

# 4-bit R-2R Ladder Digital-to-Analog Converter

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## Abstract

This project focuses on the design and simulation of a 4-bit R-2R Ladder Digital-to-Analog Converter (DAC) using operational amplifiers. The R-2R ladder DAC is one of the simplest and most efficient methods for converting digital signals into corresponding analog outputs. It is widely used in signal processing, control systems, and embedded applications due to its simplicity, scalability, and accuracy. In this work, the DAC circuit is designed using resistors in R-2R configuration and simulated using eSim software. The performance of the circuit is evaluated by observing its ability to generate discrete analog output voltages for various digital input combinations. The results confirm the effective working of the R-2R DAC, highlighting its advantages of low complexity and reliable operation, making it a fundamental building block for digital-to-analog conversion in electronic systems.

**Keywords:** 4 BIT R-2R Ladder DAC, Digital-to-Analog Converter, eSim, Operational Amplifier, Circuit Simulation

## I. INTRODUCTION

The R-2R ladder DAC is a simple and efficient design that requires only two resistor values (R and 2R). It works on the principle of binary-weighted voltage division, where each bit contributes to the output. This project implements a 4-bit R-2R ladder DAC using resistors and an operational amplifier. Simulation using eSim verifies the circuit performance and confirms its reliable digital-to-analog conversion.

## II. PURPOSE OF BISTABLE MULTIVIBRATOR

The main purpose of this 4-bit R-2R Ladder DAC circuit is to convert digital binary signals into equivalent analog voltages. It is simple in design and uses only two resistor values (R and 2R), making it cost-effective and easy to implement. This circuit is suitable for educational applications, instrumentation, and low-resolution signal processing. By using an operational amplifier, the DAC provides stable analog output proportional to the digital input. The design focuses on achieving accuracy with minimum components and clear demonstration of DAC principles.

## III. WORKING PRINCIPLE

The 4-bit R-2R Ladder DAC converts a 4-bit digital input into a corresponding analog output voltage. A resistor network of values R and 2R creates a voltage divider that assigns binary-weighted contributions from each input bit. When digital inputs are applied (logic HIGH =  $V_{cc}$ , logic LOW = GND), the ladder network combines them into a single analog voltage. The operational amplifier (UA741) is used as a summing amplifier to generate the final analog output at  $V_{out}$ . This method provides a straightforward and reliable way to perform digital-to-analog conversion using minimal hardware.

