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CSE 350: Digital Electronics and Pulse techniques

Exp-05: 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. 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

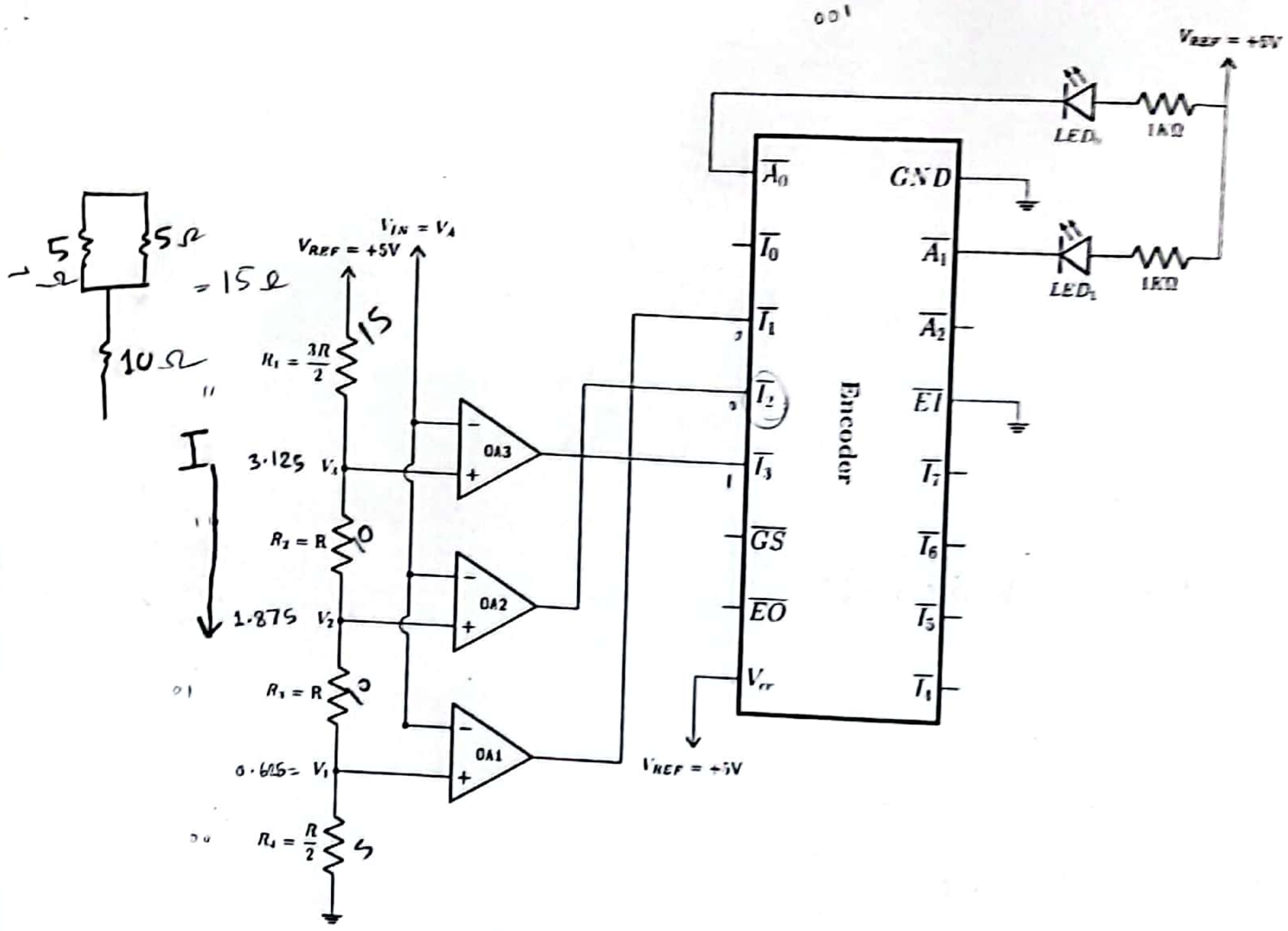


Figure 1: Flash Analog to Digital Converter (ADC)

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.

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

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

$$V_3 = I(R_1 + R_2 + R_3) = \frac{V_{REF}}{4R} \times \frac{3R}{2} = 3 \times \frac{V_{REF}}{8} \tag{5}$$

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 $V_A > V_1$, 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 laboratory.

