Semester Long Internship Report

On

Adding ICs as Subcircuits in eSim Library

Submitted by

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Acknowledgment

I am sincerely thankful to the FOSSEE team at IIT Bombay for offering me the opportunity to be part of this internship. I would like to express my deepest gratitude to Prof. Kannan M. Moudgalya for his guidance throughout the internship. This experience has been valuable in enhancing my technical skills and understanding of open-source EDA tools and circuit simulation.

It has served as a stepping stone for my technical growth in the domain of electronics. I am particularly grateful to Mr. Sumanto Kar and Dr. Ritu Pahwa, for their expert guidance, continuous support, and insightful feedback throughout the duration of the internship. Their mentorship was instrumental in deepening my knowledge of circuit design and simulation using eSim. Their insights and support helped me navigate challenges.

I extend my thanks to the developers and community behind the eSim project for making such a powerful simulation tool freely accessible, and for their continued efforts in promoting open-source electronics design.

I am grateful to my faculty members, peers, and fellow interns for their constant encouragement and support throughout this journey. This experience has not only improved my technical skills but also instilled in me a deeper appreciation for collaborative learning and open-source contributions

Contents

Chapter 1
Introduction

The field of electronics relies significantly on circuit design, simulation, and verification before their actual implementation. Electronic Design Automation (EDA) software facilitates accuracy and efficiency in the process of designing circuits. eSim, an open-source EDA tool created by FOSSEE at IIT Bombay, provides a holistic environment for circuit design and simulation. It combines KiCad for PCB design and schematic capture with Ngspice for simulation, offering an end-to-end solution for students and electronics engineers.This internship was done with the view of gaining hands-on experience in circuit simulation with eSim. Through the internship, I examined several aspects of the software, including schematic design, SPICE simulation, netlist generation, and waveform analysis. The emphasis was on mastering the entire workflow of circuit design through open-source tools and implementing the same on hands-on projects as well as exercises.The FOSSEE (Free/Libre and Open Source Software for Education) project focuses on the improvement of the quality of education by promoting the use of open-source software tools. eSim, which is developed under the FOSSEE project, is an integrated framework that combines schematic design and circuit simulation. Based on the strong simulation engine of Ngspice, eSim is especially helpful for students and teachers wanting to learn and teach electronics without worrying about costs.

eSim combines multiple tools to provide its functionality:

- KiCad: Employed for the creation of circuit schematics, PCB layout design, and component management.
- Ngspice: A powerful simulator capable of DC, transient, and AC analysis.
- KiCad to Ngspice Converter: Closes the loop from KiCad design to simulation by setting up analysis parameters and handling device models.
- Model Builder: Facilitates creation of new device models for components like diodes, BJTs, MOSFETs, JFETs, IGBTs, and magnetic cores.
- Subcircuit Builder: Lets users design reusable subcircuits that may be used in various

projects.

- NGHDL: Supports mixed-signal simulation using VHDL.

- NgVeri: Enables simulation with Verilog/SystemVerilog.

The internship offered by FOSSEE not only educates but also empowers students to make valuable contributions to the open-source environment along with acquiring practical knowledge in electronic circuit simulation and design.This report discusses the work carried out throughout the internship, major learnings, issues encountered, and skills gained. It emphasizes the need for adopting open-source solutions in electronics and how eSim enhances autonomous and affordable design practices in educational and professional environments.

Chapter 2

Workflow

The process which was followed can be outlined as follows:

2.1 Orientation and Tool Familiarization:

An introductory session was conducted to understand the work process. Tutorials and documentation provided by FOSSEE were referred during this phase.

2.2 Approach

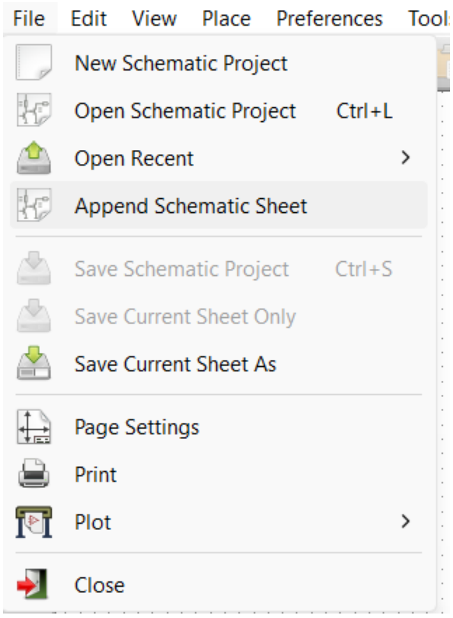
Using tutorials, creation of subcircuit in eSim was done which involved following steps:

- Opening eSim and selecting the default workspace and location.

- Creating a new project for each IC in the default workspace where we can store the designed circuits.

- Opening the schematic editor and building the circuit as per the datasheet.

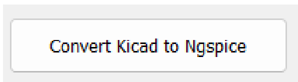
- Use the schematic and update the sheet of subcircuit by creating new subcir- cuit.



- Annotating the schematic symbols to assign identifiers to all components.

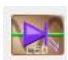
- Generating a netlist, for simulation. The netlist describes all the electrical connections and components in a format readable by the SPICE engine.

- Converting the KiCad schematic to an NgSpice compatible format.



- Creating a symbol for the subcircuit using the Symbol Editor and setting up the pin configuration.

- Designing a test circuit for simulation and validating the results against the datasheet specifications.



Chapter 3

Subcircuits

The IC subcircuits completed are listed below:

Sr. No.	IC Number	Description
1	INA129	instrumentation amplifier
2	MC74AC573	Octal D-Type Latch with 3-State Outputs
3	TDA2003	10W Car Radio Audio Amplifier
4	SN74LS92	Divide By-Twelve Counters
5	SN5444A	Gray to Decimal
6	SN5443A	Excess to Decimal
7	MC14016B	Quad Analog Switch/Multiplexer
8	SN5423	Dual 4-Input nor Gates with Strobe

Table 3.1: List of ICs and their descriptions

3.1 INA129 – INSTRUMENTATION AMPLIFIER

3.1.1 Description

The INA128 and INA129 are low-power instrumentation amplifiers with programmable gain and high accuracy. They offer low offset, wide bandwidth, and are ideal for precision, battery-operated applications.

3.1.2 Key Features

- LOW OFFSET VOLTAGE: 50μV max
- LOW DRIFT: 0.5μV/C max
- LOW INPUT BIAS CURRENT: 5nA max
- HIGH CMR: 120dB min
- INPUTS PROTECTED TO 40V
- WIDE SUPPLY RANGE: 2.25V to 18V
- LOW QUIESCENT CURRENT: 700μA
- 8-PIN PLASTIC DIP, SO-8

