Design of 12-Bit DAC Using CMOS Technology

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Abstract

This paper explores the design and development of a 12-bit Digital-to-Analog Converter (DAC) using CMOS technology. DACs are essential blocks in mixed-signal systems, facilitating the conversion of digital signals to equivalent analog signals for application in signal processing, communication systems, and control systems. The study presents various architectures of 12-bit DACs and contrasts their advantages and limitations in resolution, linearity, power consumption, and speed. The abstract emphasizes the applicability of DACs in modern electronics, highlighting their utilization in high-precision data conversion as well as between digital and analog domains. In addition, it emphasizes the utilization of a CMOS-based DAC, examining the circuit topologies such as R-2R ladder networks, current-steering DACs, and segmented architectures. Simulation and comparison of the proposed DAC design using eSim software, with those of earlier designs in industry-standard software like Cadence or Multisim, provide valuable information regarding its performance and feasibility. Overall, this paper provides an important contribution towards a complete understanding of CMOS-based DAC design, using simulation tools for performance evaluation and optimization.

Keywords: 12-bit DAC, CMOS Technology, Digital-to-Analog Converter, eSim, Circuit Design

I. INTRODUCTION

Digital-to-Analog Converters (DACs) allow digital systems to communicate with analog components. CMOS technology provides low power consumption and high integration for DACs. A 12-bit DAC has high resolution, which makes it ideal for precision applications. This paper discusses various DAC architectures and analyzes performance using eSim simulations.

II. PURPOSE OF BISTABLE MULTIVIBRATOR

The intent of this 12-bit DAC circuit is to convert digital signals into corresponding analog voltages with high precision effectively. It is intended for fine-resolution applications like audio processing, instrumentation, and communication systems. The use of CMOS-based implementation provides low power consumption and efficient operation, allowing it to be integrated into contemporary mixed-signal circuits. The design is intended to provide optimal trade-offs among speed, linearity, and power efficiency.

III. WORKING PRINCIPLE

The 12-bit DAC converts a digital input code into an analog voltage, which is derived using a weighted resistor or current-steering approach. In the R-2R ladder DAC, a network of precisely matched resistors divides a reference voltage according to the binary input and produces an output voltage proportional to the digital value. In a current-steering DAC, the controlled current sources add up the proper quantities of current to generate the target analog signal. The CMOS technology provides high accuracy, low noise, and low power consumption, making the circuit applicable for high-precision applications.

IV. CIRCUIT DIAGRAM

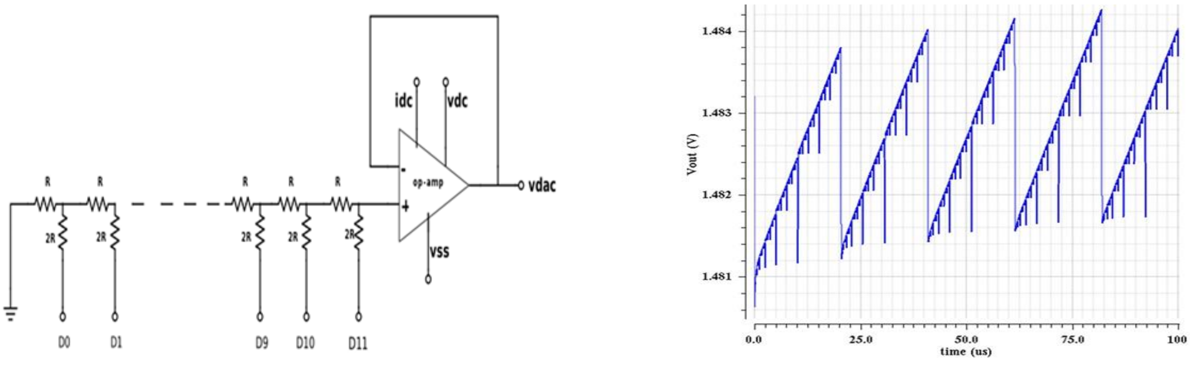


Fig. 1:12-Bit ADC with sample output waveform

The 12-bit DAC circuit consists of an R-2R resistor ladder network and an operational amplifier (op-amp). The resistor network forms a voltage divider that converts the binary-weighted digital input into an equivalent analog voltage. Each digital input bit (D0 to D11) corresponds to a specific resistance value in the ladder, determining the contribution of each bit to the final output voltage. The op-amp is configured as a summing amplifier, ensuring accurate voltage scaling and a stable, low-impedance output. The circuit's CMOS implementation enhances power efficiency and integration capability, making it suitable for high-precision applications such as audio processing, communication systems, and industrial automation.