Procedure:

1. Construct the circuit as shown in figure 1. Consider, $R = 10\ K\Omega$
2. Vary the analog input voltage, V_{IN} or, V_A from 0V to 5V.
3. 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.

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 - 0.7	OFF	OFF	00
0.7 - 2.0	OFF	ON	01
2.0 - 3.2	ON	OFF	10
3.2 - 5	ON	ON	11

Table 1: Data Table for Flash AD Converter

Signature

$2_{(VA)} \rightarrow 10$

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.

group number = '2'

for 2V input voltage V_A we got output binary $=(10)_2$ this result matches the input voltage range from oure data table for $(10)_2$, which is $\boxed{2.0V-3.2V}$

We obtained this output because, for the circuit we used:

$2V < V_3$, so only OA1 and OA1 will have higher voltage at the inverting input and give low(0) output to the active-low pin of the encoder IC. As $\bar{I}_2$ has higher priority, the encoder will give binary output of $(2)_{10}$ as $(10)_2$.

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. After adjusting the input voltage such that we get Binary output $\boxed{00}$,

output voltages of the encoder

at A_0 pin $= 2.38V$

at A_1 pin $= 2.38V$

And after adjusting the input voltage such that we get Binary output $\boxed{01}$,

output voltages of the encoder

at A_0 pin $= 0.1211$ V

at A_1 pin $= 2.415V$

for our experiment circuit,

the LEDs turn on for high voltage/when binary output 0.

the LEDs turns off for low voltage/when binary output 1.

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

Ans.

The advantage of Flash AD converter is, it can do the convertion process from analog to digital very fast.

The disadvantage of Flash AD converter is, it requires a lot of power supply and large space for the comparators.

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

Ans. according to data table measurement,

$$V_1 = 0.7\,V$$
$$V_2 = 2.0\,V$$
$$V_3 = 3.2\,V$$

according to theory:

current from V_{ref} to ground, $I = \frac{5}{R_1+R_2+R_3+R_4} = \frac{5}{(\frac{3}{2}+1+1+\frac{1}{2})R} = \frac{5}{4R}$

now, $V_1 = I \cdot \frac{R}{2} = \frac{5}{4R} \times \frac{R}{2} = 0.625V$

$$V_2 = V_1 + IR = V_1 + \frac{5}{4R} \times R = 0.625 + \frac{5}{4} = 1.875\,V$$

$$V_3 = V_2 + IR = V_2 + \frac{5}{4R} \times R = 1.875 + \frac{5}{4} = 3.125\,V$$

$\therefore$ the values closely matches the theory with slight changes due to manual measurement

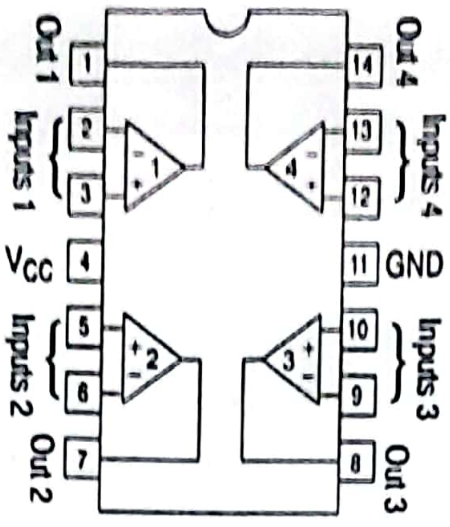
5. If we wanted to build a 3-bit Flash AD converter, how many resistors and comparators (op-amps) would we need?

Ans.

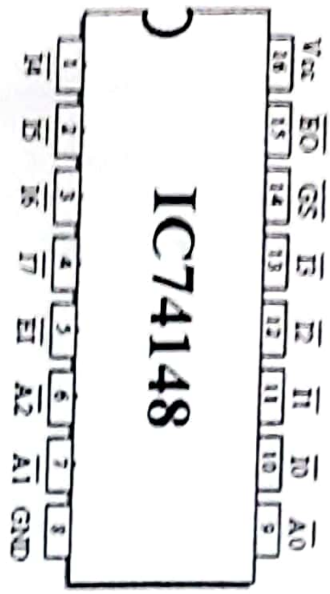
If we wanted to build a 3-bit Flash AD converter we would need,

resistors number $= 2^3 = 8$

comapators(op-amps) number $= 2^3 - 1 = 7$



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