3.1.3 Circuit Diagrams

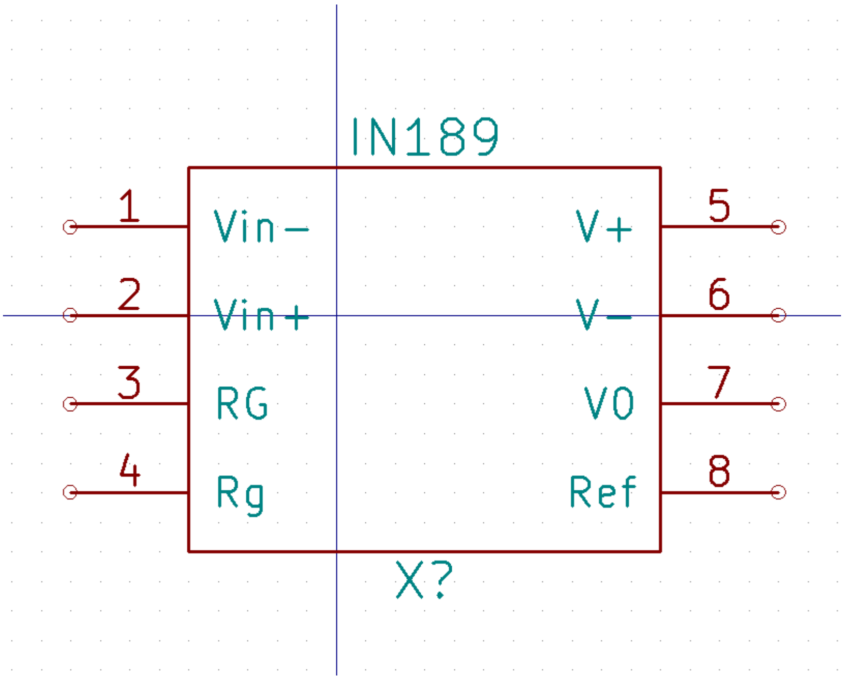


Figure 3.1: Pin Diagram of INA129

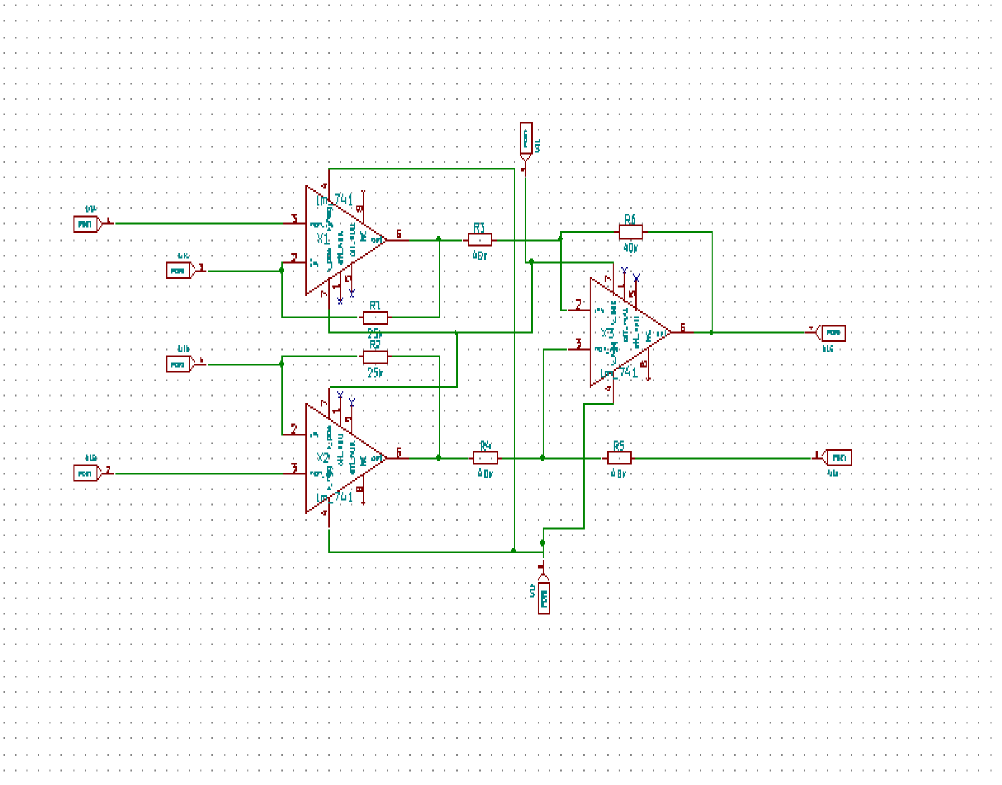


Figure 3.2: Schematic of INA129

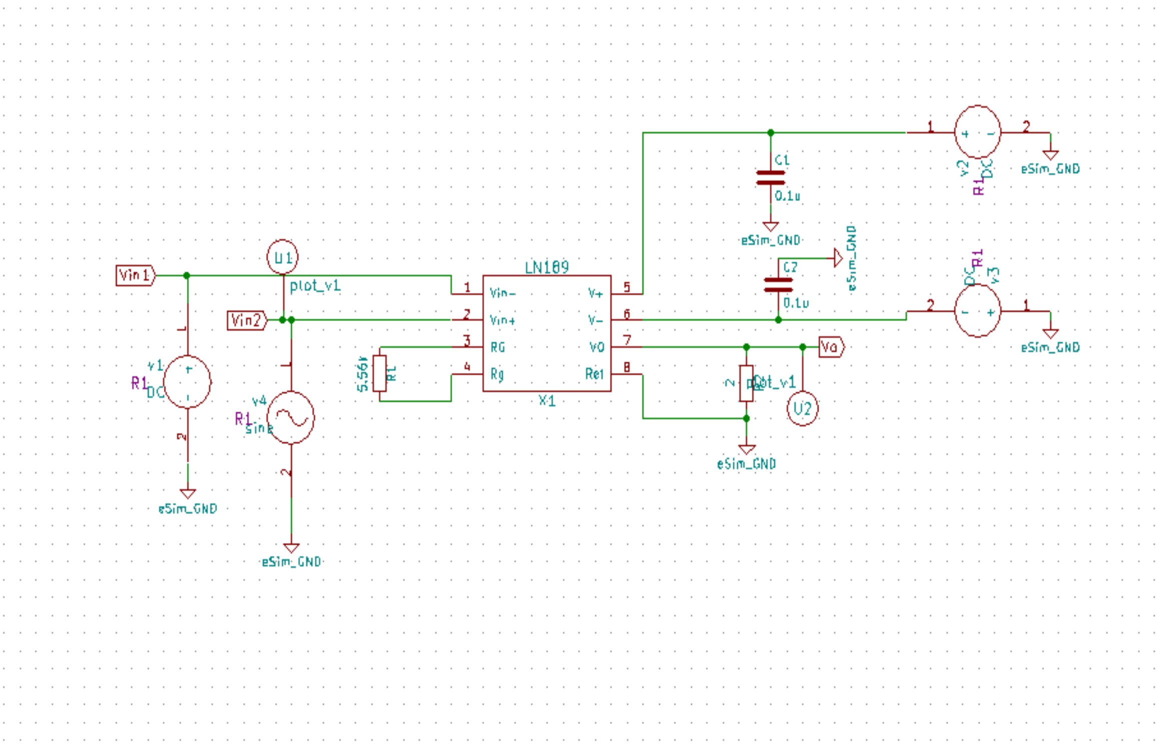


Figure 3.3: Test Circuit of INA129

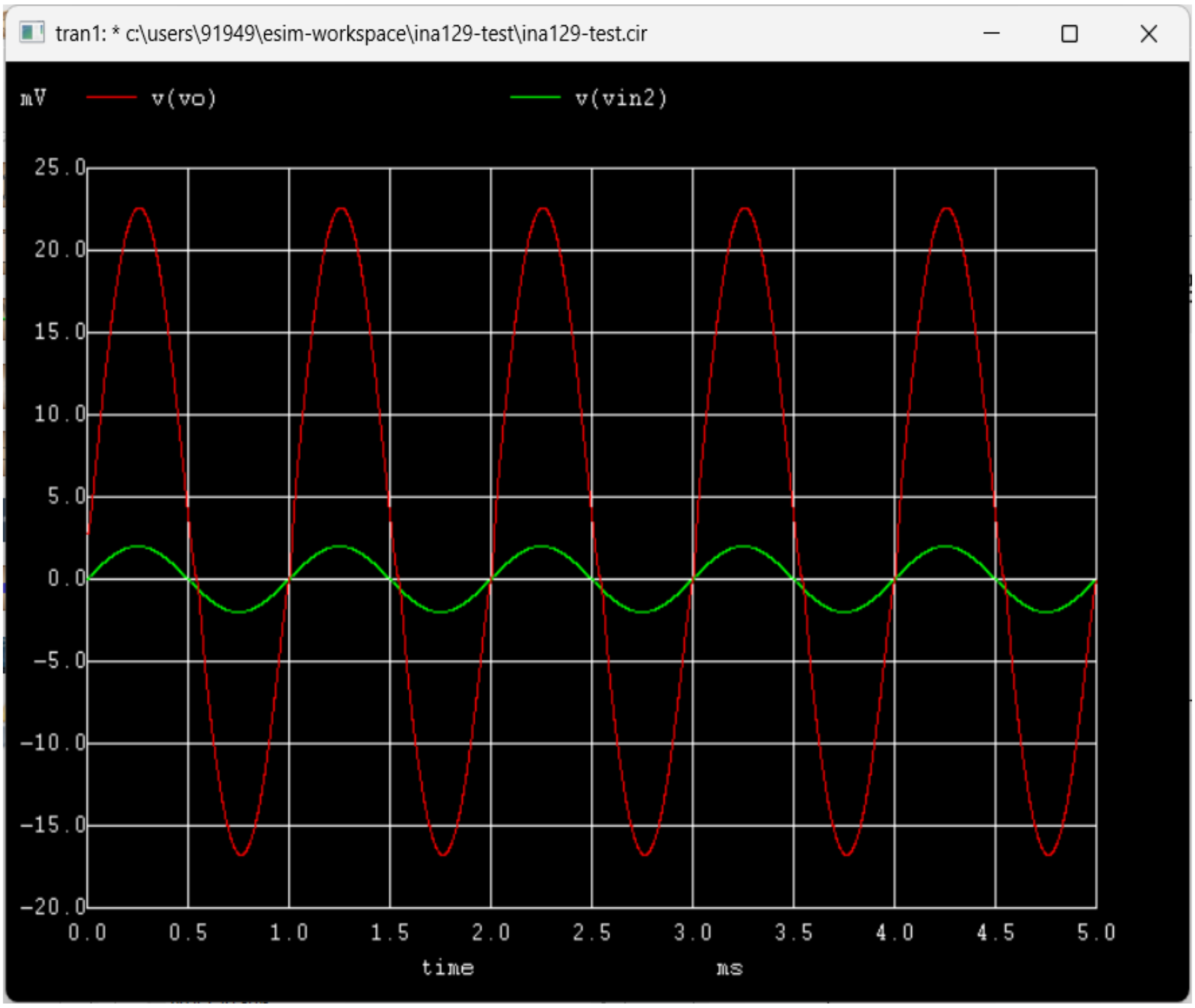


Figure 3.5: Results of Test Circuit

3.2 MC74AC573 – Octal D-Type Latch with 3-State Outputs

3.2.1 Description

The MC74AC573/74ACT573 is a high-speed octal latch with buffered common Latch Enable (LE) and buffered common Output Enable (OE) inputs.

The MC74AC573/74ACT573 is functionally identical to the MC74AC373/ 74ACT373 but has inputs and outputs on opposite si.

3.2.2 Key Features

- Inputs and Outputs on Opposite Sides of Package
- Allowing Easy Interface with Microprocessors
- Useful as Input or Output Port for Microprocessors
- Functionally Identical to MC74AC373/74ACT373
- 3-State Outputs for Bus Interfacing
- Outputs Source/Sink 24 mA
- ACT573 Has TTL Compatible I

