Digital to Analog Converter (DAC) and Analog to Digital Converter (ADC)

Objective: Construct and study DAC and ADC.

Background: Digital-to-Analog converters (DACs) and Analog-to-Digital converters (ADC) are important building blocks which interface sensors (e.g. temperature, pressure, light, sound, cruising speed of a car) to digital systems such as microcontrollers or PCs. An ADC takes an analog signal and converts it into a binary one, while a DAC converts a binary signal into an analog value.

Digital to Analog Converter: Addition of digital inputs (0 or 1, where say 1 corresponds to 5 volt) give rise to analog output, which can be added with different weights considering their place in binary number. But this type of circuit has a disadvantage of requirement of large number accurate resistors for high number of bits. For example, 8 bit converter requires eight resistors ranging from some value R to $128R$. R/2R ladder DAC circuit (Figure 1) eliminates this problem.

Task1: Design a 4 bit R/2R ladder DAC using 741 op amp by choosing components appropriately and test the circuit.

Performance of DAC is characterized by Resolution, Accuracy, Linear errors, Monotonicity and settling time. What above terms mean?

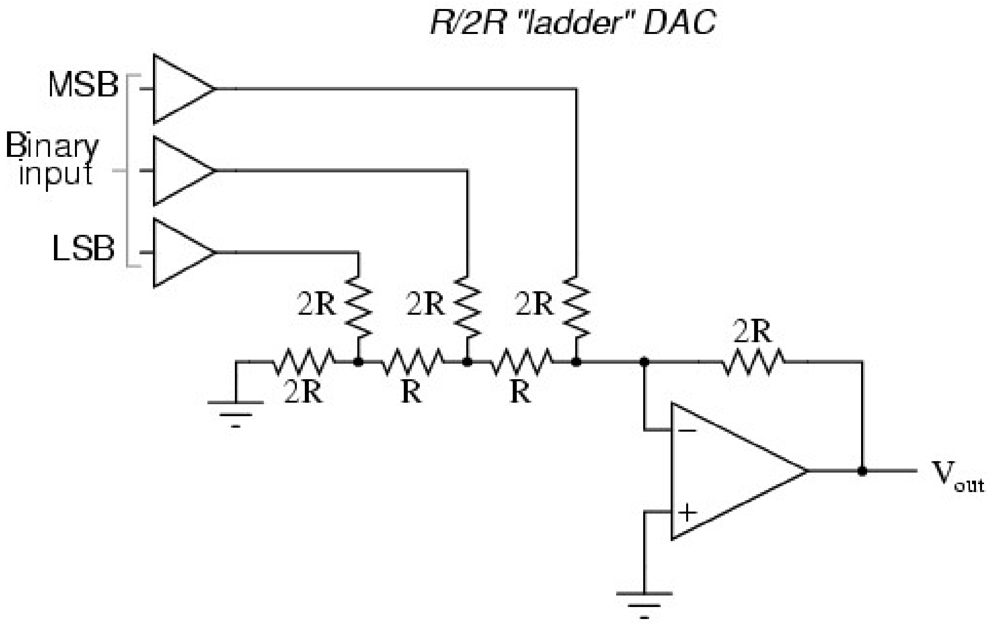


Figure 1. Circuit diagram for digital to anolog conversion

Output voltage of the DAC circuit is given by $V_{out} = -\frac{R_F}{R}\left(\frac{d_1}{2^1} + \frac{d_2}{2^2} + \frac{d_3}{2^3}\right)$ where d_1 is M.S.B and d_3 is L.S.B. In the above circuit, feedback resistance $R_F = 2R$.

Output impedance of the R-2R network is always R, for any number of bits in the network. This is another advantage of the circuit as it simplifies the design of circuits which use DAC such as filtering, amplification etc.

Analog to Digital Converter: This circuit is for conversion of anolog input (any physical quantity such as temperature) to digital output in binary form (which can be read by computer) and further it can be converted to binary decimal format.

