

# Research Migration Project

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**Title of the circuit :** Study of R2R 4-Bit and 8-Bit DAC Circuit using eSim

## **Abstract:**

The R-2R ladder Digital-to-Analog Converter (DAC) is a widely used and cost-effective method for digital-to-analog conversion, utilizing a resistor network arranged in a ladder structure. This project focuses on the research migration of 4-bit and 8-bit R-2R DAC circuits using eSim, an open-source EDA tool developed by FOSSEE, IIT Bombay. The primary objective is to design, simulate, and analyze the performance of these DAC circuits while comparing theoretical calculations with simulated results. Key performance metrics such as resolution, output voltage accuracy, and linearity are evaluated to assess the effectiveness of eSim in modeling R-2R DAC behavior. The results demonstrate that eSim provides reliable simulation accuracy while offering advantages like ease of design modification, cost reduction, and accessibility. By successfully migrating the R-2R DAC circuit to eSim, this project enhances the open-source electronics design ecosystem and serves as a valuable resource for researchers and students in digital-to-analog conversion studies.

## **Theory/Description :**

The **R-2R Ladder DAC** is one of the most efficient methods for digital-to-analog conversion. It consists of resistors arranged in a ladder-like structure with only two values: **R** and **2R**. This design ensures high precision and minimal component variation, making it ideal for high-resolution DACs.

## **Working Principle of R-2R DAC**

1. The input binary signal is applied to different branches of the resistor network.

2. The resistors form a voltage divider circuit, where the binary inputs determine the output voltage.
3. The superposition principle governs the analog output voltage based on the weighted sum of binary inputs.
4. The output voltage  $V_{out}$  is given by:

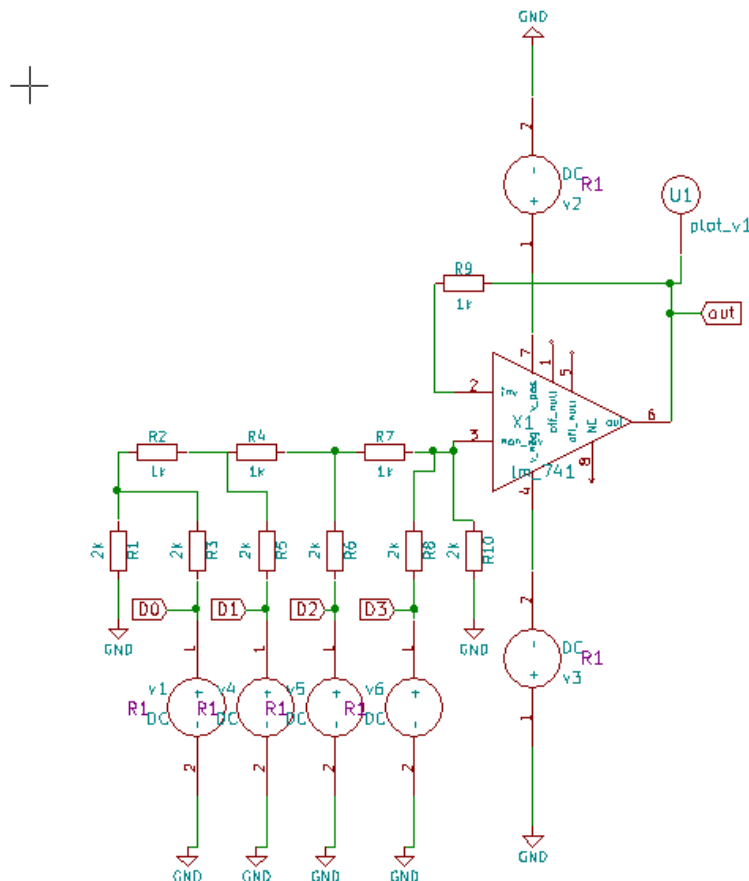
$$V_{out} = V_{ref} \times \left( \frac{D}{2^n} \right)$$

where:

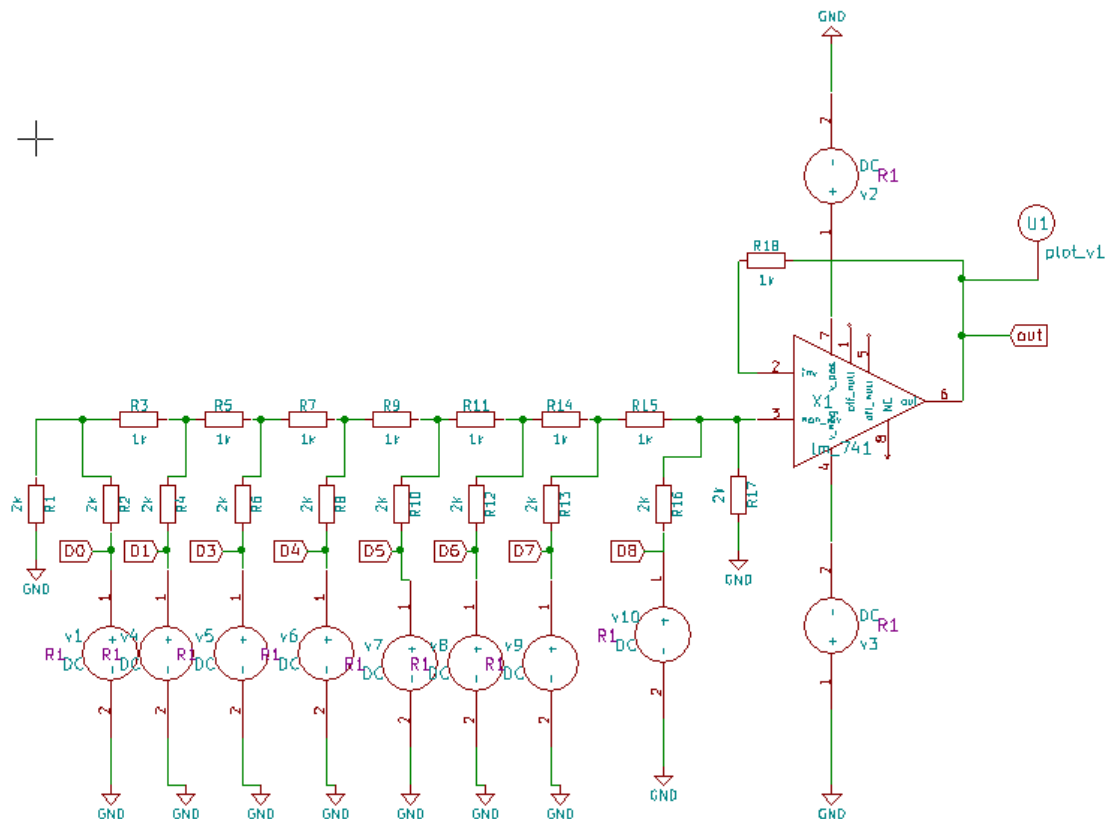
- $V_{ref}$  is the reference voltage,
- $D$  is the decimal equivalent of the binary input,
- $n$  is the number of bits.