3.2.3 Circuit Diagrams

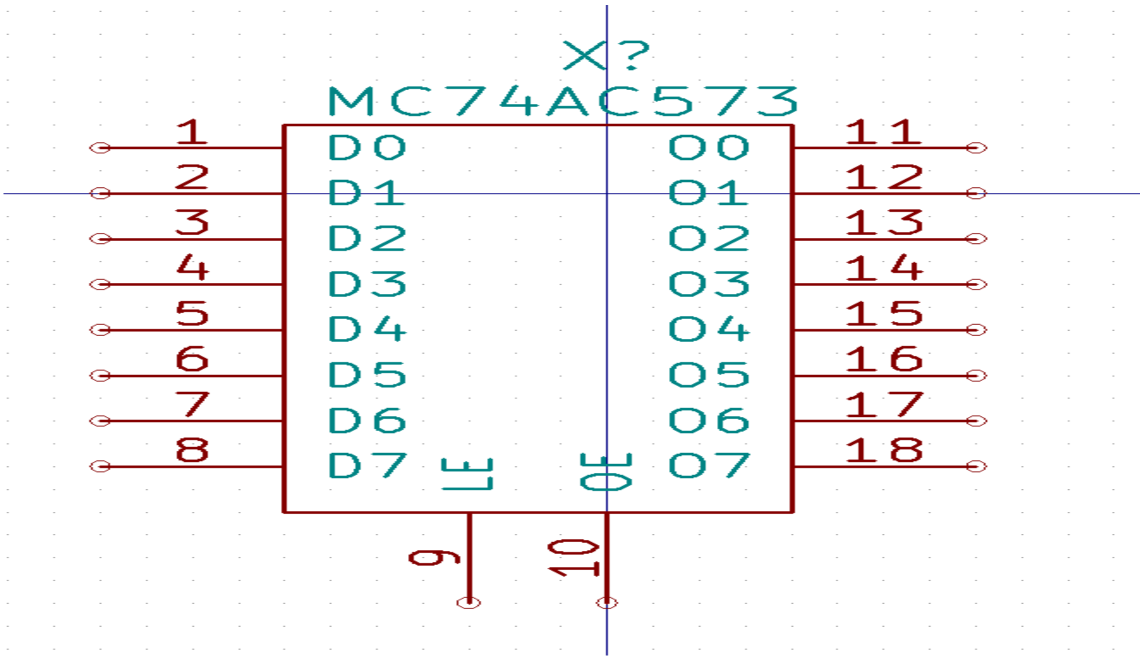


Figure 3.6: Pin Diagram of MC74AC573

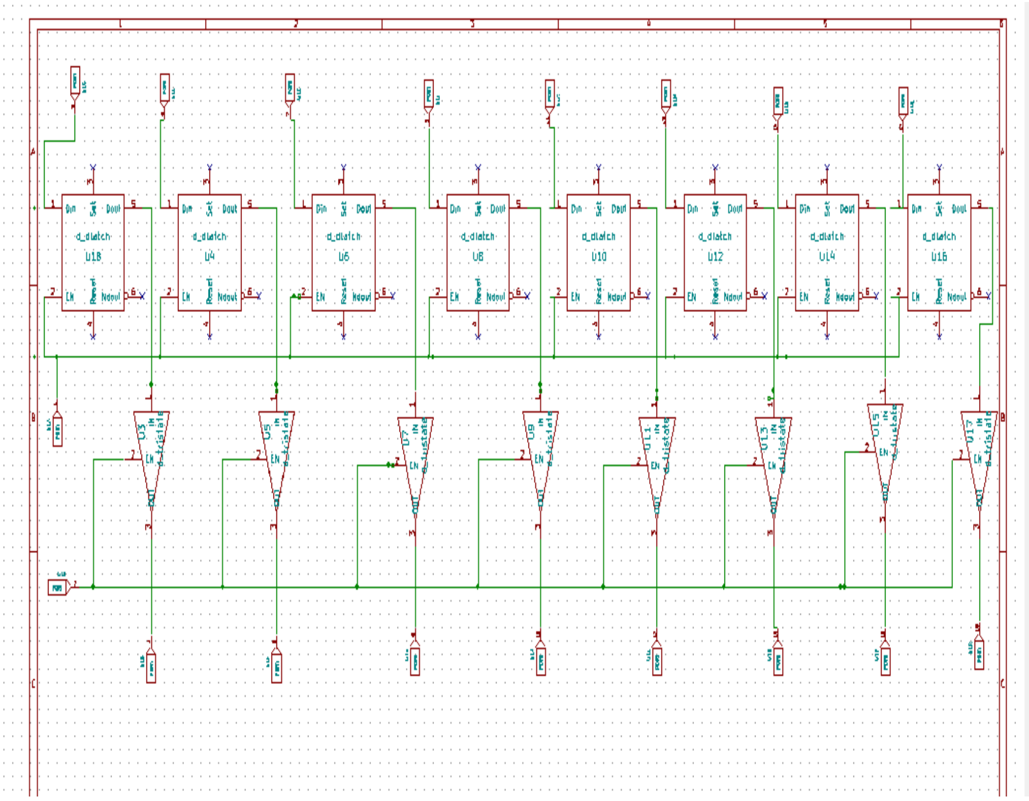


Figure 3.7: Schematic of MC74AC573

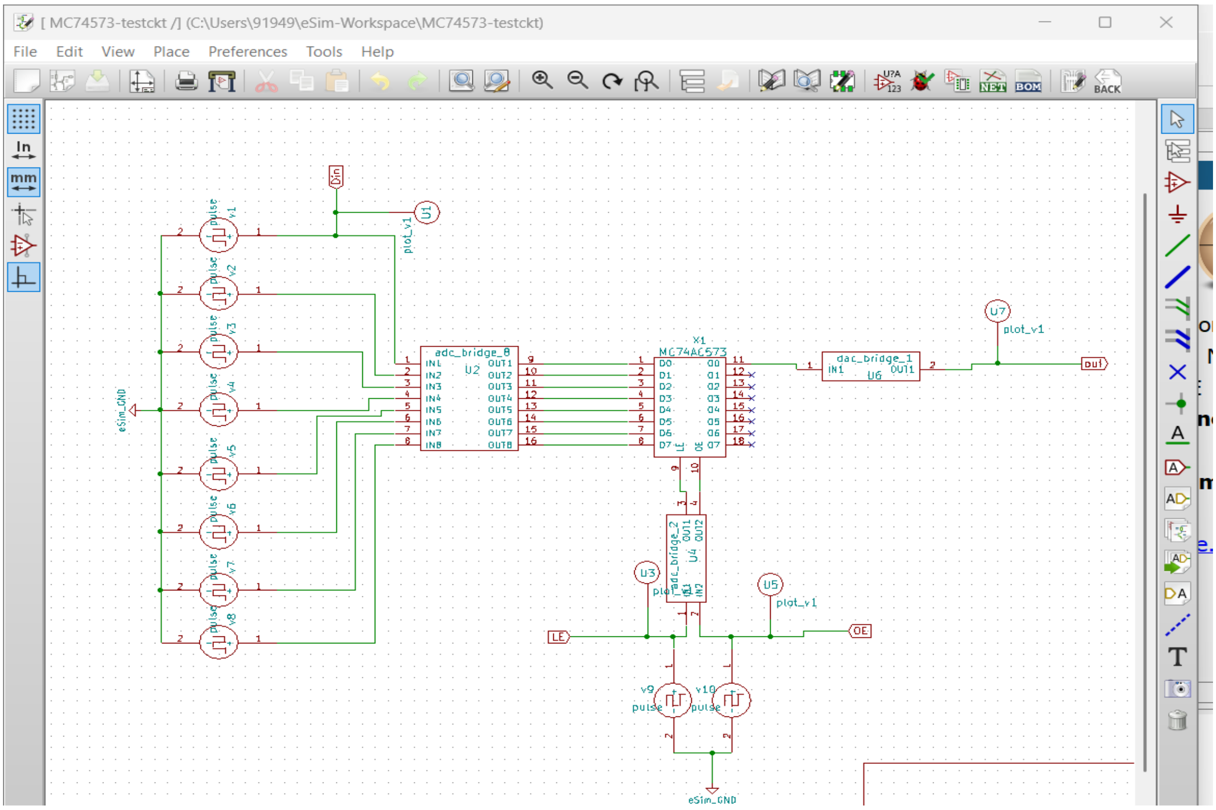


Figure 3.8: Test circuit of MC74AC573

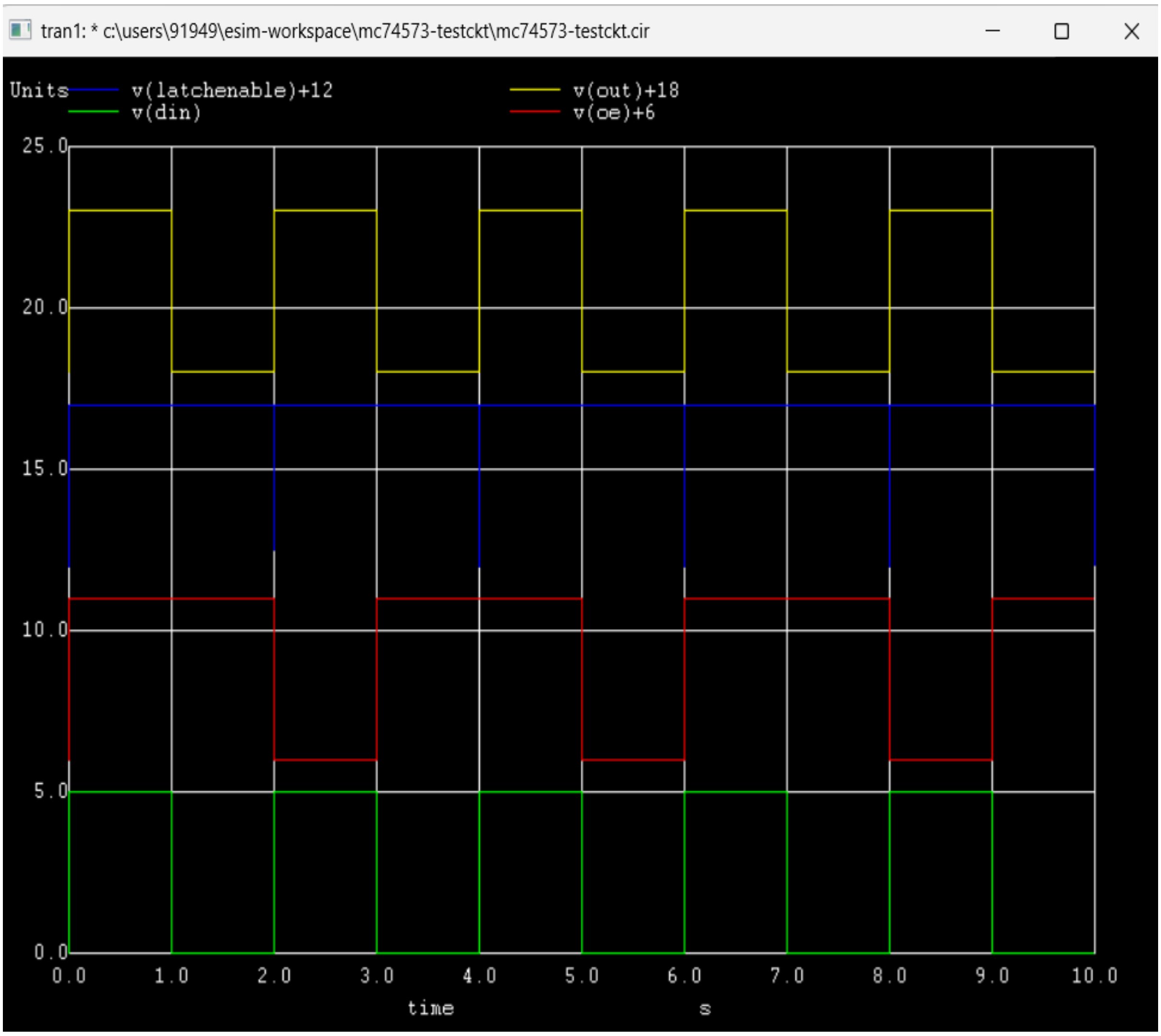


Figure 3.9: Test circuit Results

3.3 TDA2003 – 10W Car Radio Audio Amplifier

3.3.1 Description

The TDA2003 is an upgraded version of the TDA2002 audio amplifier, offering improved performance while maintaining the same pin configuration. It delivers high output current and superior distortion control, ensuring safe and efficient audio applications.

3.3.2 Key Features

- High output current capability up to 3.5A
- Very low harmonic and crossover distortion
- Full protection against DC/AC short circuits and thermal overload
- Tolerates load dump voltage surges up to 40V and open-ground conditions

3.3.3 Circuit Diagram

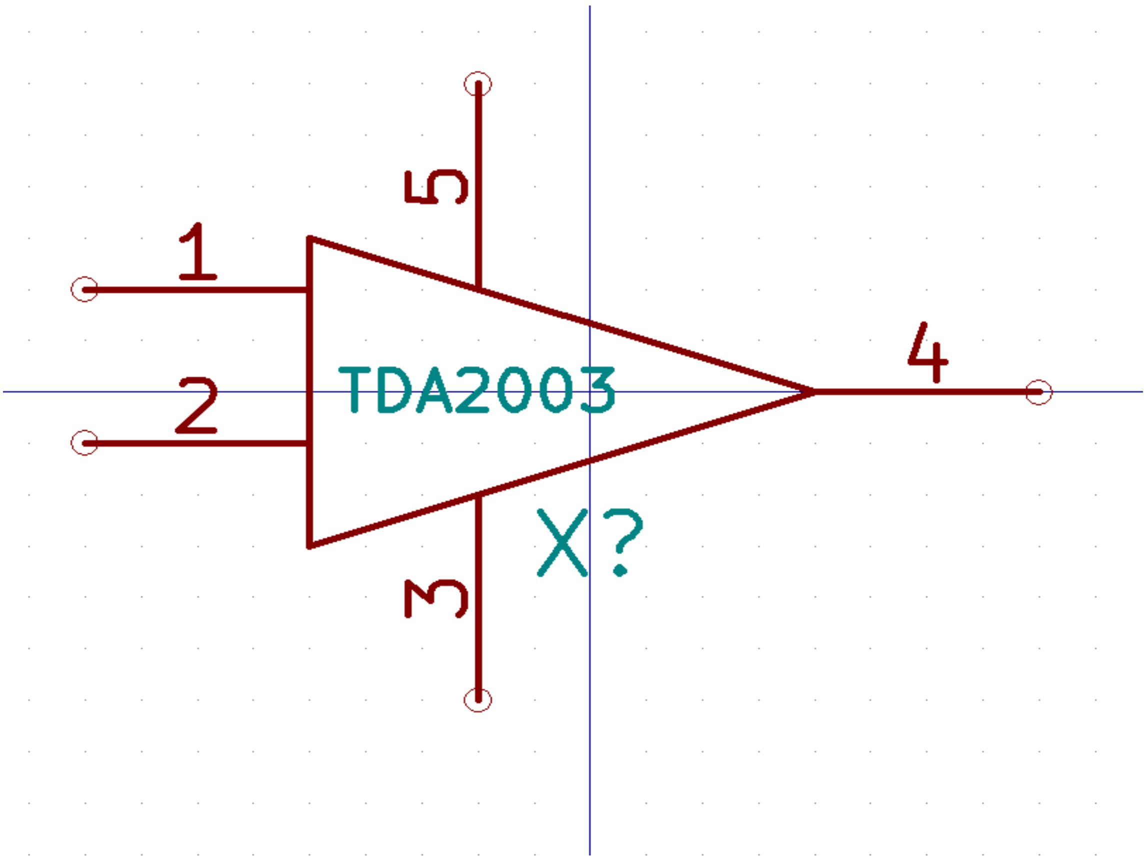


Figure 3.10: Pin Diagram of TDA2003

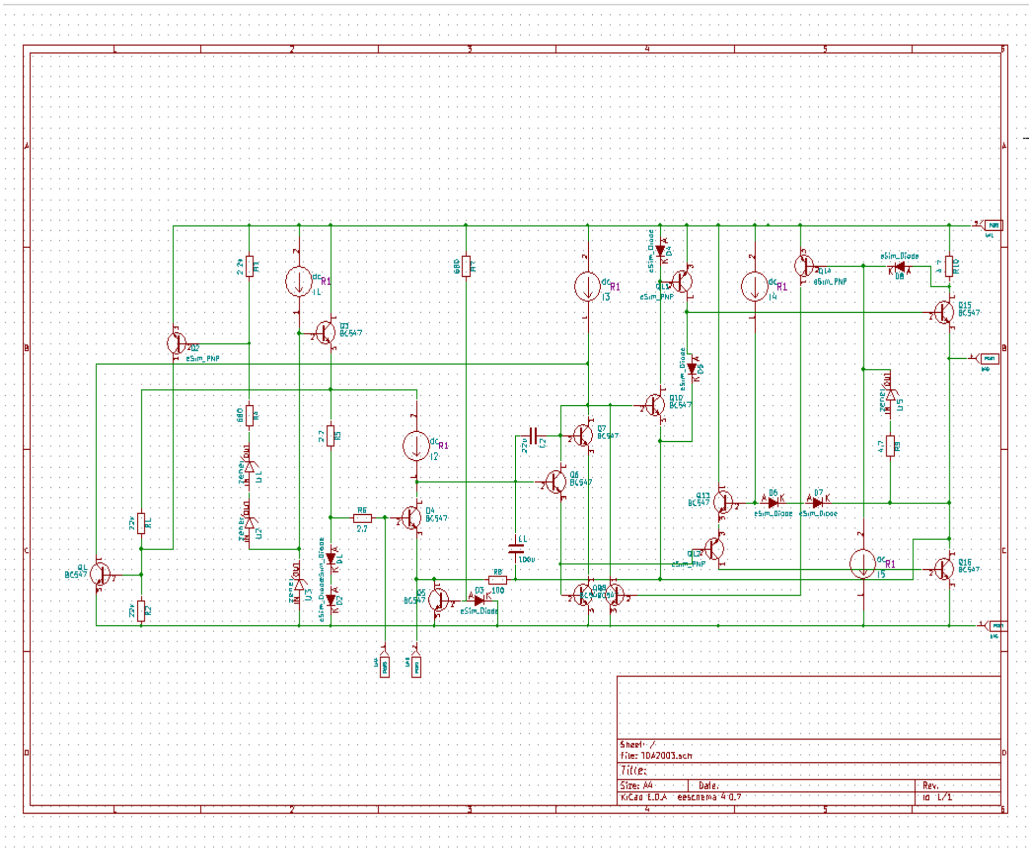


Figure 3.11: Schematic of TDA2003

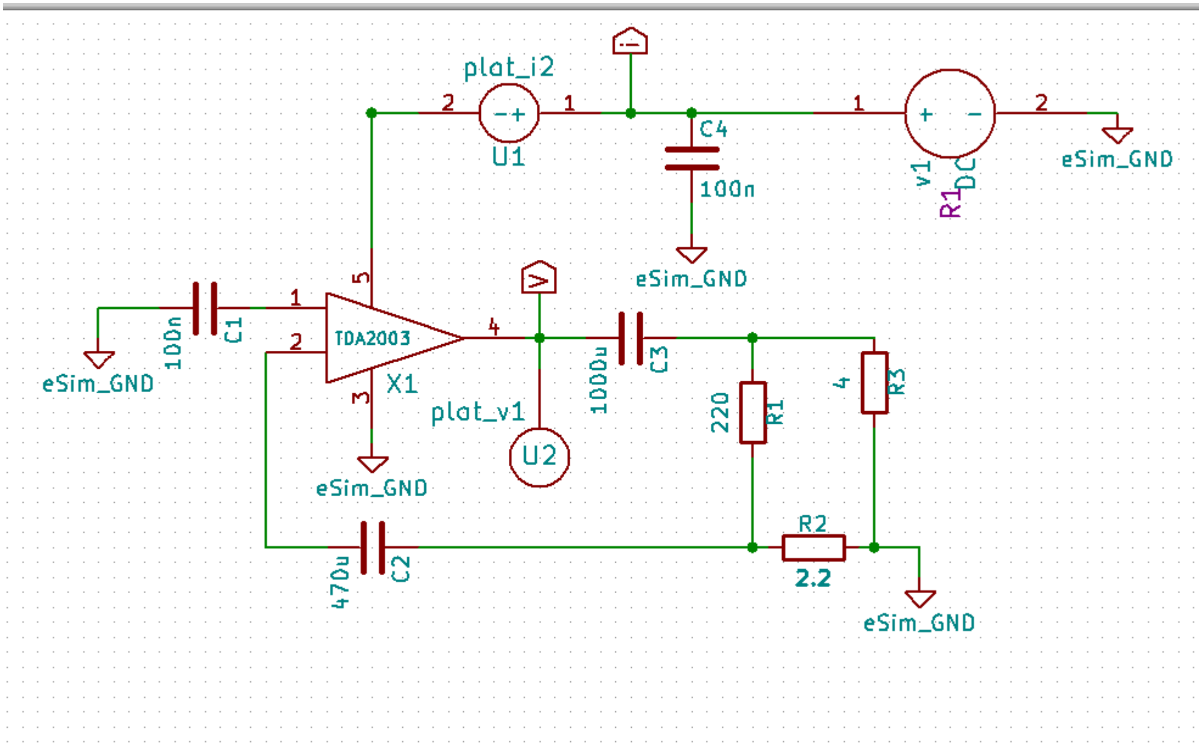


Figure 3.12: D C Test Circuit of TDA2003

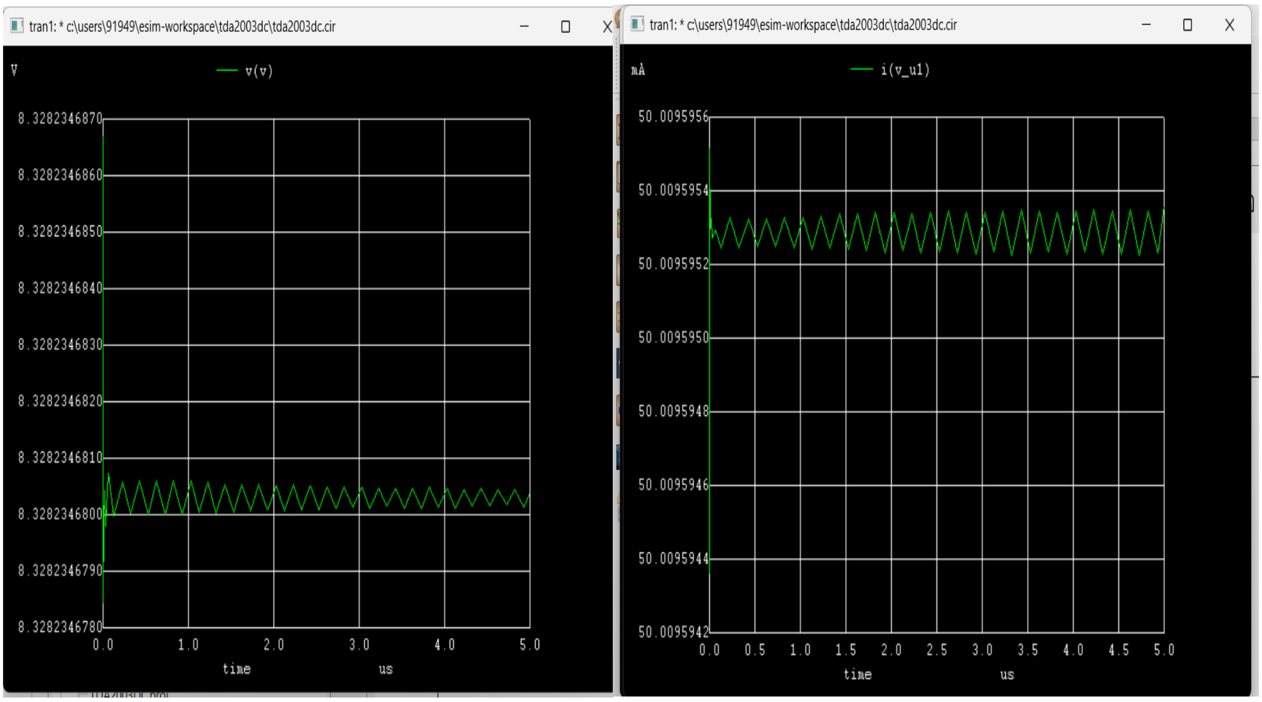


Figure 3.13: Q-Point analysis of TDA2003

3.4 SN74LS92 – Divide By-Twelve Counters

3.4.1 Description

The SN74LS92 is a 4-bit asynchronous binary counter integrated circuit (IC) from Texas Instruments' 74LS logic series. It is specifically designed as a divide-by-12 counter, combining a divide-by-2 and a divide-by-6 section using internal JK flip-flops. It's widely used in frequency counters, digital clocks, and other timing-related applications.