IV. CIRCUIT DIAGRAM

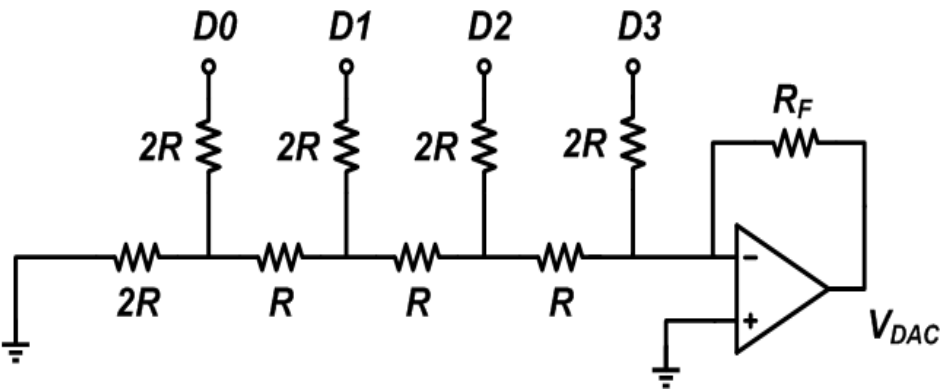


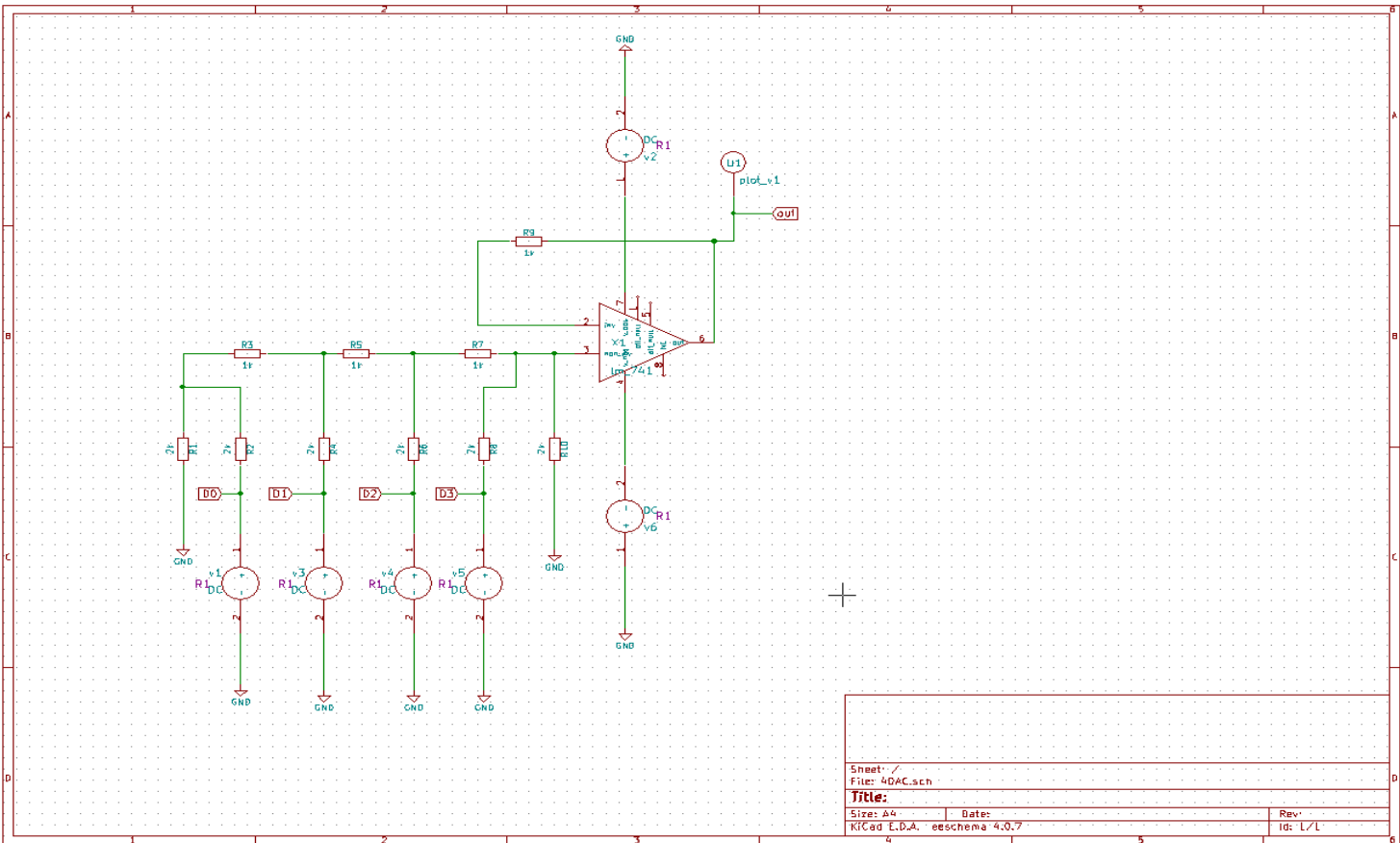
Fig. 1:4-Bit DAC with sample output waveform

The output waveform of the 4-bit R-2R Ladder DAC is a stepped analog signal corresponding to the applied binary inputs. For each increase in the digital input code, the output voltage rises in fixed increments, creating a staircase-like waveform. The smallest voltage change corresponds to the Least Significant Bit (LSB), while the Largest Significant Bit (MSB) produces the highest step. When a sequence of binary inputs (0000 to 1111) is applied, the output increases linearly in 16 discrete steps. This confirms the correct working of the DAC, as it successfully converts digital signals into equivalent analog voltages.

V. PROPOSED SYSTEM

The proposed system implements a 4-bit R-2R Ladder Digital-to-Analog Converter (DAC) using resistors and an operational amplifier. It converts binary digital inputs into corresponding analog output voltages in discrete steps. The design ensures simplicity, low power consumption, and accurate digital-to-analog conversion for educational and signal processing applications.

