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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. 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

$$R_{Total} = \Sigma R_i = R_1 + R_2 + R_3 + R_4 \tag{1}$$

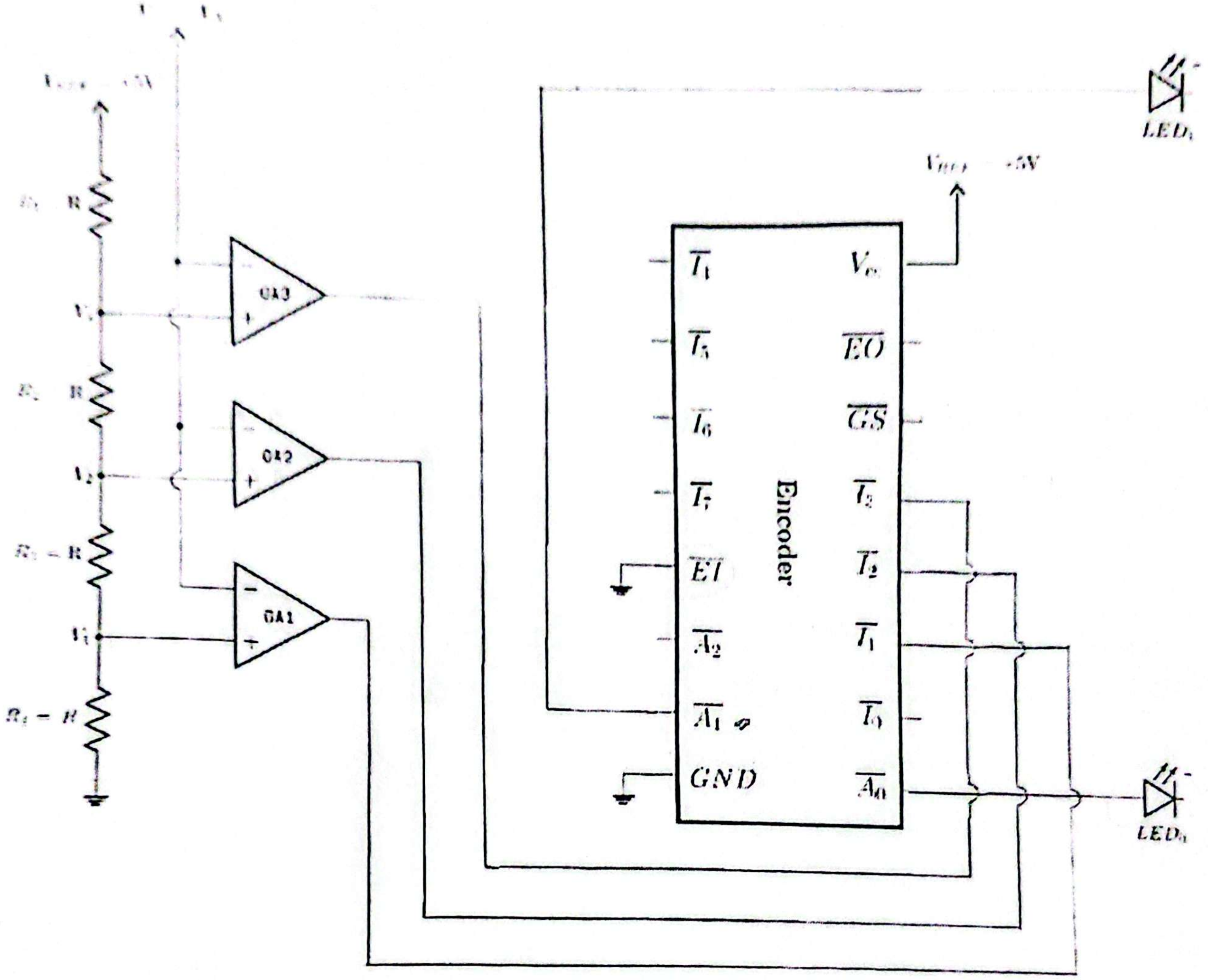
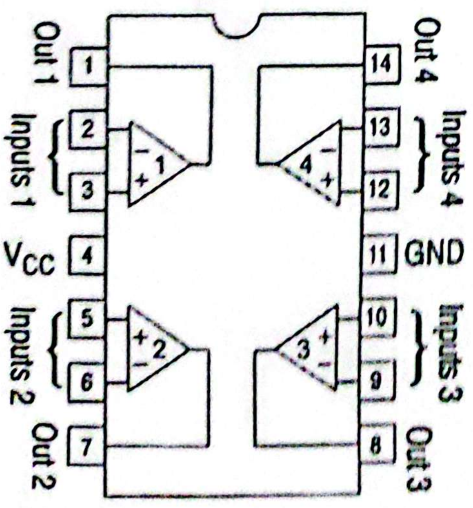
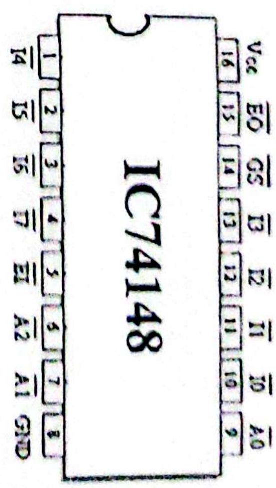


Figure 1: Flash Analog to Digital



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 Ri's

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

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

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

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

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

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 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!

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 - 1.5	ON	ON	00
1.5 - 2.6	ON	OFF	01
2.6 - 3.8	OFF	ON	10
3.8 - 5	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 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.

Group number = 10

$\therefore V_A = \frac{10}{2} = 5$

$A_0 = 5.4$ mV

$A_1 = 5.5$ mV

Since $V_A = 5$, it falls in the range 3.8 to 5V, the output is 11. The reason for obtaining the output is priority encoder. Among all the high comparators, 11 is the highest, that's why we get it as output.

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 turn off when the output is '01' and turn on when the output is '00' due to active low logic. That means when the output bit is logical 0, there is high voltage and if the output bit is logical 1, there is low voltage.

Output bits. A_1A_0	Output voltage (V)	
00	2.7	2.78
01	2.91	0.3

Lab Task 3

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

According to theory,

$V_1 = \frac{5}{4} = 1.25$ V

$V_2 = 5/2 = 2.5$ V

$V_3 = \frac{3}{4} \times 5 = 3.75$ V

V_1 (V)	V_2 (V)	V_3 (V)
1.26	2.51	3.76

So, the measured values and theoretical values are almost same.

Ehtashamu

Signature

CamScanner

Report

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

Ans.

Advantage: It is very fast, convert the Analog signal to digital signal in one cycle as all the comparators works simultaneously.

Disadvantage: Requires lots of components. For n-bit flash ADC, $2^n - 1$ comparators and 2^n resistors are required.

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

Ans.

For n-bit flash ADC,

$2^n - 1$ comparators $= 2^3 - 1 = 7$ comparators

2^n resistors $= 2^3 = 8$ resistors.

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

The Flash ADC experiment provided a clear understanding of high-speed analog to digital conversion using comparators and a priority encoder. The measured data was mostly accurate with minor deviations near voltage thresholds due to component tolerances and noise. Setting up the resistor ladder and maintaing stable reference voltages was challenging Ocational comparator instability highlighted the need for precise components and clean wiring Despite these issues, the digital outputs responded as expected with changes in input voltage. Overall, the ~~experience~~ experiment was informative and emphasized the practical challenges in designing accurate and fast ADC circuit.