**Circuit Diagram(s) :**

**4 bit DAC:**



## 8 bit DAC:

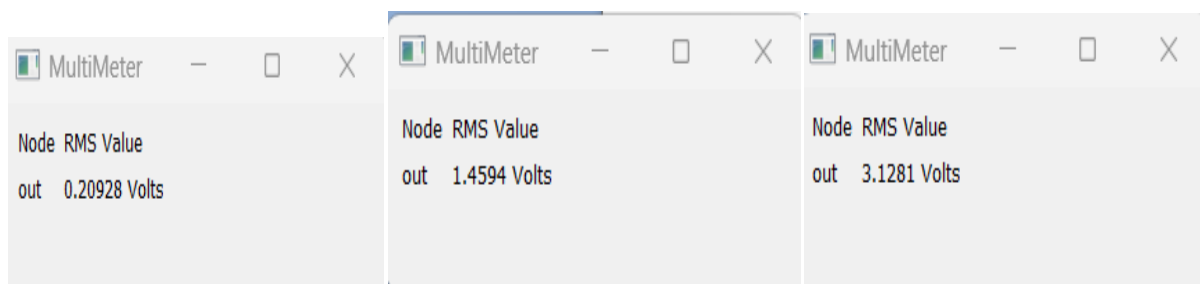


## Results (Input, Output waveforms and/or Multimeter readings) :

Decimal Equivalent	4-Bit R2R DAC circuit Table of Readings					
	Digital Inputs				Analog o/p Voltage	
	D3	D2	D1	D0	Theoretical Value Vo	Experimental Value (eSim)
1	0	0	0	1	0.20833	0.20928
2	0	0	1	0	0.41666	0.41726
3	0	0	1	1	0.62500	0.62608
4	0	1	0	0	0.83333	0.82499
5	0	1	0	1	1.04166	1.0434
6	0	1	1	0	1.25000	1.2496
7	0	1	1	1	1.45833	1.4594
8	1	0	0	0	1.66666	1.6674
9	1	0	0	1	1.87500	1.8761
10	1	0	1	0	2.08333	2.0834
11	1	0	1	1	2.29166	2.2941
12	1	1	0	0	2.50000	2.5024
13	1	1	0	1	2.70833	2.7067
14	1	1	1	0	2.91666	2.9165
15	1	1	1	1	3.12500	3.1281

8-Bit R2R DAC circuit Table of Readings										
Decimal Equivalent	Digital Inputs								Analog o/p Voltage	
	D7	D6	D5	D4	D3	D2	D1	D0	Theoretical Values	Experimental Values
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	0.01302	0.013964
2	0	0	0	0	0	0	1	0	0.26041	0.2611
126	0	1	1	1	1	1	1	0	1.64062	1.6403
127	0	1	1	1	1	1	1	1	1.65364	1.6551
128	1	0	0	0	0	0	0	0	1.66666	1.6674
129	1	0	0	0	0	0	0	1	1.67968	1.6795
130	1	0	0	0	0	0	1	0	1.69270	1.6940
254	1	1	1	1	1	1	1	0	3.30729	3.3042
255	1	1	1	1	1	1	1	1	3.32031	3.3186

**For 4 bit DAC:**

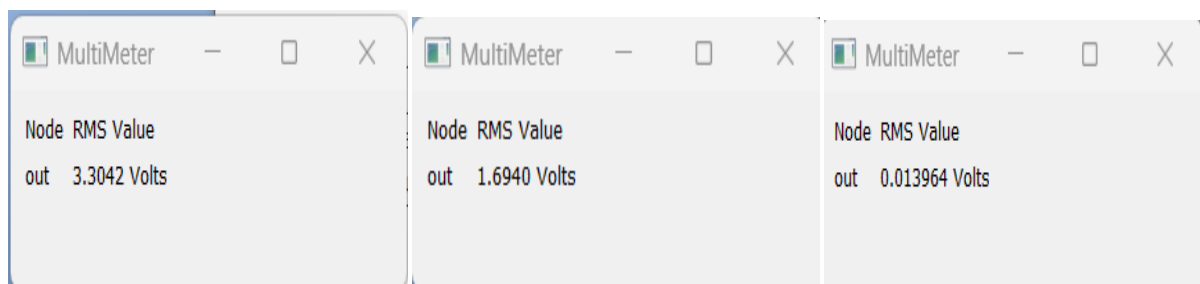


**For 0001**

**For 0111**

**For 1111**

**For 8 bit DAC:**



**For 11111110**

**For 10000010**

**For 00000001**

**Conclusion :**

The R-2R ladder DAC using the LM741 in ESim successfully converted digital inputs to analog outputs, demonstrating binary-weighted conversion. The LM741 acted as a summing amplifier, producing expected voltage levels. Minor errors arose from resistor tolerances and op-amp limitations. The experiment confirmed the DAC's working principle, highlighting the need for precision components in real-world applications for accurate digital-to-analog signal conversion

**Source/Reference(s) :**

**Title of Paper:** Study of R2R 4-Bit and 8-Bit DAC Circuit using Multisim Technology

**Link to paper:** [Study of R2R 4-Bit and 8-Bit DAC circuit using Multisim Technology](#)