Task2: Construct an ADC circuit to convert 2 bit digital input to anolog output

Circuit diagram for the conversion is given in Figure 2. LM339 comparator and 74147 priority encoder are used in this circuit.

Analog input from the DC power supply is compared with reference voltage using LM339 comparator chip and then given to 74LS147 priority encoder chip. Binary output obtained from 74LS147 further can be converted to BCD (Binary coded decimal) format using 7447 chip, which can displayed on common cathode 7-sement BCD display as decimal digit.

Use three out of four comparators available in LM339. IC pin diagrams of LM339 and IC 74147 are given in following pages. Digital binary output can be obtained from D0, D1 and D2 or pin nos. 9,7 and 6 of IC 74147.

Note that LM339 is a quad comparator integrated circuit. It has open collector, therefore requires pull up resistors as shown in Figure 2 at the output of comparator. Use pull up resistors of 3 kΩ. Always use 1 kΩ resistors in series with the LEDs while using LM339 chip. Supply voltage to LM339 can be up to 15 V. Set the reference voltage appropriately. Before connecting ADC circuit, understand the operation of LM339 by connecting one of the comparator and checking the output. Pin diagram of LM339 is given below.

74LS147 is 10 to 4 priority encoder. For this IC, Input is active low and output is active low. Pin diagram is given below. Unused input pins of 74147 should not be left open and they need to be connected to 5 V input supply.

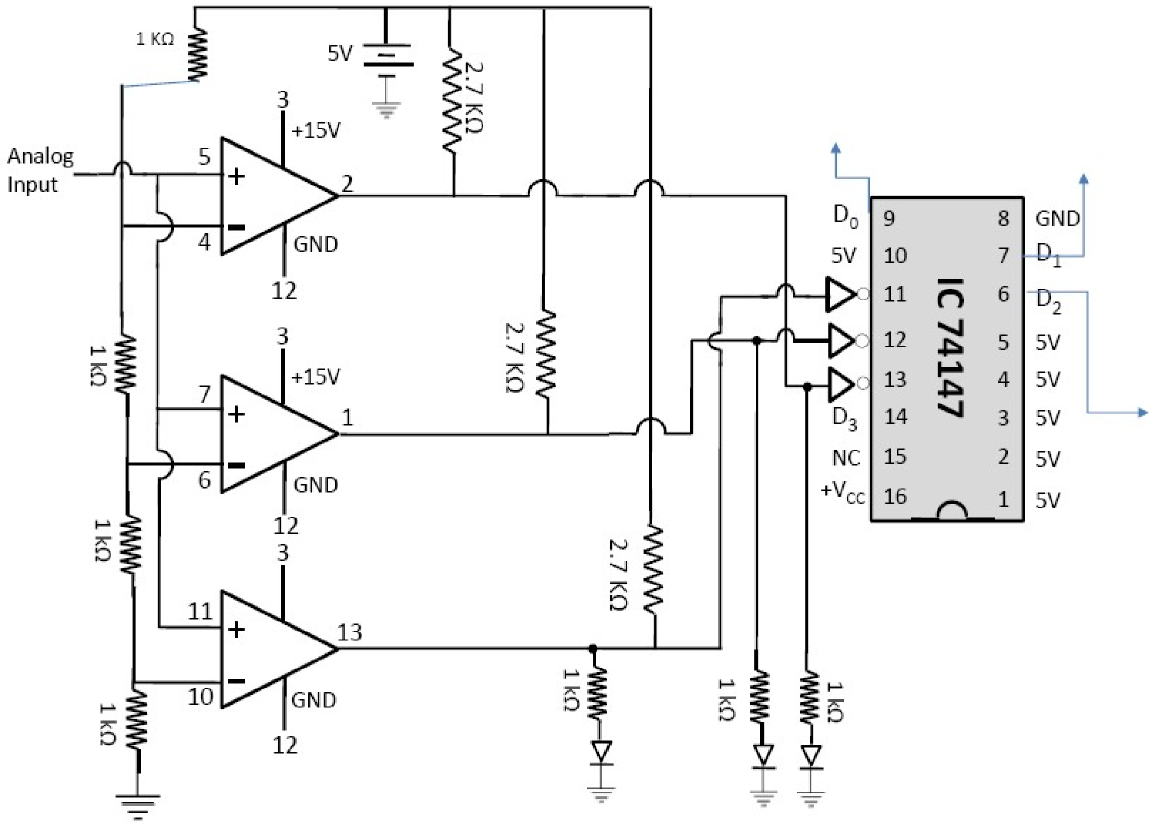
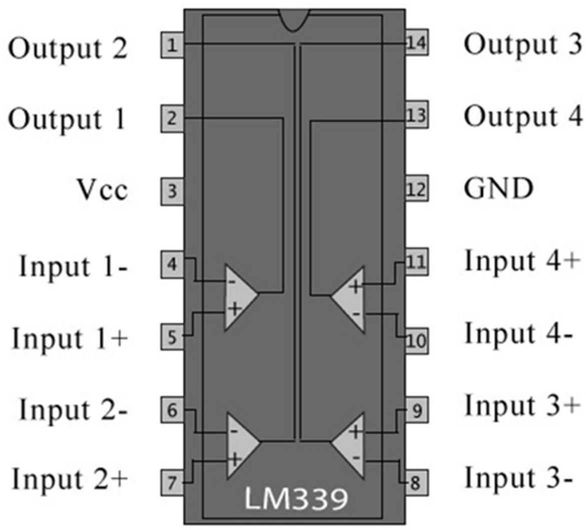


