2} = 3 \times \frac{V_{REF}}{8} \tag{4}$$

$$V_3 = I(R_2 + R_3 + R_4) = \frac{V_{REF}}{4R} \times \frac{5R}{2} = 5 \times \frac{V_{REF}}{8} \quad (5)$$

Now, closely analyze the operation of all the op-amps. OA1 has input voltage V_A at its '+' input (non-inverting input) and V_1 at '-' input (inverting input). If $V_A > V1$, 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 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 switches ON or OFF and measure the input voltage which causes the transitions. Fill up data table 1 using these 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!

Data Tables

Fill up the table for the Flash AD Converter.

Input Voltage $V_{IN} = V_A$	State of LED1	State of LED0	Digital Binary Output
0·0	ON	ON	00
1·89	ON	OFF	01
3·07	OFF	ON	10
4·42	OFF	OFF	11

Table 1: Data Table for Flash AD Converter

Signature

Report

Please answer the following questions briefly in the given space.

1. Use your "group number" as input voltage V_A and observe the output. If group number is greater than 5, divide by 2 and use the resultant value as input. Explain the reason for obtaining the output.

Ans.

$2.04 \rightarrow 01$

We gave $V_A = 2.04$ V. Then we got the digital binary output 01. For this 2 bit flash ADC there are 4 Quantization level. For the range 1.25 V to 2.5 V fold we were supposed to get the output 01. As we gave 2.04V as input we got 01. here LED A1 is ON and LED A0 is OFF.

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)

Ans. For binary output 01 we gave the input voltage 1.63 V. For this case A1 will be ON (Logical 0) as A1 will be at low (0). LED A_0 will be OFF (Logical 1) as A_0 will be at High (1). The output voltage of the encoder was,

$$A_0 = 0.16\text{ V},\ A_1 = 2.6\text{ V}$$

For binary output 00 we gave the input voltage 0V. For this case A_1 and A_0 will be at LOW (0). Both LEDs are ON, it represents "Logical 0". The output voltage of the encoder was,

$$A_0 = 0.00\text{ V},\ A_1 = 0.00\text{V}$$

Active low logic means that "Logical 1" turns the LED ON, and "Logical 0" turns the LED off.

3. Write down an advantage and disadvantage of Flash AD converter.
Ans.

advantage: It is the fastest type of ADC because the conversion is performed simultaneously through a set of comparators.

disadvantage: To design n-bit ADC we need $2^n - 1$ op-amps. This presents a huge disadvantage in terms of practical implementation in laboratory.

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

Practically we got, $V_1 = 1.42$, $V_2 = 2.67$, $V_3 = 3.78$.

Theory based,
$$V_1 = \frac{V_{REF}}{8} = \frac{5}{8} = 0.625$$

$$V_2 = 3 \times \frac{V_{REF}}{8} = \frac{3 \times 5}{8} = 1.875$$

$$V_3 = 5 \times \frac{V_{REF}}{8} = \frac{5 \times 5}{8} = 3.125$$

The values don't match with the theory

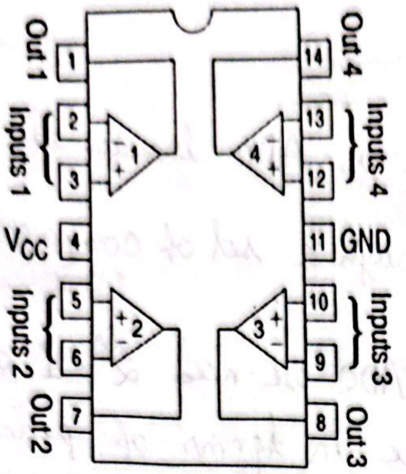
5. If we wanted to build a 3-bit Flash AD converter, how many resistors and comparators (op-amps) would we need?
Ans.

For 3-bit Flash AD converter,

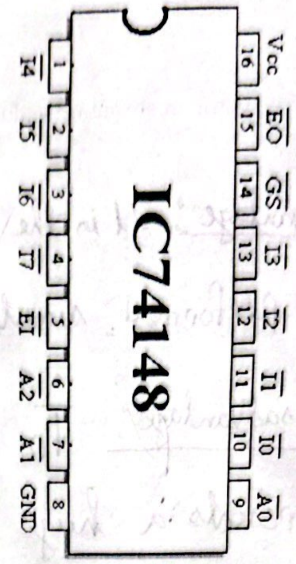
$$\text{op-amps} = 2^n - 1 = 2^3 - 1 = 7$$

$$\text{resistors} = 2^n = 2^3 = 8$$

We will need 8 resistors and 7 op-amps.



LM324 IC (Quad Op-Amp) pin diagram



74148 IC (Encoder) pin diagram

	INPUTS								OUTPUTS		
EI	0	1	2	3	4	5	6	7	A2	A1	A0
H	X	X	X	X	X	X	X	X	H	H	H
L	H	H	H	H	H	H	H	H	H	H	H
L	X	X	X	X	X	X	X	L	L	L	L
L	X	X	X	X	X	X	L	H	L	L	H
L	X	X	X	X	X	L	H	H	L	H	L
L	X	X	X	X	L	H	H	H	L	H	H
L	X	X	X	L	H	H	H	H	H	L	L
L	X	X	L	H	H	H	H	H	H	L	H
L	X	L	H	H	H	H	H	H	H	H	L
L	L	H	H	H	H	H	H	H	H	H	H

74148 IC (Encoder) Truth Table