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CSE 350: Digital Electronics and Pulse techniques

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

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 - 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 op-amp's input terminals are negligible. First, the total resistance of the ladder network is

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

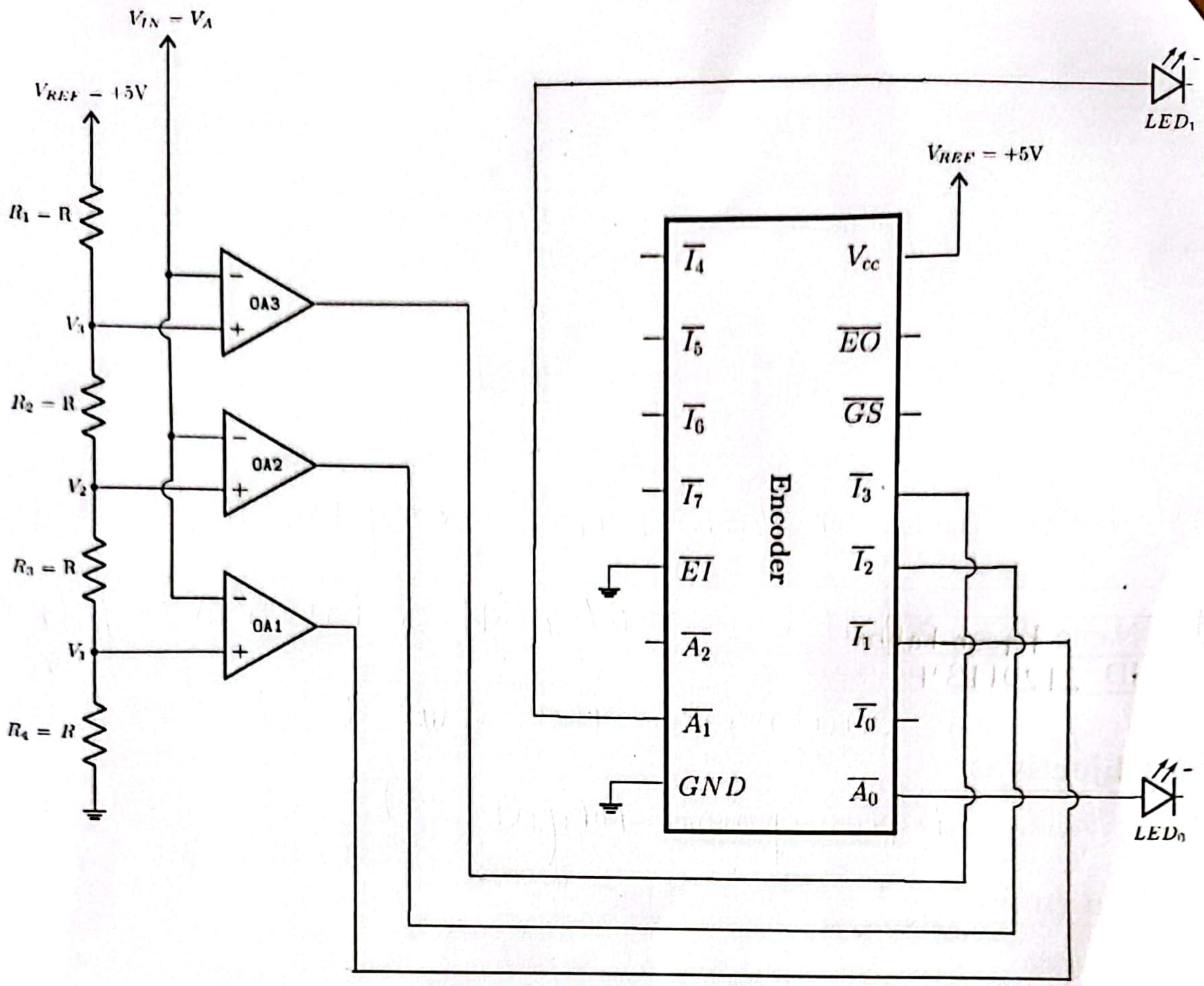
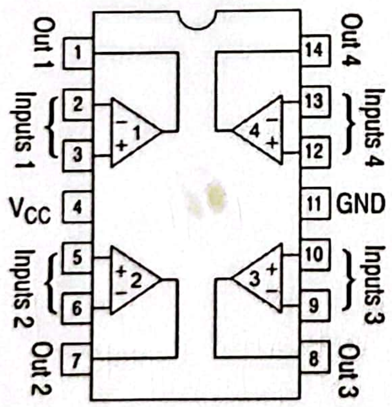
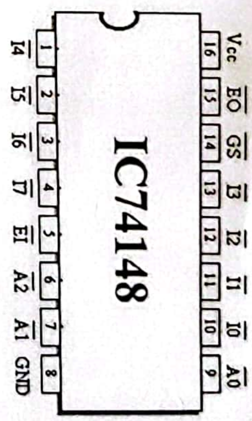


Figure 1: Flash Analog to Digital



LM324 IC (Quad Op-Amp) pin diagram



74148 IC (Encoder) pin diagram

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.

$$V_1 = IR_4 = \frac{V_{REF}}{4} \tag{3}$$

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

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

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 KΩ.
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 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!

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
187.7 mv	ON	ON	00
1.340 v	ON	OFF	01
2.585 v	OFF	ON	10
3.89 v	OFF	OFF	11

Table 1: Data Table for Flash AD Converter

Shafayat
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 the group number is greater than 5, divide it by 2 and use the resultant value as input. Explain the reason for obtaining the output.

Ans.

Input Voltage	State of LED1	State of LED2	Output Digital Binary
VA = 5.02V	off	off	11

When input voltage $V_A = 5$, it is higher than the reference voltages V_1, V_2 and V_3. No reference voltage exceeds the input voltage because all comparators are of low output, which means "off". Digital binary output will be 11.

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.

Output bits. A_1A_0	Output voltage (V)	
00	2.162	2.401
01	~~0.4~~ 40.1mV	1.440

For 00 output, the output voltages are above the low threshold for an active low encoder. Therefore, outputs are high which means logical '0' for Active low. LED's will be 'on' since the encoder outputs low voltage to switch them ~~off~~.

For 01 output, ~~output voltage A_1 is low~~ A_1 is low and A_0 is above low threshold which means is high (logical 0 for active low). LED A_1 will be off, LED A_2 will be on.

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

Advantage: Fastest ~~Analog Digital (AD)~~ converter which is suitable for bandwith with larger application.

Disadvantage: Costly, Requires a lot more components. Power consumption is higher.

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

V_1 (V)	V_2 (V)	V_3 (V)
1.275	2.509	3.77

$$V_1 = \frac{R}{4R} \times 5$$

$$= 1.25 \simeq 1.275\,V$$

$$V_2 = \frac{2R}{4R} \times 5 = 2.5 \simeq 2.509\,V$$

$$V_3 = \frac{3R}{4R} \times 5 = 3.75 \simeq 3.77\,V$$

Yes, the values match with theory.

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

No. of comp $= 2^n - 1$ $\quad\because$ Given, $n = 3$

$2^3 - 1$ $\quad$ Resistor $= 2^n$

$= 8 - 1$ $\quad = 2^3$

$= 7$ (comparator) $\quad = 8$ (Resistor)

Discussion:

* Learnt how ~~a ft to~~ convert analog to digital using Comparator and resistor.

* One part of the breadboard was not working properly. So, we had to change the position of our circuit in the breadboard.

* In the ~~fur~~ future, it will help me to build an Analog to Digital ~~comp~~ converter using comparator and resistor.