3.4.2 Key Features

- Divide-by-12 counter using asynchronous (ripple) logic
- Built from four JK flip-flops internally
- Operates on 5V TTL logic (Low power Schottky)
- Reset and Set pins available for control
- Available in 14-pin DIP package

3.4.3 Circuit Diagram

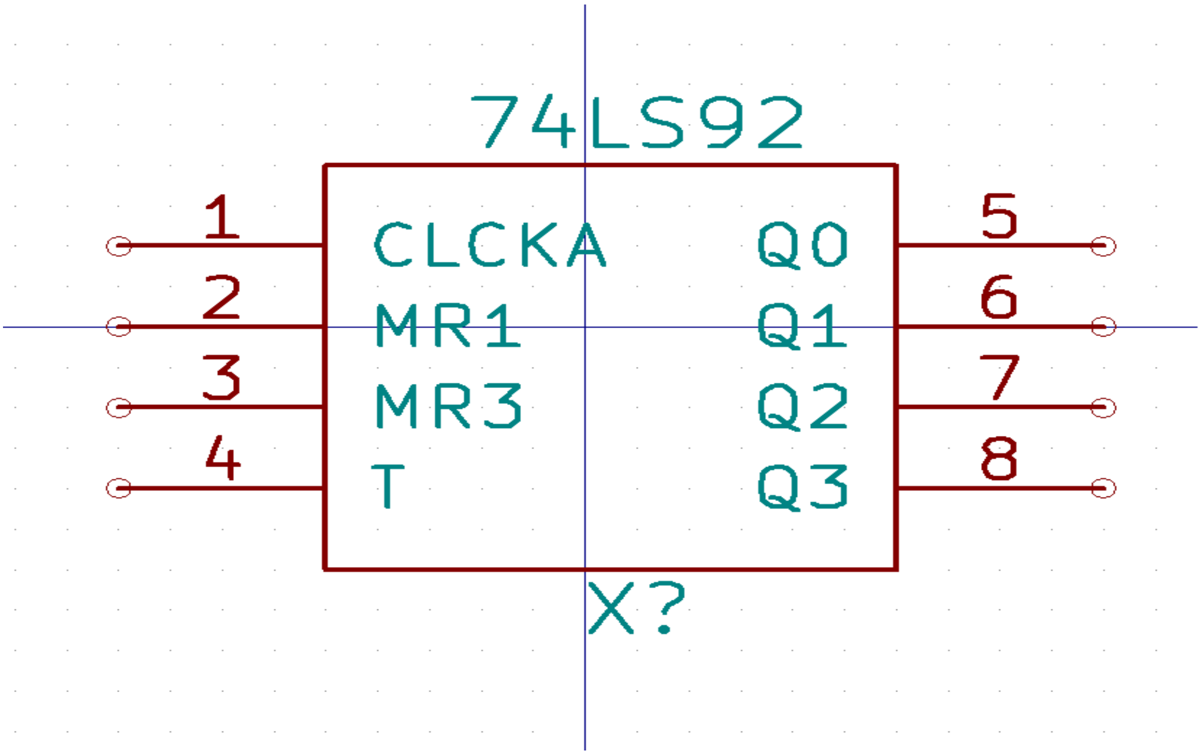


Figure 3.14: Pin Diagram of SN74LS92

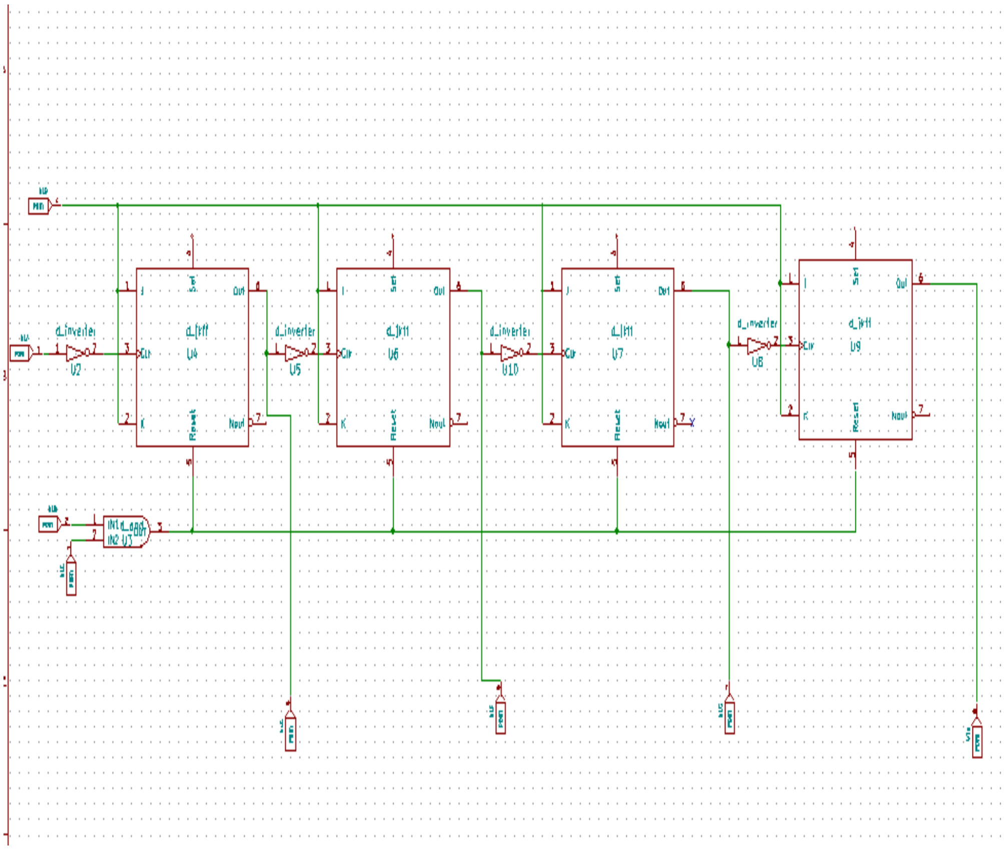


Figure 3.15: Pin Diagram of SN74LS92

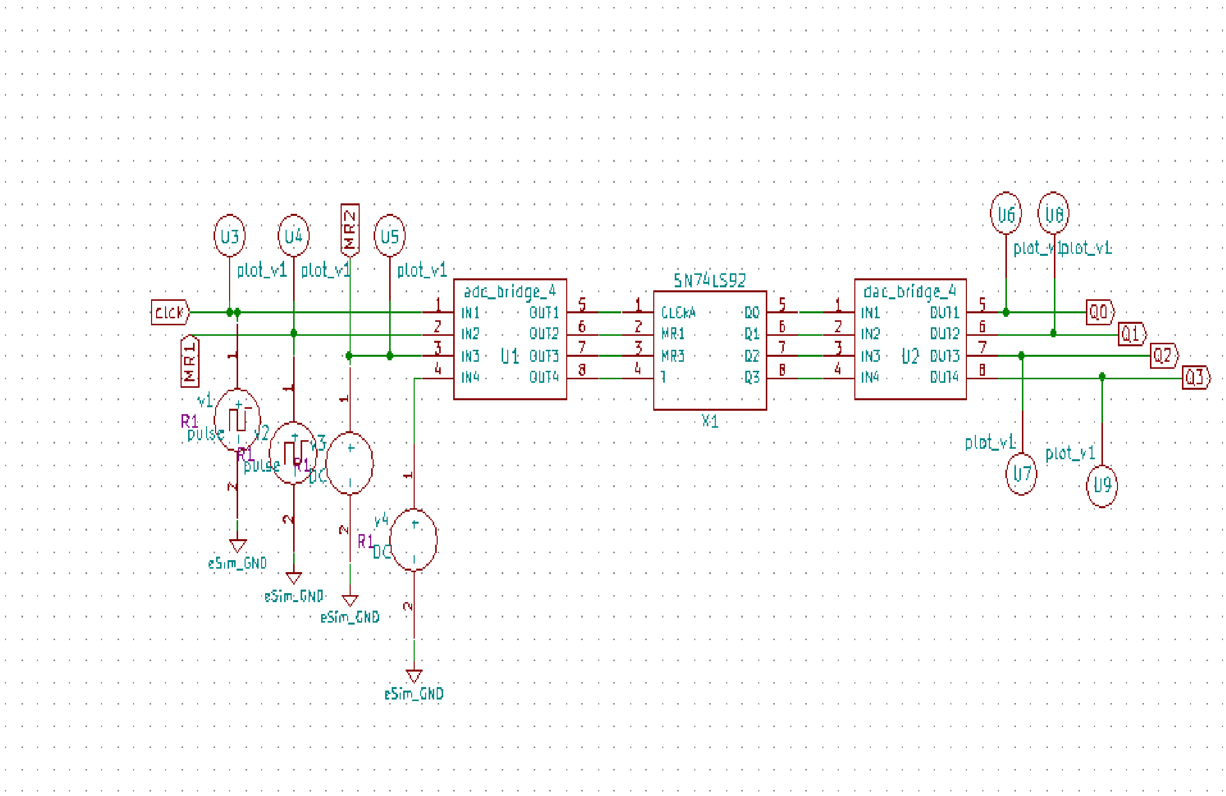


Figure 3.16: Test Circuit of SN74LS92

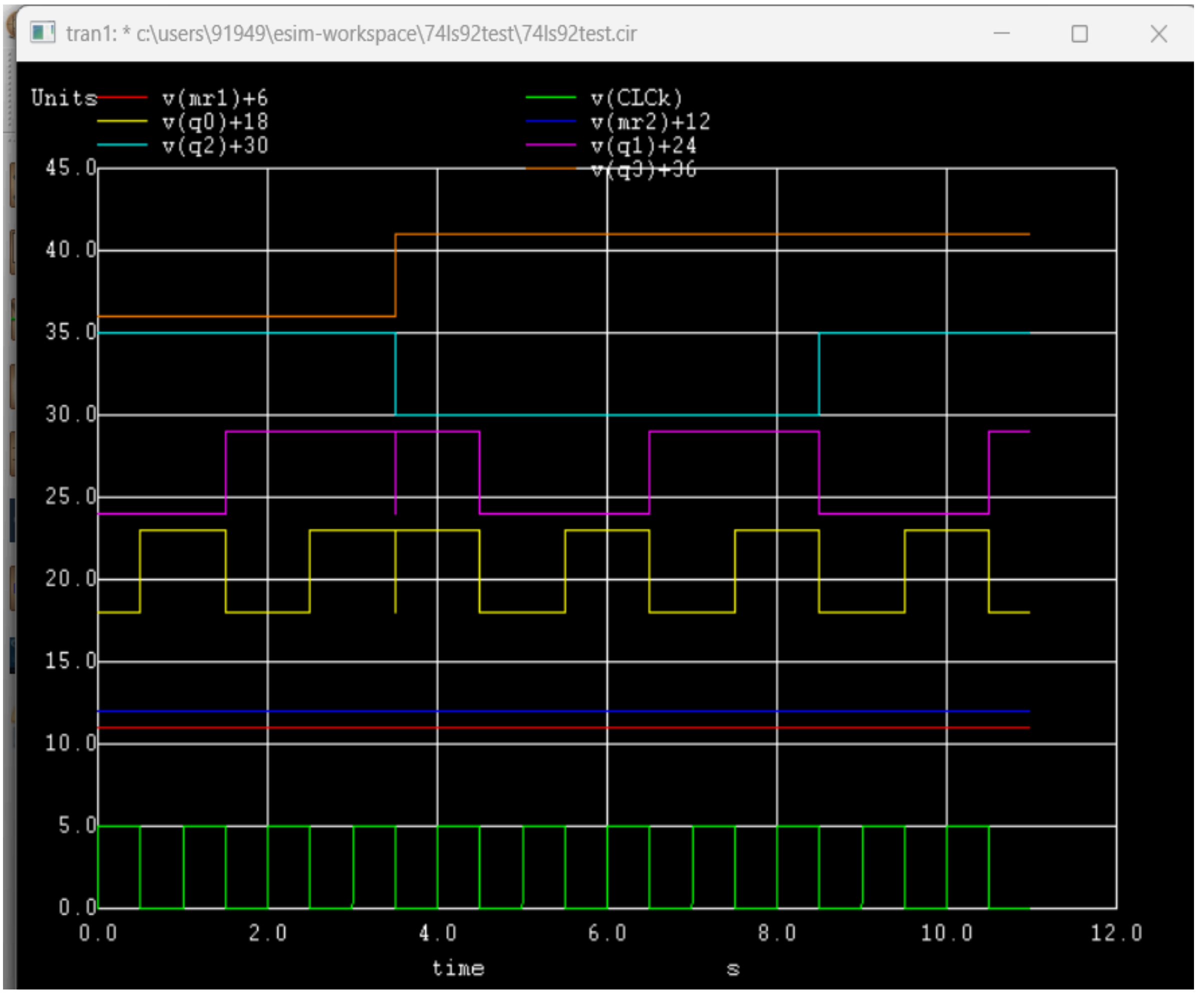


Figure 3.17: Test Circuit Results of SN74LS92

3.5 SN5444A – Gray to Decimal

3.5.1 Description

The SN5444A is a gray code to decimal decoder featuring high-speed monolithic construction using NAND gates and inverters. It is designed for compatibility with TTL logic and operates reliably over military temperature ranges.