eSIM CIRCUIT



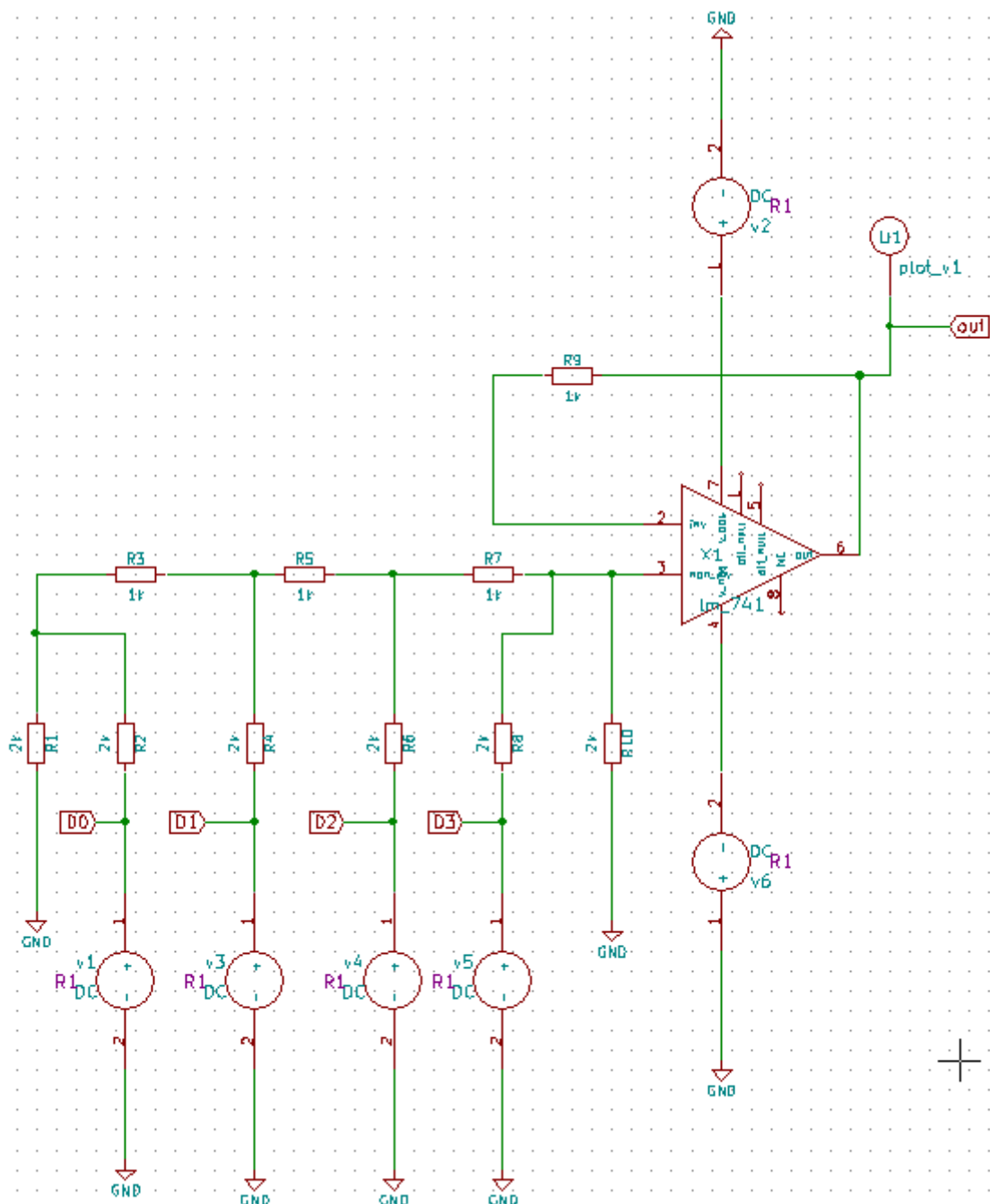
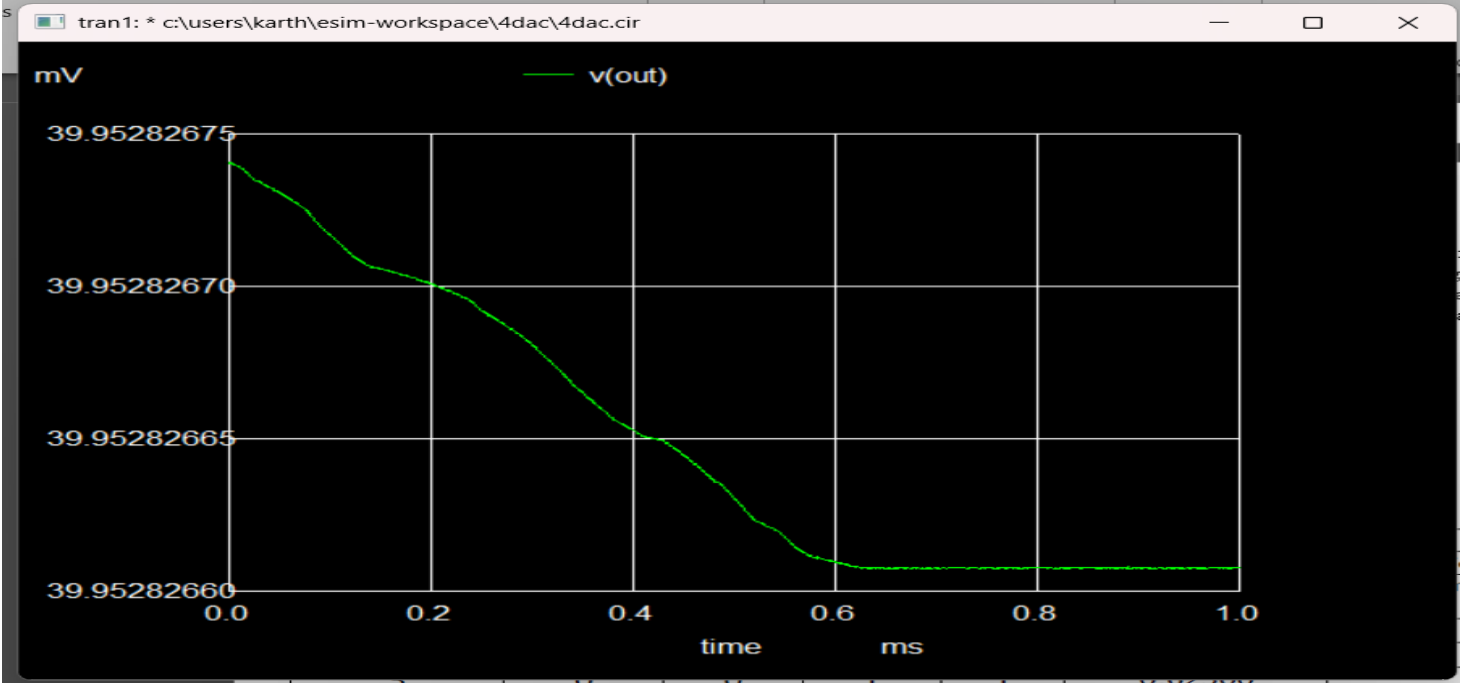


