Practical No.18: Test the output of given R-2R type Digital to Analog Converter for the given input.

I **Practical Significance**

A digital to analog converter (DAC) is a circuit that converts digital numbers into analog voltage or current output. R-2R ladder is a resistive network of which output voltage is a properly weighted sum of the digital inputs. With this experiment you will get an exposure to R-2R network which is used in digital to analog converters.

II **Industry/Employer Expected Outcome(s)**

Students will be able to test the functionality of the digital circuits/system.

III **Course Level Learning Outcome(s)**

Interpret the functions of data converters and memories in digital electronic systems.

IV **Laboratory Learning Outcome(s):**

1. Build R-2R resistive network on breadboard to convert given digital data into analog.

V **Relevant Affective Domain related outcome(s)**

Identify PIN configuration of IC.
Handle the component and equipment carefully.
Follow all safety precaution

VI **Relevant Theoretical Background**

An enhancement of the binary-weighted resistor DAC is the R-2R ladder network. This type of DAC utilizes Thevenin's theorem in arriving at the desired output voltages. The R-2R network consists of resistors with only two values - R and 2R. If each input is supplied either 0 volts or reference voltage, the output voltage will be an analog equivalent of the binary value of the three bits. This is elaborated in fig.18.1.

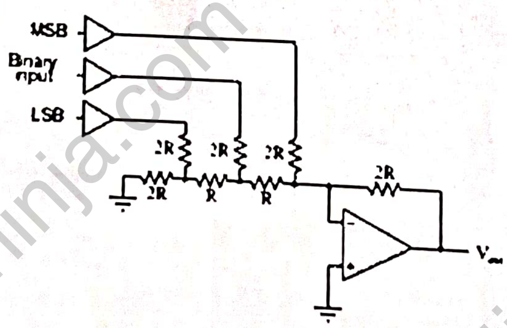


Fig 18.1: Basic diagram of R-2R ladder network working of R-2R ladder network DAC

- R-2R weighted resistor ladder network uses only 2 set of resistors R and 2R. If you want to build a very precise DAC, be precise while choosing the values of resistors that will exactly match the R-2R ratio.

- This is a 4bit DAC. Let us consider the digital data $D_3D_2D_1D_0$=0001 is applied to DAC, then the Thevenin's equivalent circuit reduction is shown below.