3.5.2 Key Features

- Converts Gray code inputs to decimal outputs
- Integrated eight inverters and ten four-input NAND gates
- TTL-compatible inputs/outputs with 1V DC noise margin
- Designed for -55°C to +125°C operation in military environments

3.5.3 Circuit diagram

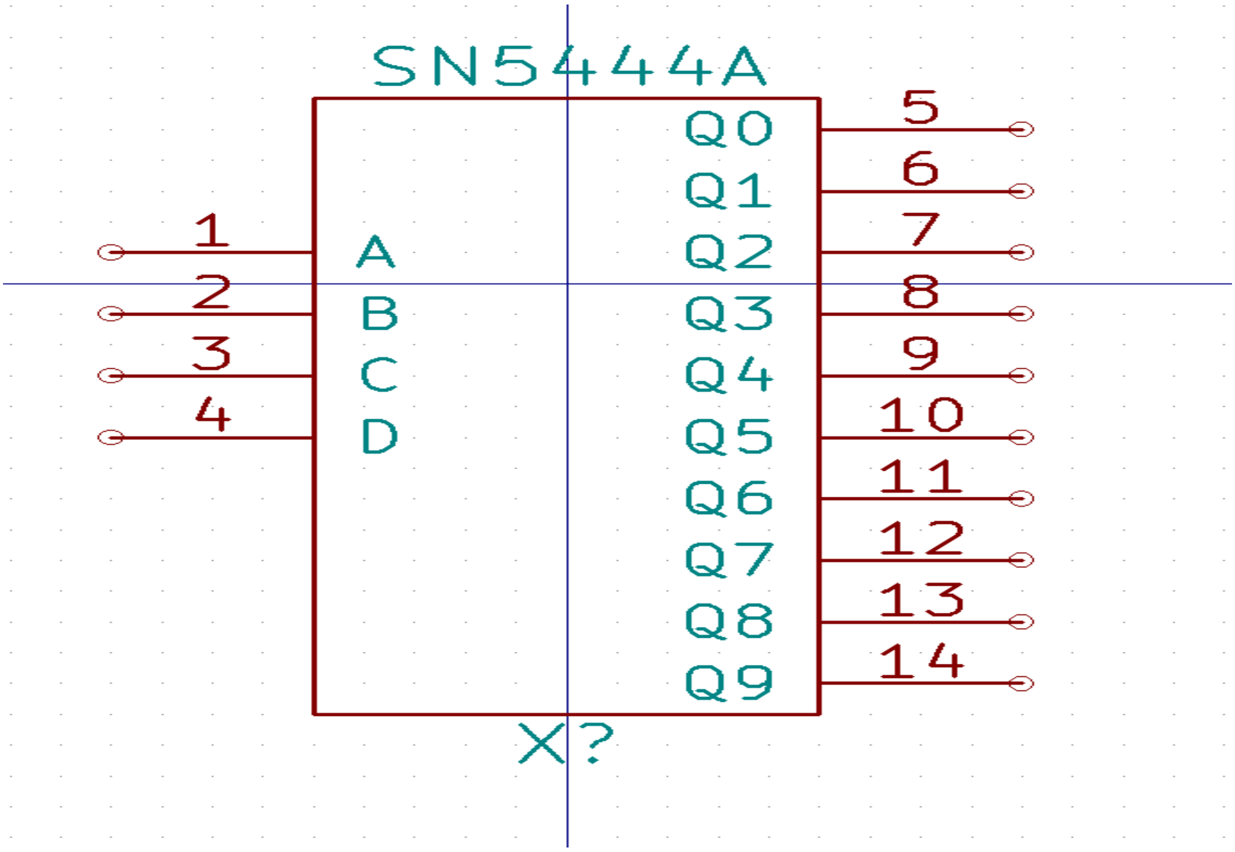


Figure 3.18: Pin Diagram of SN5444A

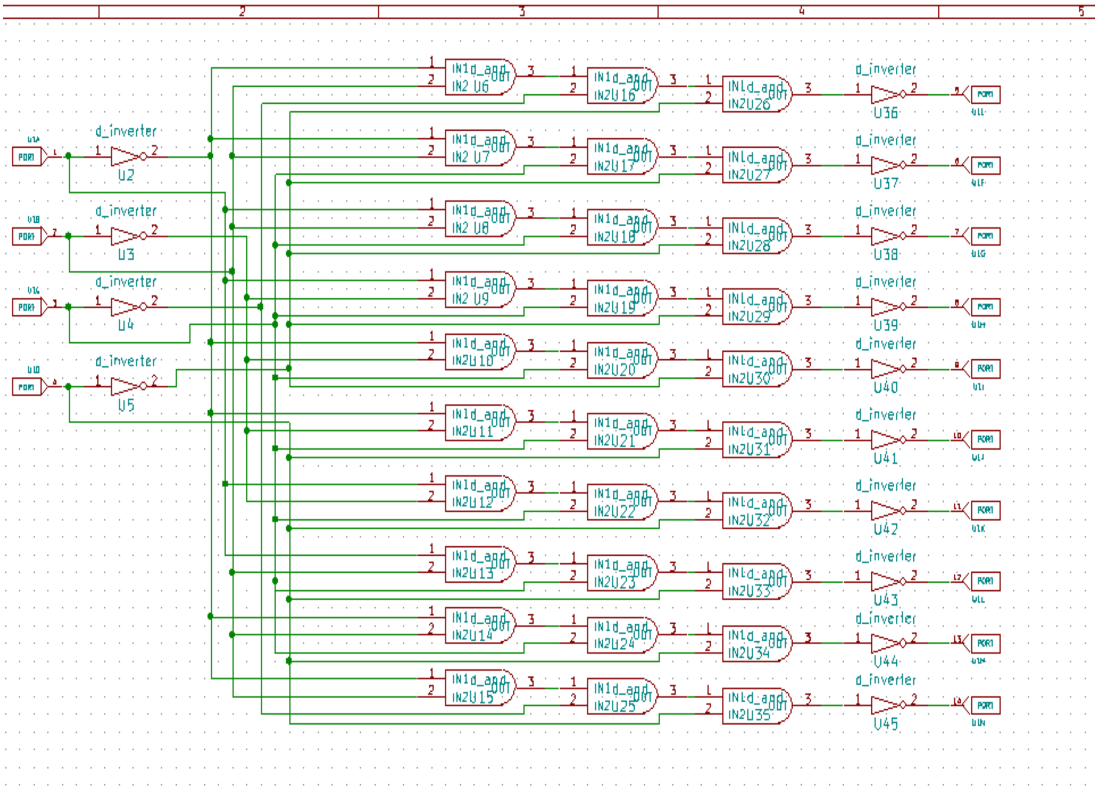


Figure 3.19: Schematic of SN5444A

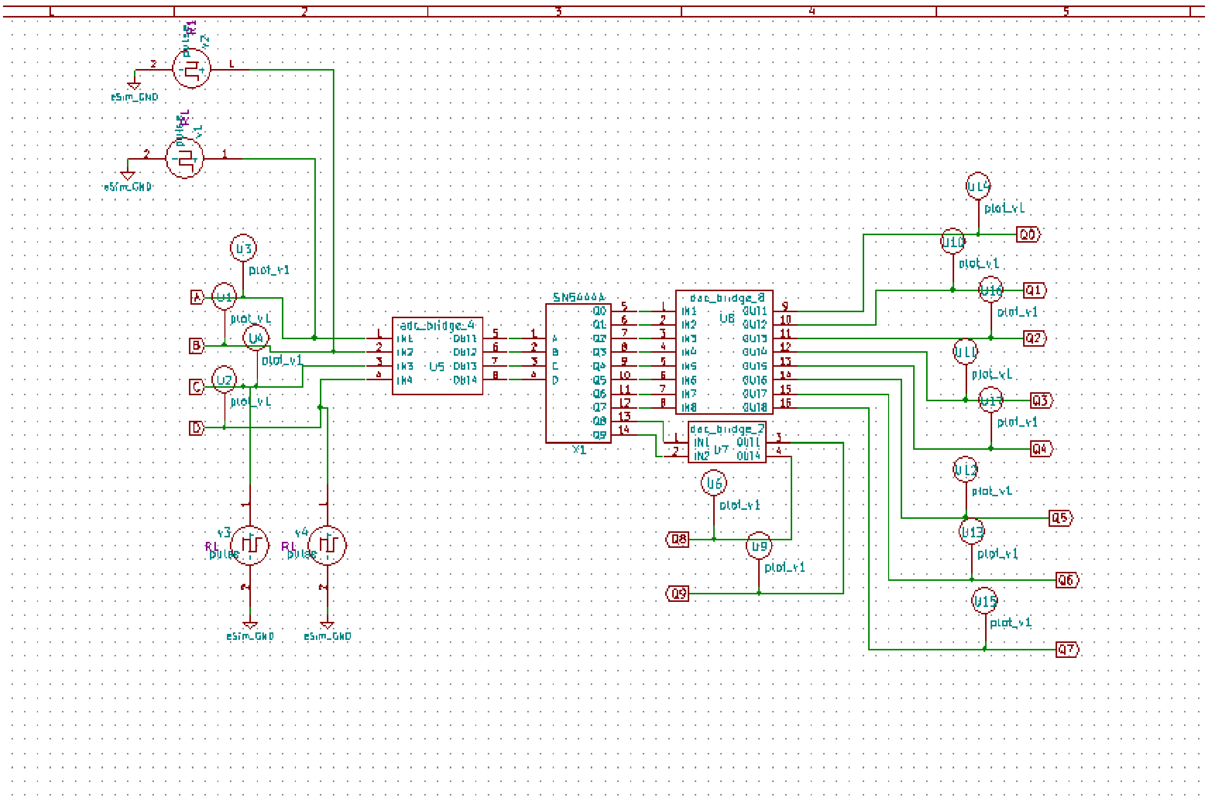


Figure 3.20: Test Circuit of SN5444A

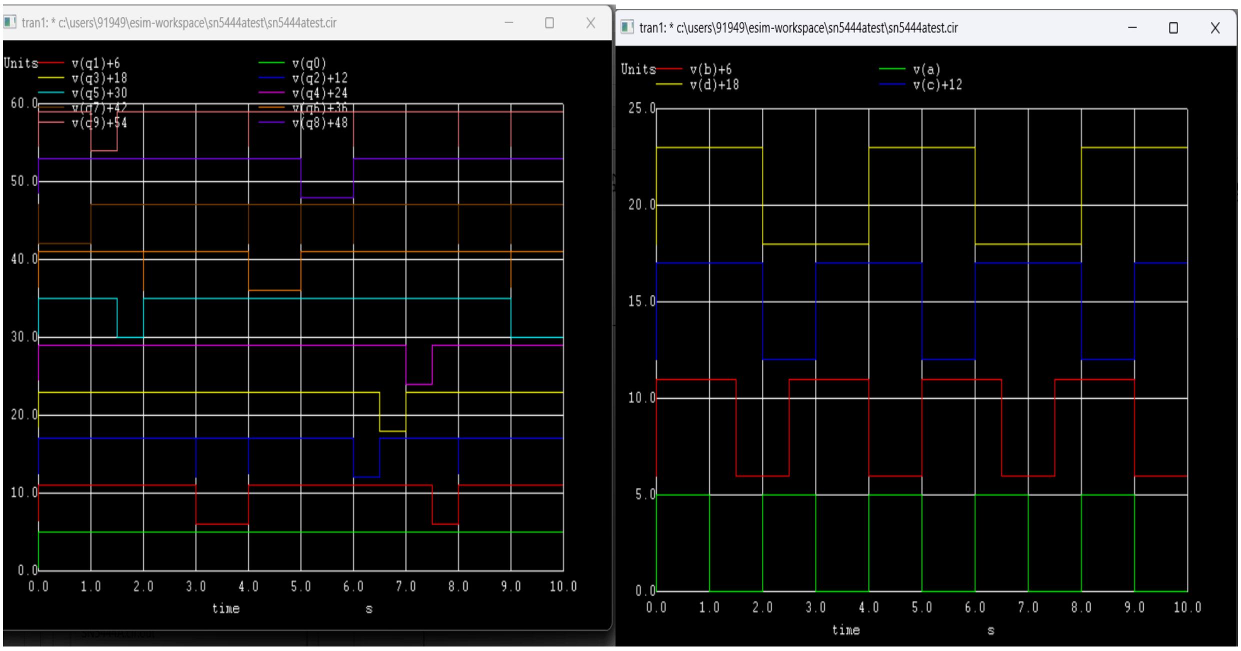


Figure 3.21: Test Circuit Results

3.6 SN5443A – Excess to Decimal

3.6.1 Description

The SN5443A is an excess-3 to decimal decoder designed to convert 4-bit excess-3 coded binary inputs into ten active-low decimal outputs. It ensures reliable decoding with full suppression of outputs for invalid input conditions.