V. PROPOSED SYSTEM

The proposed system implements a 12-bit DAC using eSim software. It employs an R-2R resistor ladder and an operational amplifier to achieve accurate digital-to-analog conversion. The simulation in eSim validates its resolution, linearity, and power efficiency.

eSIM CIRCUIT

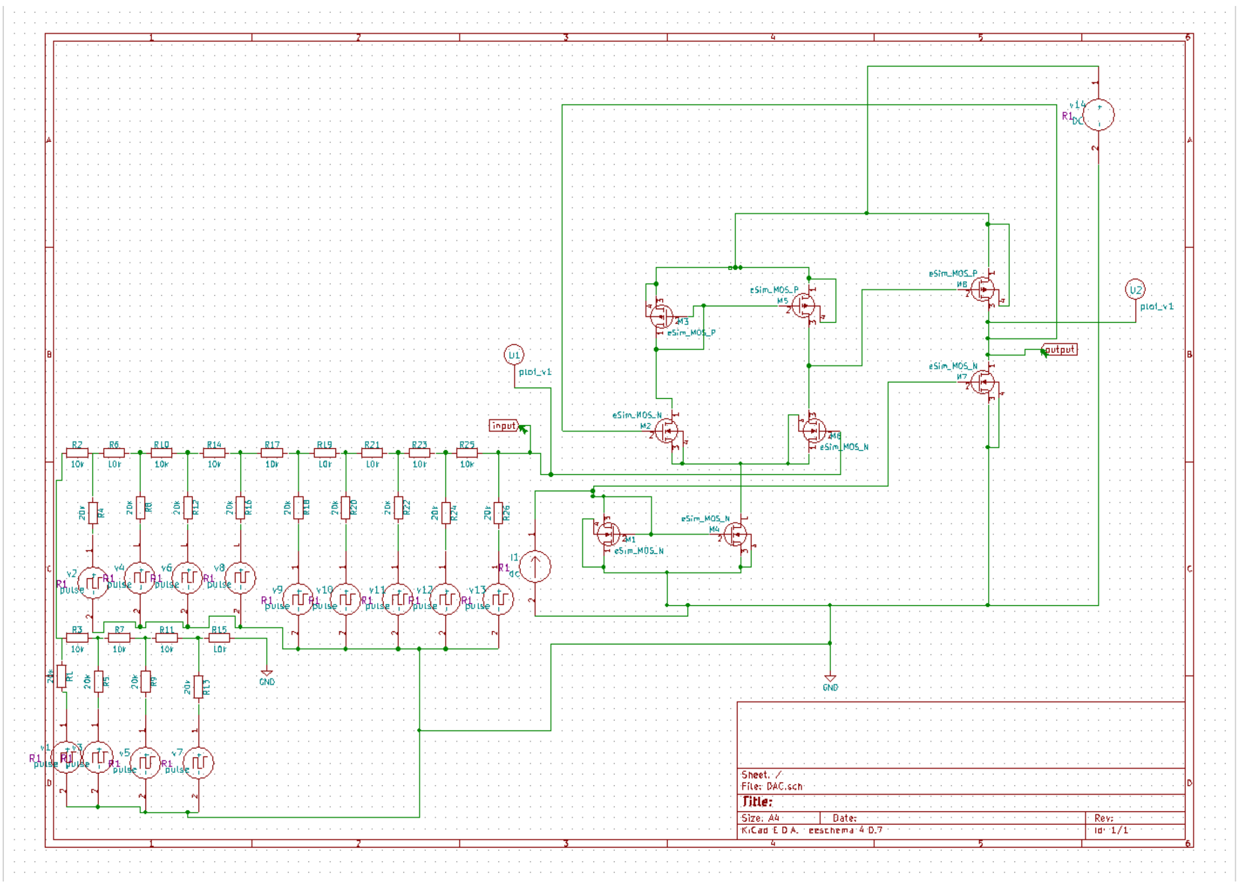
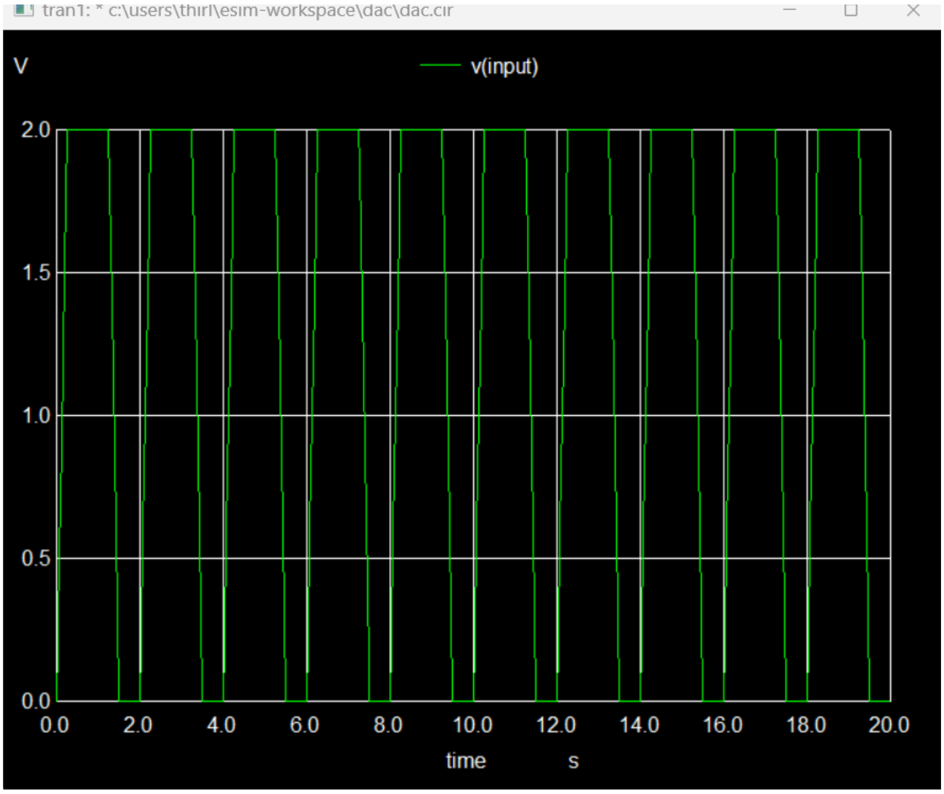