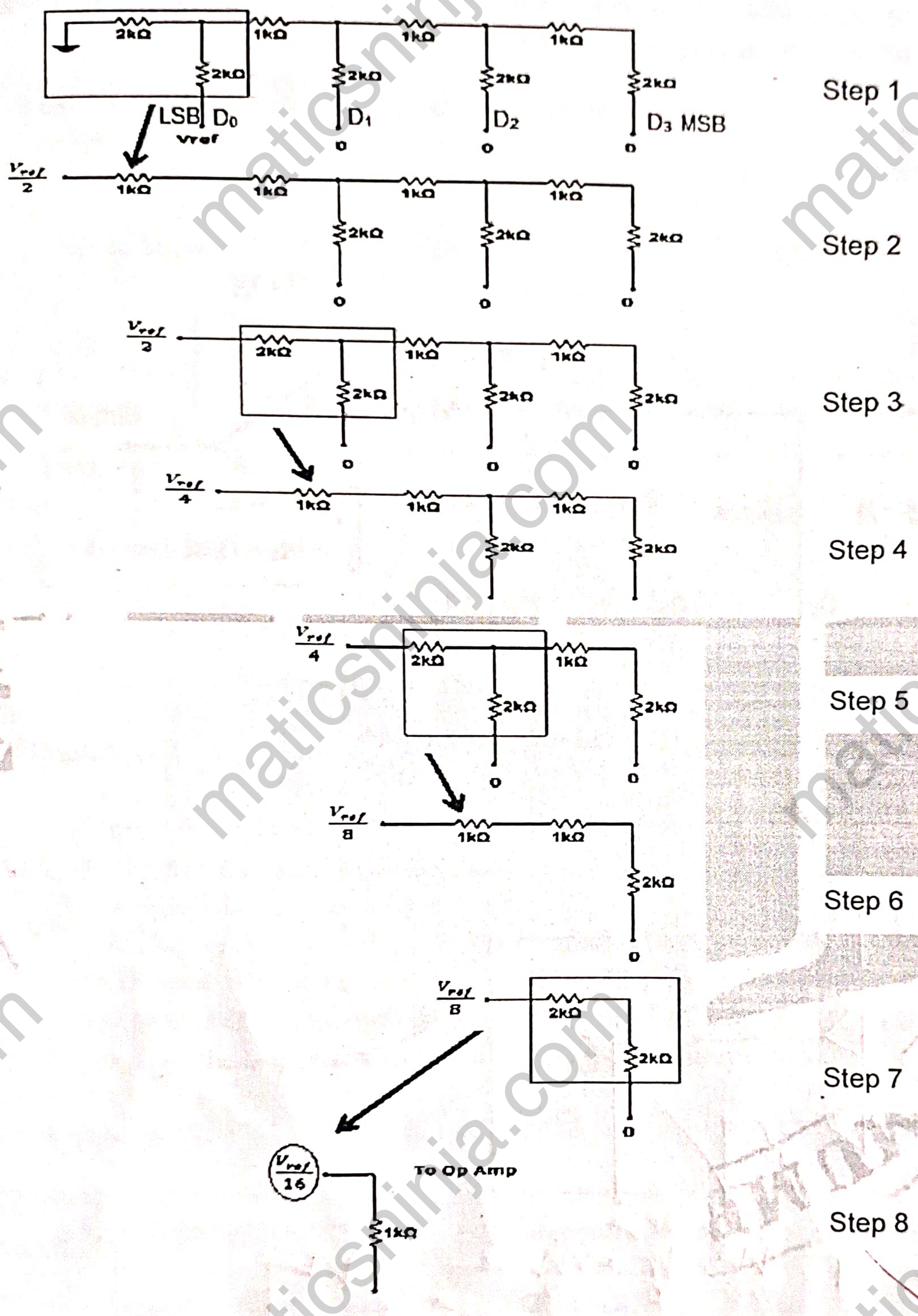


Fig 18.2: Basic diagram of R-2R ladder network working of R-2R ladder network DAC

- Vref is nothing but the input binary value reference voltage, that is for binary 1, Vref =5V and for binary 0, Vref =0V.

- For 0001 only D0=Vref, all other inputs are at 0V and can be treated as ground. So finally Vref/16 volt is appearing as the input to op amp. This value gets multiplied by the gain of op amp circuit – (Rf/Ri).
- If we proceed in this manner (Thevenin equivalent reduction), we will get

$$V_{out} = -\frac{R_f}{R_i} V_{ref} \left[\frac{D_0}{16} + \frac{D_1}{8} + \frac{D_2}{4} + \frac{D_3}{2} \right]$$

- Note that you can build a DAC with any number of bits you want, by simply enlarging the resistor network, by adding more R-2R resistor branches.