3.6.2 Key Features

- Decodes **excess-3 (XS-3)** code into **decimal outputs (0–9)**
- Built with **eight inverters** and **ten four-input NAND gates**
- Compatible with **TTL logic levels**, offering ~1V noise margin
- Operates over the **military temperature range** of −55°C to +125°C

3.6.3 Circuit Diagram

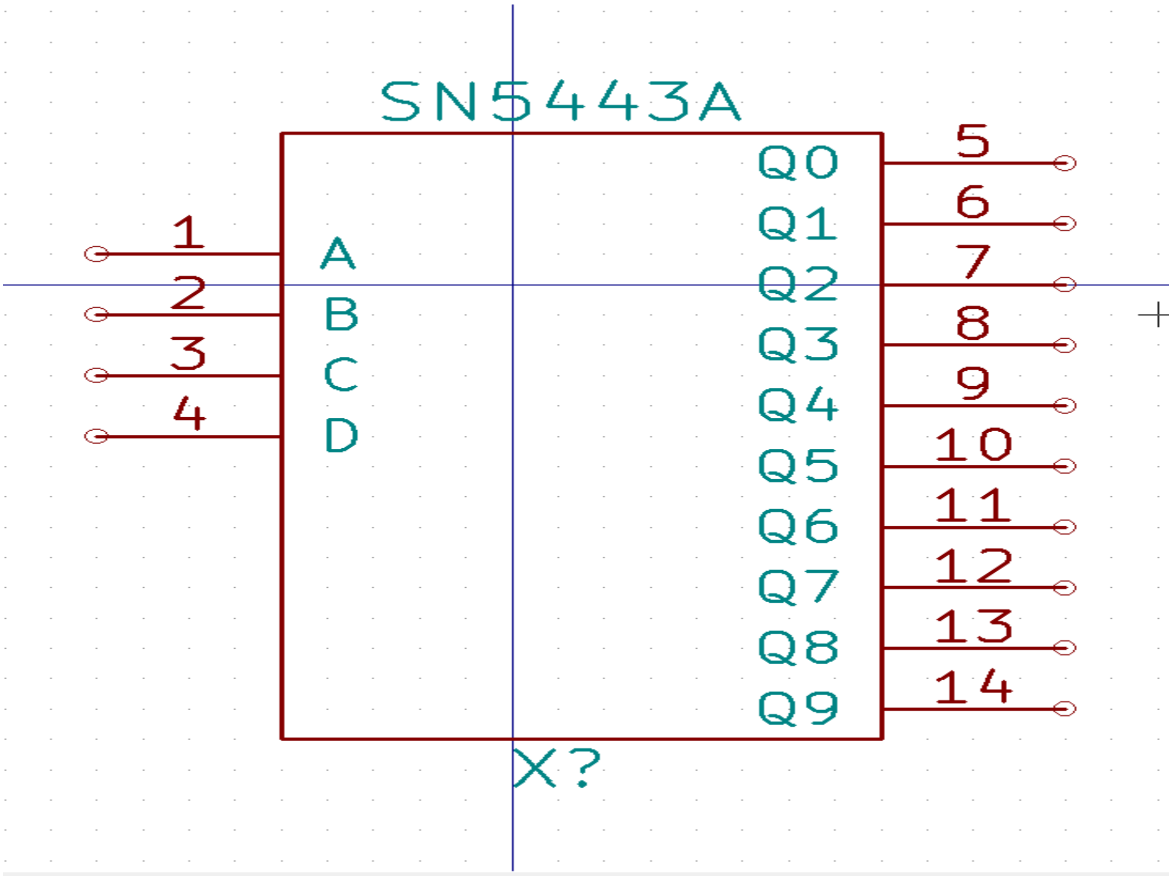


Figure 3.22: Pin Diagram of SN5443A

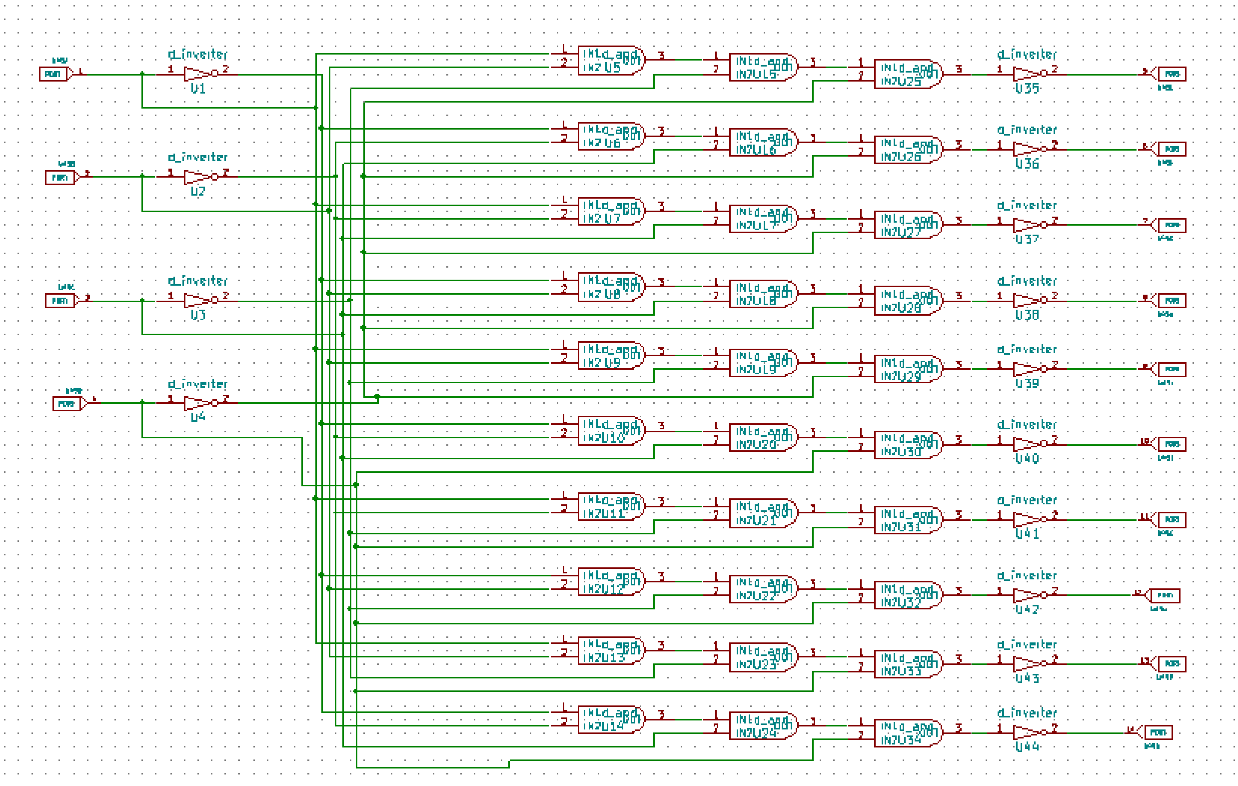


Figure 3.23: Schematic of SN5443A

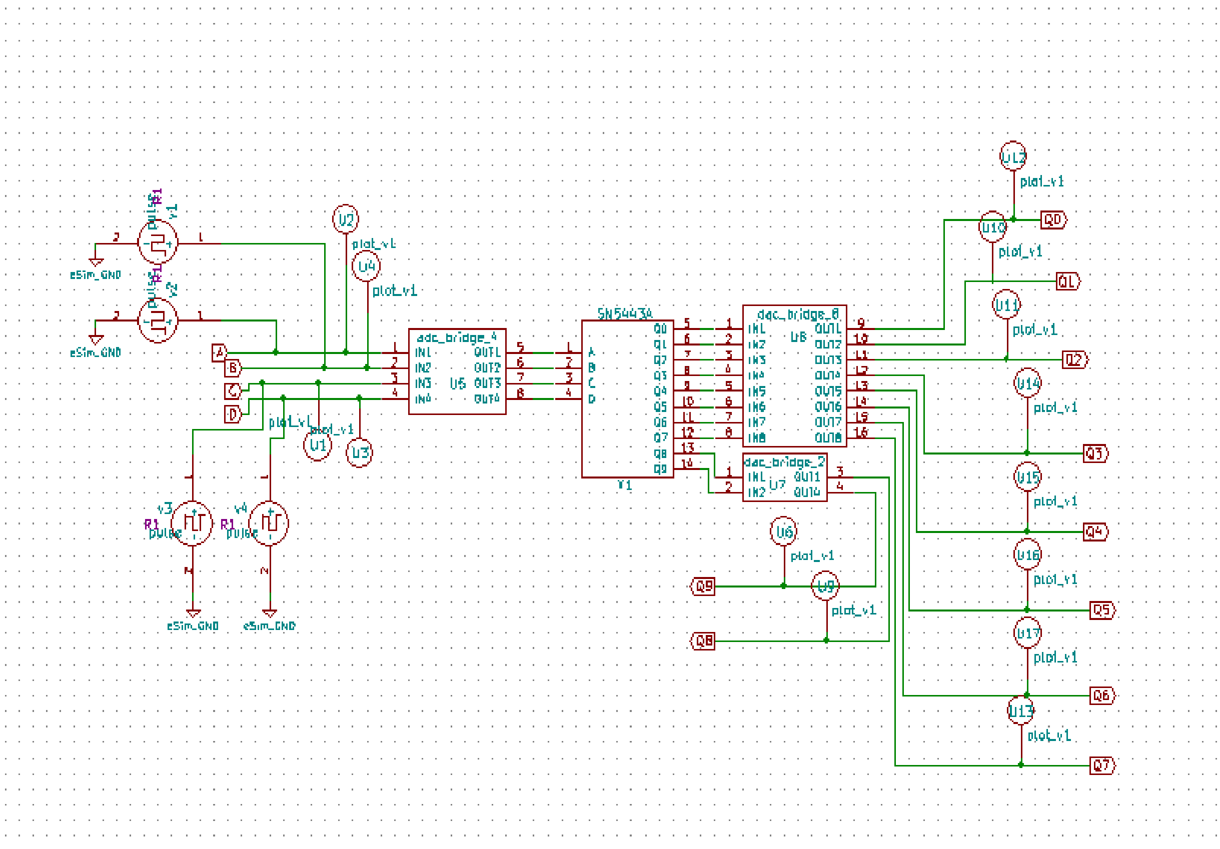


Figure 3.24: Test Circuit of SN5443A

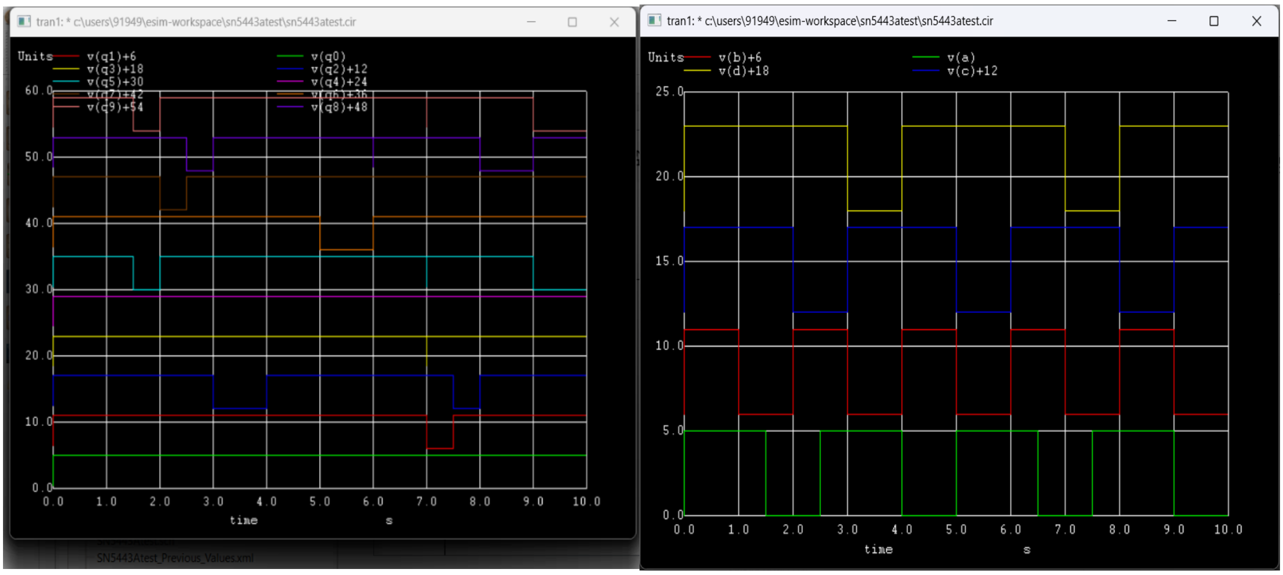


Figure 3.25: Test Circuit Results

3.7 MC14016B – Quad Analog Switch/Multiplexer

3.7.1 Description

The MC14016B is a quad bilateral switch built using complementary MOS (CMOS) technology, featuring both P-channel and N-channel enhancement mode devices. It is suitable for switching analog or digital signals in applications like modulators, demodulators, and signal gating.