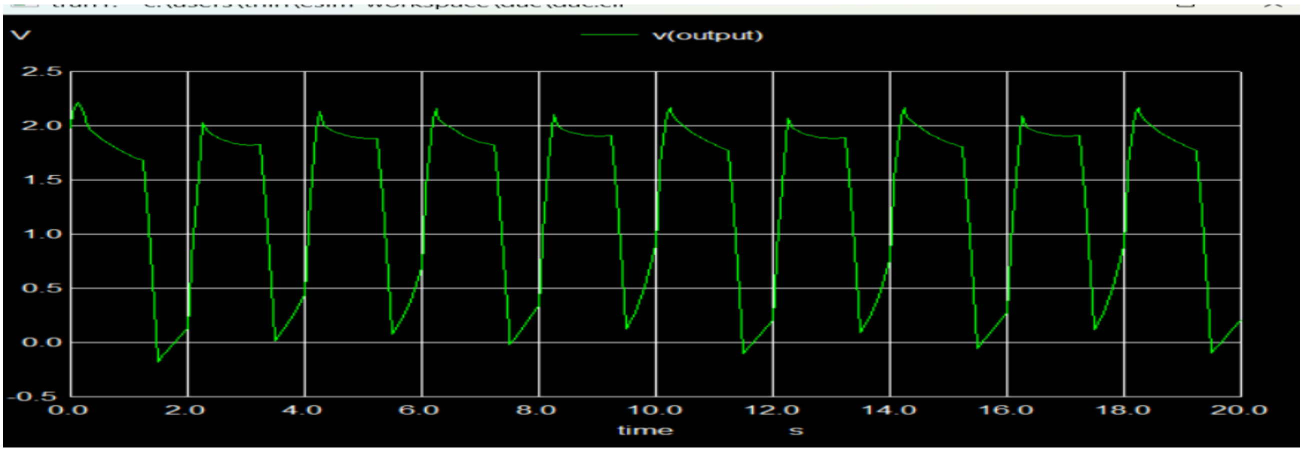
Fig. 2:12-Bit ADC Circuit in eSim

Figure 2 shows the circuit diagram of a 12-bit Digital-to-Analog Converter (DAC) implemented using eSim software. The circuit includes an R-2R resistor ladder network, MOSFET digital input selection based on CMOS technology, and an operational amplifier as a summing amplifier. The resistor ladder network converts binary-weighted digital inputs to proportional analog voltages, which the op-amp amplifies and outputs in the form of a continuous analog signal. This layout guarantees high resolution, low power dissipation, and effective digitalto-analogconversion.