VII Circuit diagram

a) Sample circuit

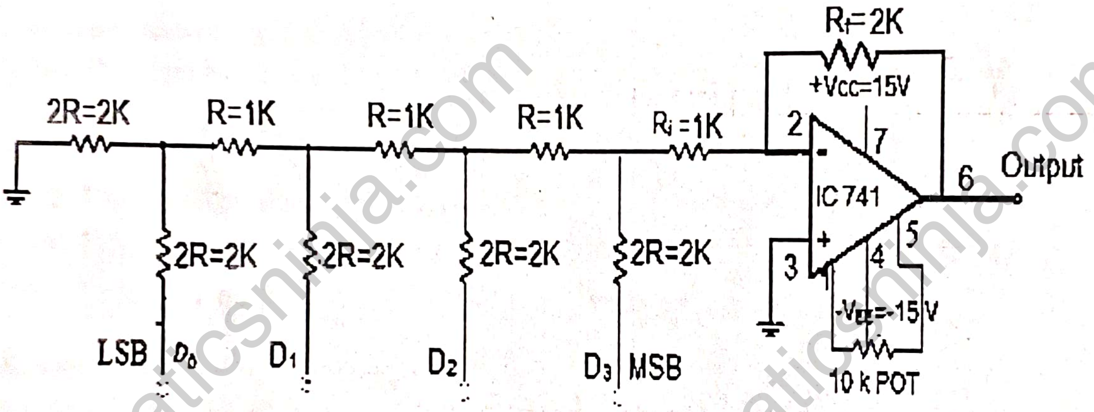
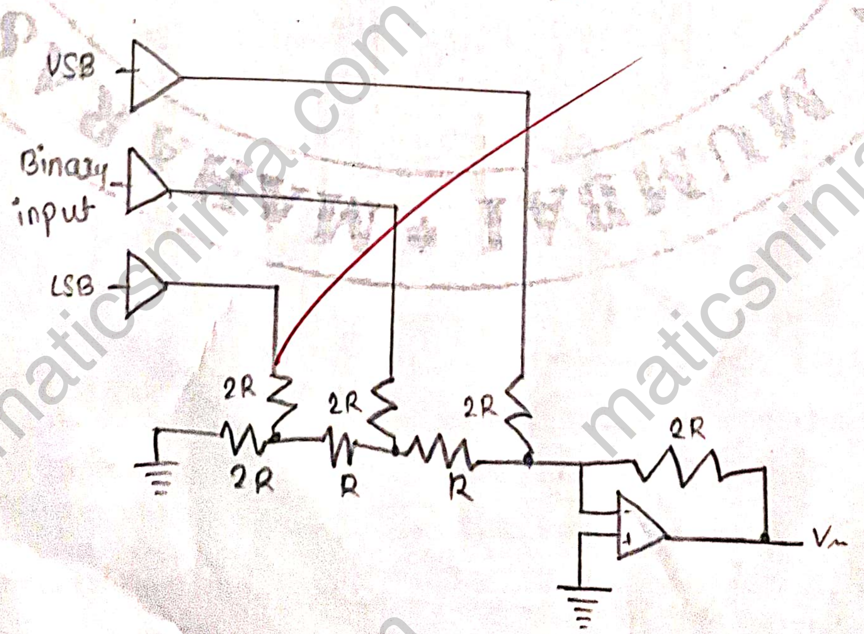


Fig 18.3 R-2R Ladder DAC Network

b) Actual circuit



VIII Resources Required

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Digital Multimeter	3 ½ digit display	1 or 2
2	Analog IC Tester	Tests a wide range of Analog IC's	1
3	DC Dual Power supply	±15V fixed power supply or Variable DC power supply (0-30V)	1
4	Breadboard	5.5cm X 17cm	1
5	Connecting Wires	Single strand wires of 0.6 mm	As per Requirement
6	IC	741	1
7	LED	Red/Yellow color 5 mm	2
8	Resistor	1KΩ and 2KΩ	6 (2 KΩ) 4 (1KΩ)
9	Potentiometer	10 KΩ	1

IX Precautions to be followed

1) Check IC before use.
2) Set power supply to 15V (Variable DC Power Supply) before connecting.
3) Check all the connections as per circuit diagram

X Procedure

1. Test IC using IC tester.
2. Mount IC on bread board.
3. Build circuit as per circuit diagram.
4. Write down observation table.
5. With all inputs (D_0 to D_3) shorted to ground(D_0=0,D_1=0,D_2=0,D_3=0), adjust the 10KΩ POT until the output is 0V.This will nullify any offset voltage at the input of the OPAMP.(POT connected between pin 1& pin 5 of OP-AMP)
6. Measure the output voltage for all binary input states.(0000 to 1111).