3.7.2 Key Features

- Four independent bilateral switches in one IC
- Supports both analog and digital signal switching
- Low ON resistance for minimal signal distortion
- Wide voltage range: typically operates from 3V to 18V
- High noise immunity and low power consumption
- Compatible with standard CMOS logic levels

3.7.3 Circuit Diagram

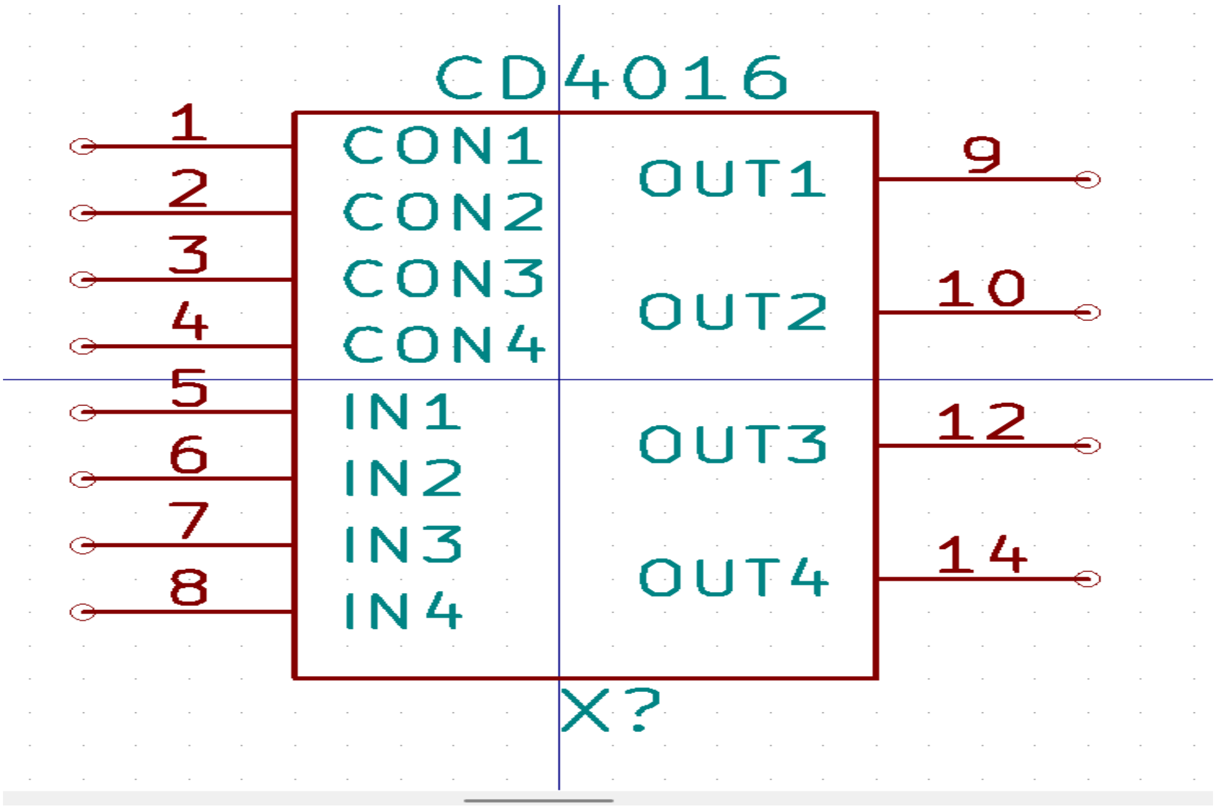


Figure 3.26: Pin Diagram of MC14016B

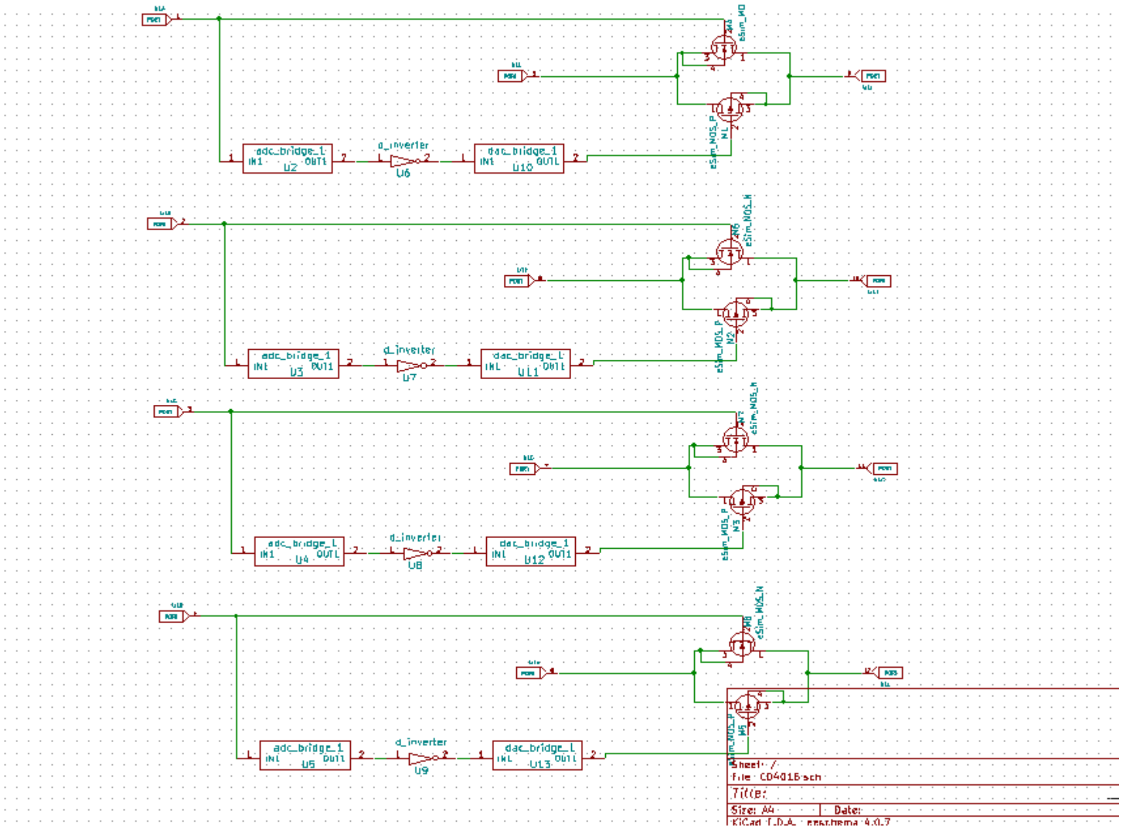


Figure 3.27: Schematic of MC14016B

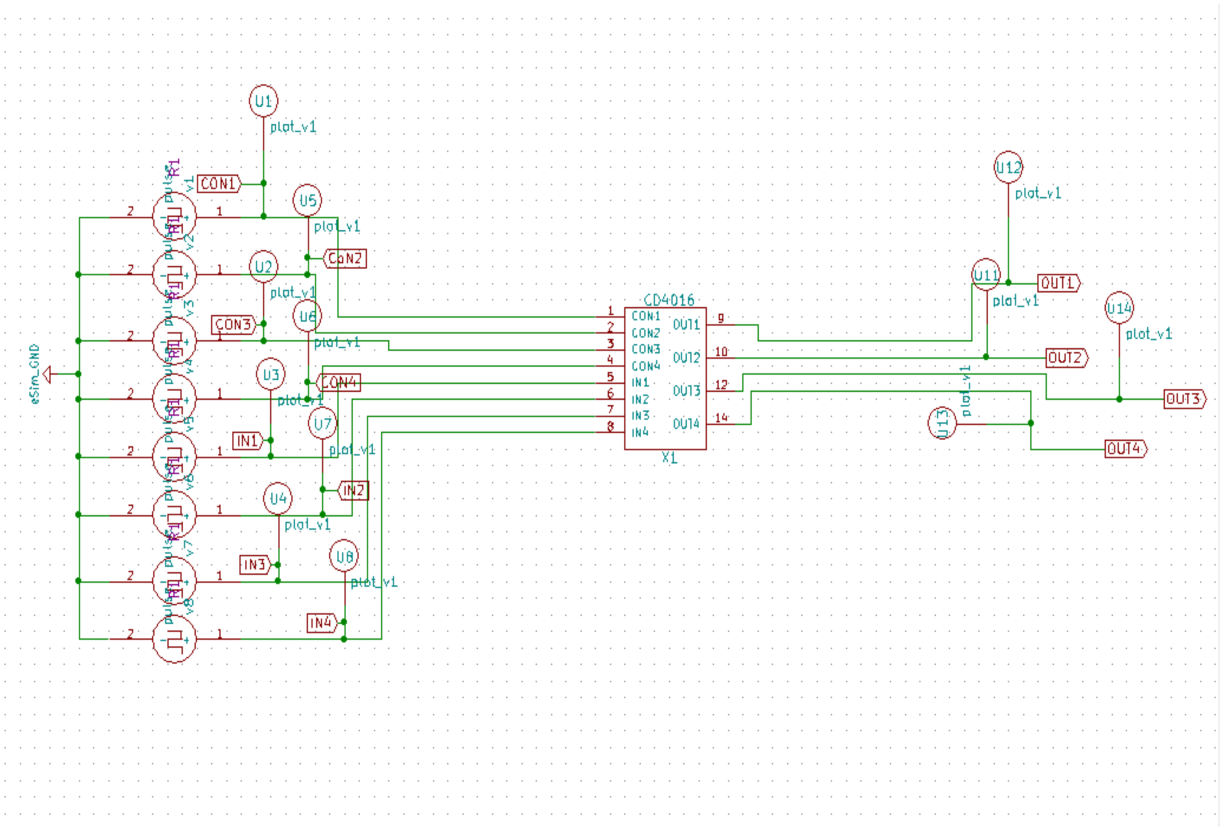


Figure 3.28: Test Circuit of MC14016B

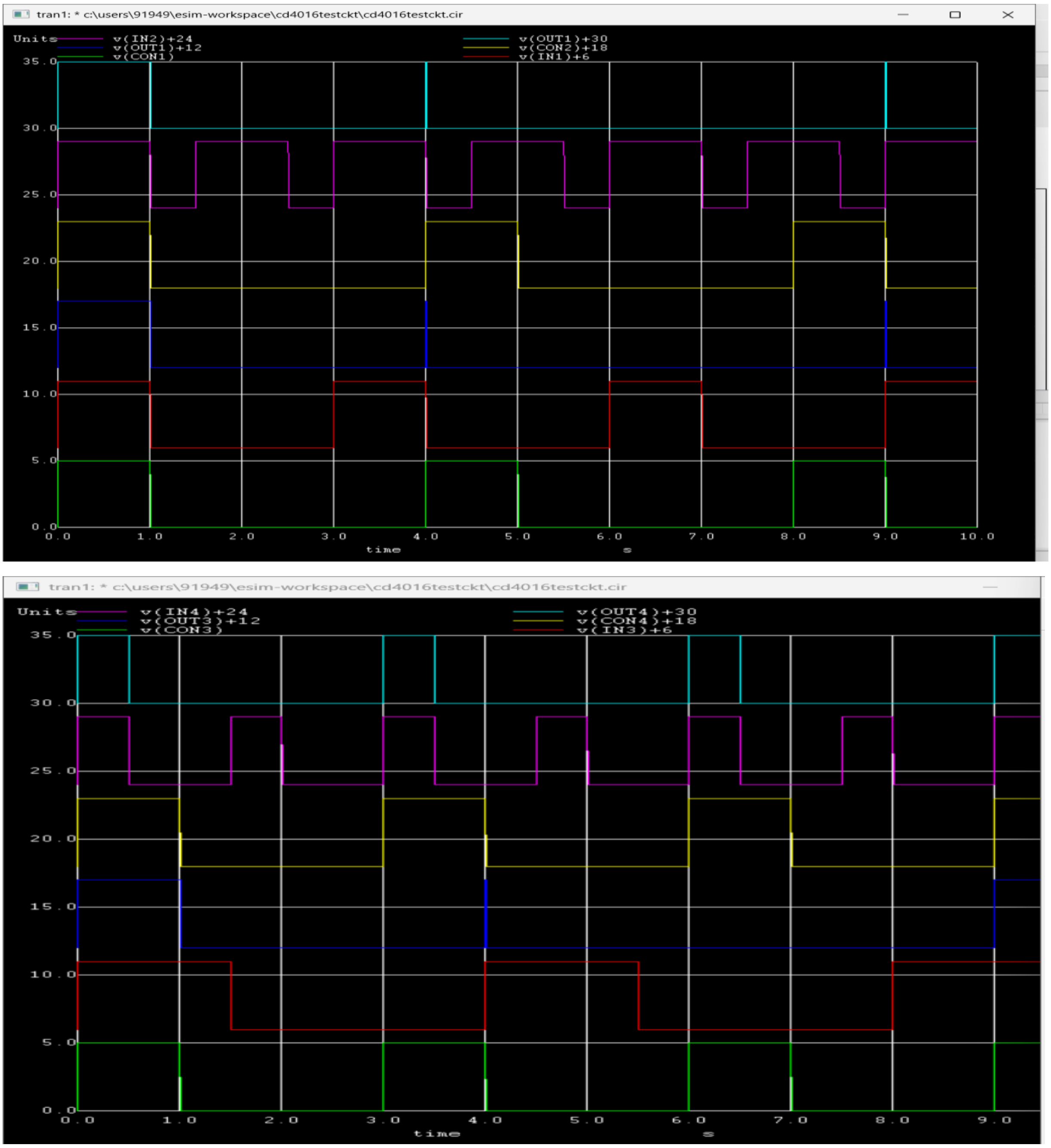


Fig 3.29: Schematic of MC14016B

3.8 SN5423 – Dual 4-Input nor Gates with Strobe

3.8.1 Description

The SN5423 and the SN5425 are characterized for operation over the full military temperature range of -55°C to 125°C. The SN7423 and the SN7425 are characterized for operation from 0°C to 70°C.