Fig. 2:4-Bit DAC Circuit in eSim

shows the circuit diagram of a 4-bit R-2R Ladder Digital-to-Analog Converter (DAC) implemented using eSim software. The circuit consists of a resistor ladder network made up of resistors with values **R** and **2R**, and an operational amplifier (UA741) configured as a summing amplifier. The digital inputs are applied through the resistor ladder, which divides the reference voltage according to the binary weights of the inputs. The op-amp then amplifies and combines these voltages to generate a proportional analog output. This design demonstrates the simplicity, low power consumption, and effectiveness of the R-2R ladder DAC for digital-to-analog conversion.

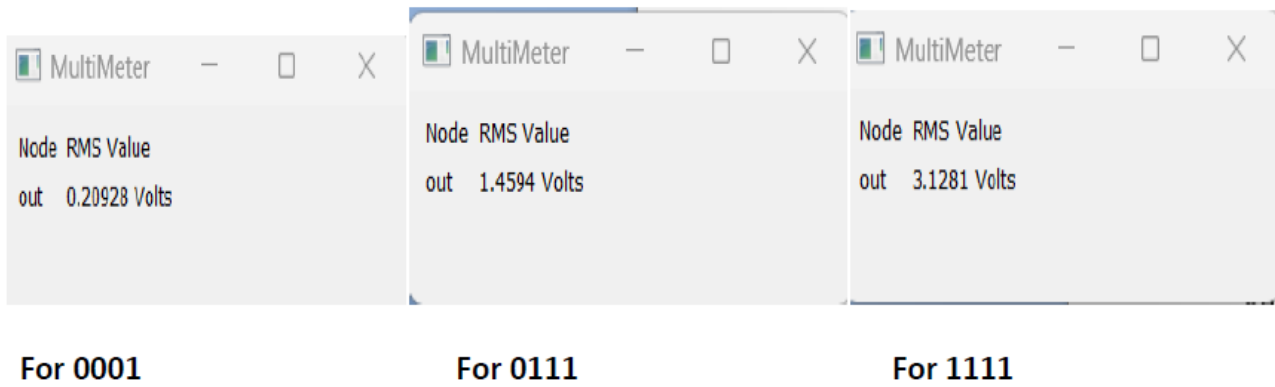
OUTPUT WAVEFORM



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

## 4 BIT R-2R DAC:-



## CONCLUSION

This project successfully demonstrates the design of a 4-bit R-2R ladder Digital-to-Analog Converter (DAC) using resistors and an operational amplifier. The circuit converts digital binary inputs into proportional analog outputs with simplicity and accuracy. The R-2R ladder structure offers advantages such as easy implementation, low power consumption, and high reliability compared to other DAC architectures. Simulation results from **eSim** validate the linearity, resolution, and functionality of the DAC, proving its suitability for basic signal conversion and educational applications.

## REFERENCES

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