XI Resources Used

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Digital multimeter	3½ digit display	1 or 2
2	Breadboard	5.5 cm X 17 cm	1
3	IC	741	1
4	Resistor	1KΩ & 2KΩ	6,4

XII Actual Procedure:

1) Test I.C on I.C tester.
2) Mount I.C on breadboard

XIII Observation:

Observation Table for R-2R Ladder DAC:

D3	D2	D1	D0	R-2R Ladder DAC Theoretical (V) $V_0 = -\frac{R_f}{R_l} * V_{ref}\left(\frac{D_0}{16}+\frac{D_1}{8}+\frac{D_2}{4}+\frac{D_3}{2}\right)$	Practical(V)
0	0	0	0	-0.625	0
0	0	0	1	-1.250	-0.669
0	0	1	0	-1.875	-1.302
0	0	1	1	-2.500	-1.970
0	1	0	0	-3.125	-3.297
0	1	0	1	-4.375	-4.930
0	1	1	0	-3.750	-4.597
0	1	1	1	-5.000	-5.216
1	0	0	0	-5.625	-5.884
1	0	0	1	-6.250	-6.520
1	0	1	0	-6.875	-7.180
1	0	1	1	-7.500	-7.840
1	1	0	0	-8.125	-8.518
1	1	0	1	-8.750	-9.140
1	1	1	0	-8.980	-9.810
1	1	1	1	-9.375	-9.479

XIV Result(s)

In this practical we learnt about to test the output of given R-2R type digital to analog converter for the given input

XV Interpretation of results

In this practical we observe the output of given R-2R type digital to analog converter for the given input

XVI Conclusion and recommendation

Hence, we learnt the output of given R-2R type digital to analog converter for the given input.

XVII **Practical related questions**

Note: Below given are few sample questions for reference. Teacher must design more suchquestions so as to ensure the achievement of identifies CO.

1 Define resolution of DAC.
2 State the purpose of op-amp in this circuit?
3 Write the steps to nullify any offset voltage at the input of the OPAMP.
4 Write down effect of number of input bits on output of DAC?
5 ....

[Space for Answers]

Q.1) → The resolution of a digital-to-analog converter (DAC) refers to the smallest change in the output voltage that can be produced by a change in the digital input code. Resolution is typically measured in bits, with each bit repr- esenting a power of 2.

Q.2) → The purpose of an op-amp (Operational Amplifier) can be:
1> Amplification : To increase the amplitude of weak signal.
2> Buffering : To isolate stages of a circuit, preventing loading or impedance mismatch.
3> Comparison : To compare two voltages & produce an output based on the comparison.
4> Integration : To integrate a signal over time.
5> Differentiation : To differentiate a signal.

Q.3) → To nullify any offset voltage at the input of an OPAMP, follow these steps :
1> Connect OPAMP as voltage follower.
2> Ground non-inverting input.
3> Add 10kΩ pot between inverting input & ground.
4> Connect pot wiper to output.
5> Apply zero input signal.
6> Adjust pot until output reads zero.

This minimizes offset voltage. consult OPAMP datasheet for specific instructions.

Q.4) → The number of input bits in a digital-to-analog con- verter (DAC) has the following effects on a input.

1> Resolution : More input bits result in higher resolution, mean- ing smaller steps between output voltage levels.

2> Accuracy : Increased input bits improve accuracy, reducing quantization error.
3> output voltage steps : More input bits reduce the size of output voltage steps, allowing for smoother transitions.
4> Dynamic range : increased input bits expand the dynamic range, enabling the DAC to produce a wider range of output voltages.

XVIII References/Suggestions for further reading

1. http://vlabs.iitkgp.ac.in/psac/newlabs2020/vlabiitkgpAE/exp10/index.html# (Virtual Lab Link R-2R DAC)
2. https://www.youtube.com/watch?v=LUMhObAm1Qs (NPTEL Video Link)
3. https://datasheetspdf.com/datasheet-pdf/1463096/IC741.html

XIX Assessment Scheme

	Performance Indicators	Weightage
	Process Related : 15 Marks	**60 %**
1	Handling of the components	10%
2	identification of components	20%
3	Measuring value using suitable instrument	20%
4	working in teams	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusion	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process related (15)	**Product related (10)**	**Total (25)**	
13	10	23	[signature]