Figure 2.Circuit diagram for 2 bit binary Anolog to Digital conversion



Pin Description:

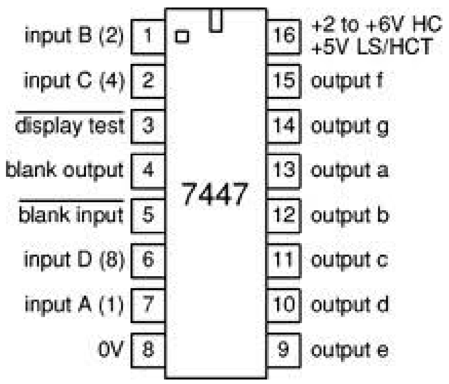
Pin No	Functions of LM339 pins	Name

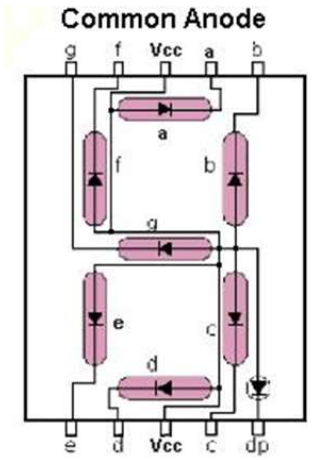
1	Output of 2nd comparator	Output 2
2	Output of 1st comparator	Output 1
3	Supply voltage; 5V	Vcc
4	Inverting input of 1st comparator	Input 1-
5	Non-inverting input of 1st comparator	Input 1+
6	Inverting input of 1st comparator	Input 2-
7	Non-inverting input of 2nd comparator	Input 2+
8	Inverting input of 3rd comparator	Input 3-
9	Non-inverting input of 3rd comparator	Input 3+
10	Inverting input of 4th comparator	Input 4-
11	Non-inverting input of 4th comparator	Input 4+
12	Ground (0V)	Ground
13	Output of 4th comparator	Output 4
14	Output of 3rd comparator	Output 3

Task3 (optional): Conversion of binary display to decimal display

After converting analog voltage to binary number, further it can be converted to binary coded decimal and displayed on a BCD display. Pin diagram for 7447 (binary to BCD decoder) and common anode BCD display are given below. 7447 is an input active high IC and output active low IC. Output of the 7447 must be connected to BCD display via a 330 Ω resistor. There are two types of BCDs. We use in the lab Common anode BCD display, which is input active low.

What are the advantages and disadvantages of this flash conversion method for ADC? Try reconstructing Digital input by combining both ADC and DAC.





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