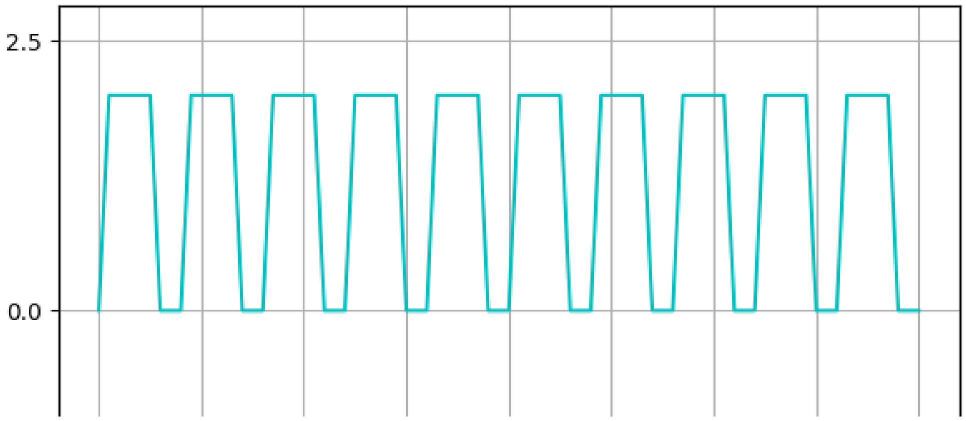
OUTPUT WAVEFORM



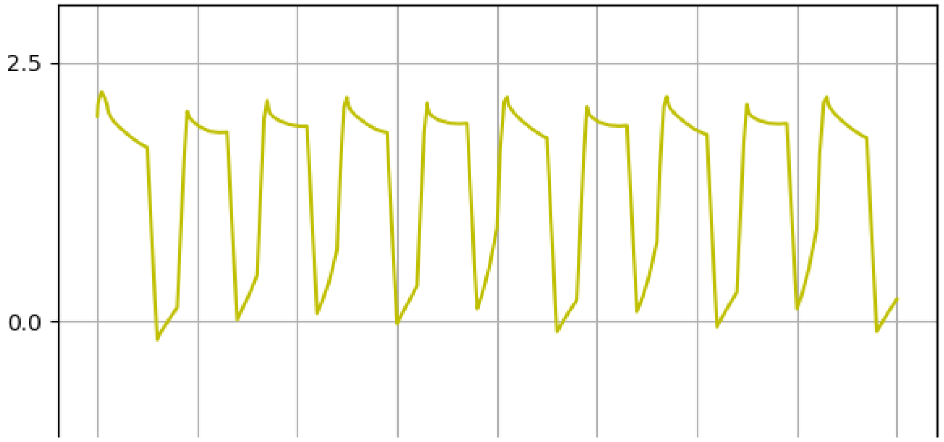
INPUT WAVEFORM



OUTPUT WAVEFORM



INPUT WAVEFORM(PYTHON PLOT)



OUTPUT WAVEFORM(PYTHON PLOT)

Fig. 5: Output Waveform Bistable multivibrator Circuit in Esim

The output waveform of the 12-bit DAC represents the analog voltage corresponding to the given digital input. As the digital code increments, the output voltage follows a stepwise pattern, producing a smooth analog approximation of the input signal. The waveform should exhibit linearity, ensuring that equal digital steps result in equal voltage increments. Any deviation from the ideal linear response may indicate non-linearity errors, such as glitches or missing codes. The eSim simulation provides a graphical representation of the DAC's performance, verifying its accuracy, resolution, and dynamic response in converting digital signals into analog form.

CONCLUSION

Designing a 12-bit digital-to-analog converter (DAC) using CMOS technology has been explored in this study. The circuit effectively converts digital inputs to precise analog outputs with the assistance of an R-2R resistor ladder and an operational amplifier, achieving high resolution and low power consumption. The CMOS-based design achieves higher efficiency, thereby making the DAC suitable for signal processing, communication, and instrumentation applications. Simulation results of eSim validate its linearity, accuracy, and performance, which are found to be viable for inclusion in modern mixed-signal systems.

REFERENCES

[1] Tutorial: Digital to Analog Conversion The R-2R DAC, Alan Wolke, May 2013.

[2] Anshul Agarwal, Design of Low Power 8-Bit Digital-to-Analog Converter with Good Voltage-Stability, Center for VLSI and Embedded System Technologies International Institute of Information Technology Hyderabad, India May 2013.