3.8.2 Key Features

- Implements dual 4-input positive NOR logic with enable (strobe) functionality
- Compatible with standard TTL logic levels
- SN54xx series rated for −55°C to +125°C (military grade)
- SN74xx series rated for 0°C to +70°C (commercial grade)

3.8.3 Circuit Diagram

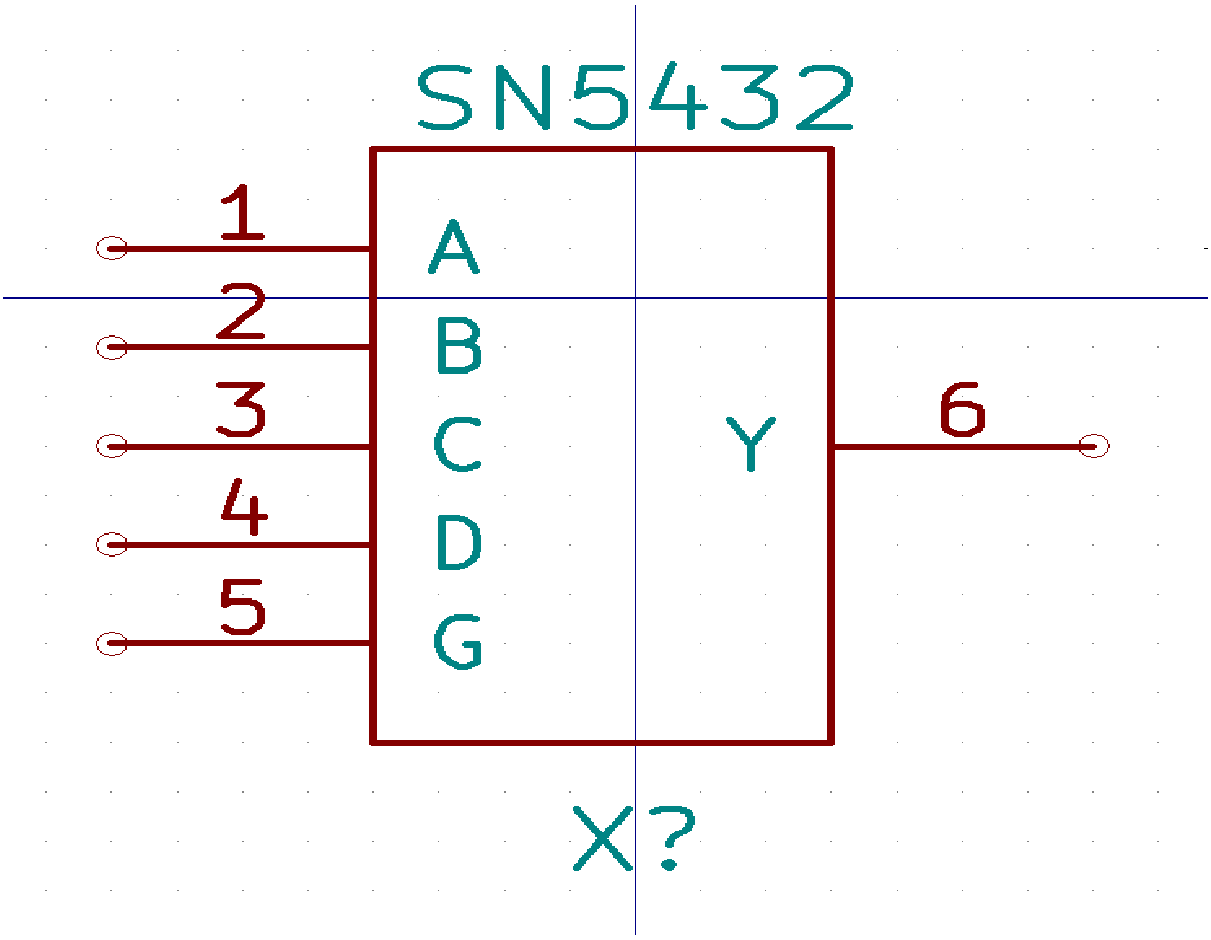


Figure 3.30: Pin Diagram of SN5423

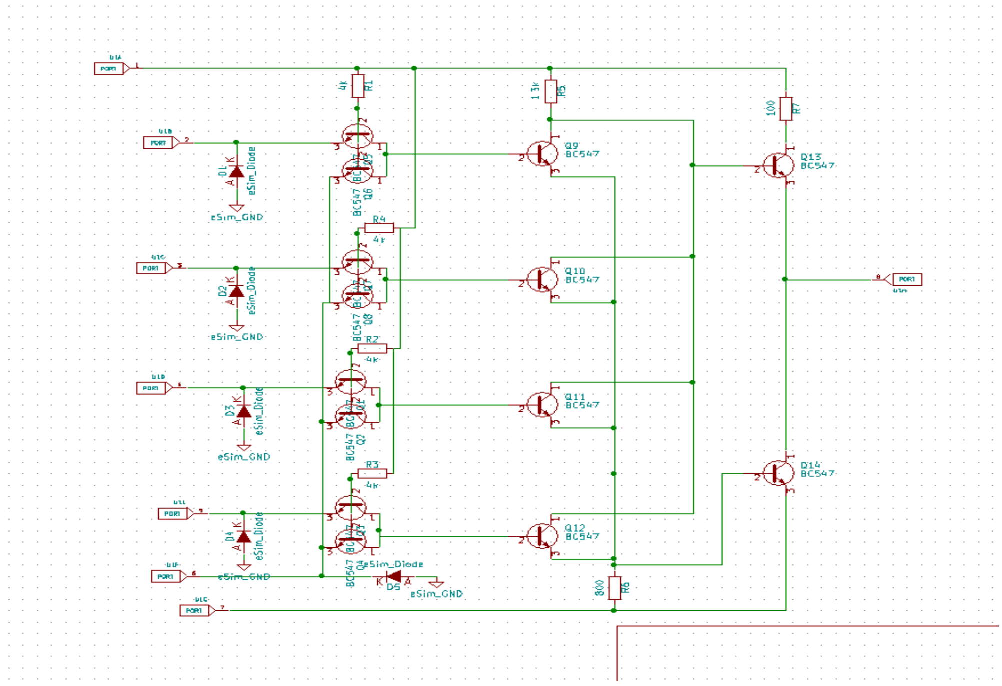


Figure 3.31: Schematic of SN5423

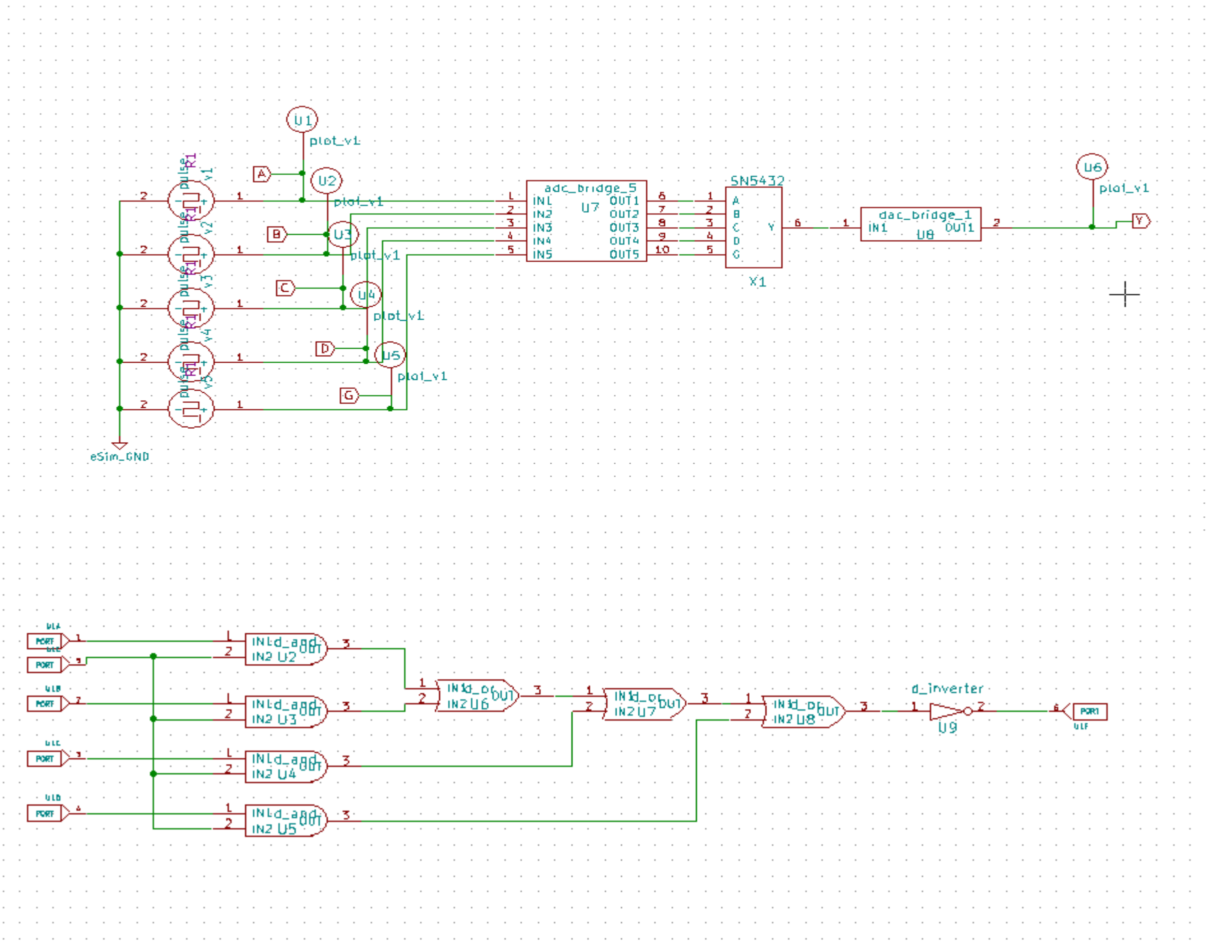


Figure 3.32: Test Diagram of SN5423

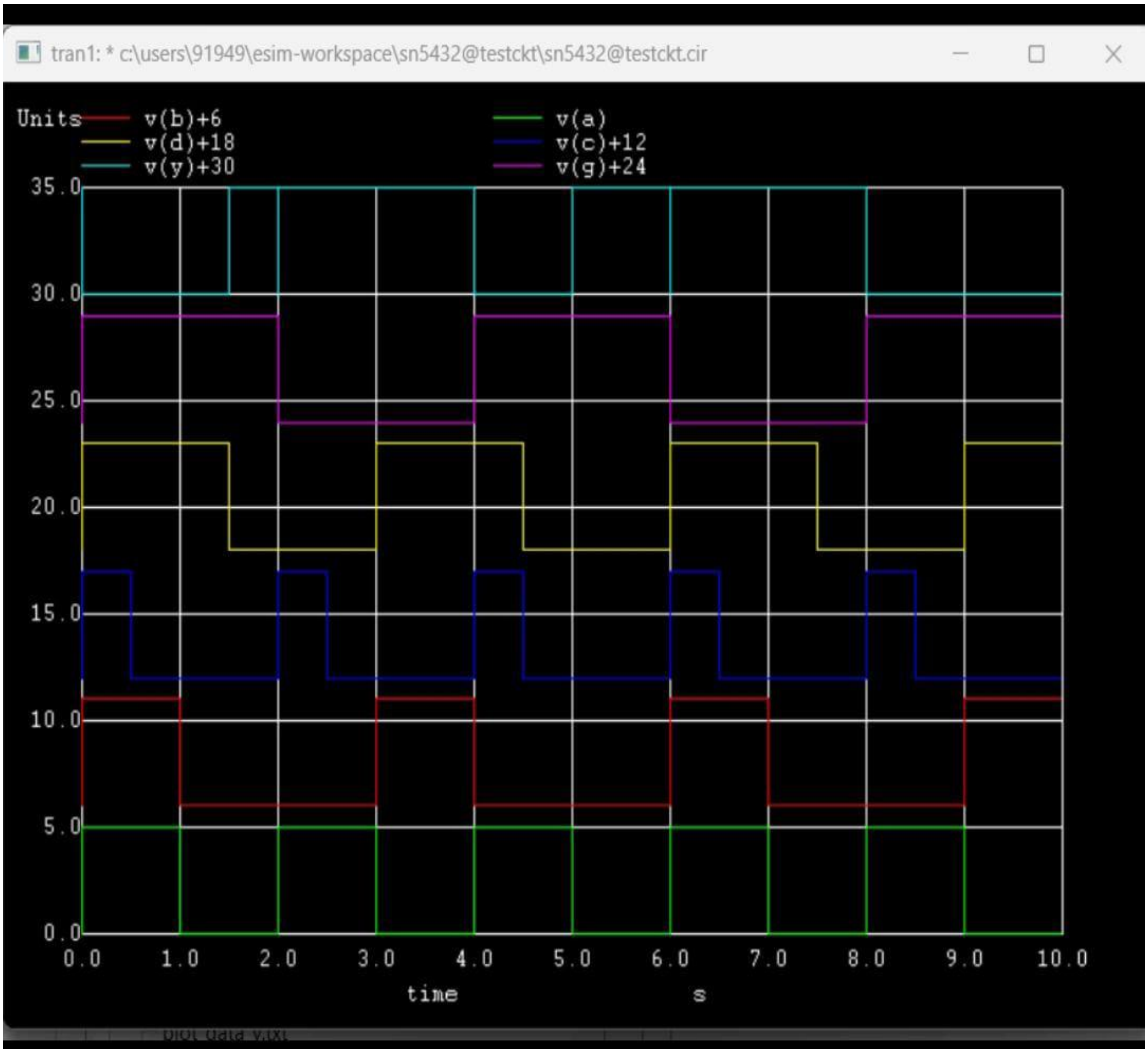


Figure 3.33: Test Diagram Results

Chapter 4

Conclusion and Future Scope

The eSim internship provided a strong foundation in circuit design and simulation. Through hands-on practice, I gained valuable experience in creating schematics, mapping SPICE models, generating netlists, and performing various types of circuit simulations. The structured workflow of eSim, helped me understand the end-to-end process of electronic design automation.

This internship not only enhanced my technical proficiency in EDA tools but also emphasized the importance of open-source solutions in promoting accessible and cost-effective learning. The exposure to debugging techniques and simulation analysis has further strengthened my readiness for real-world applications in electronics systems.

We were able to design ICs subcircuits and then transform them into package which can be used in any other circuits for simulation in eSim.

There is scope for contributing to Research and Development in the field of circuit simulation tools, working on improving accuracy and the including more features.

In future we can contribute to the development and improvement of eSim itself by identifying bugs or adding new features.

eSim can be improved by providing more precise and user-friendly error messages that clearly indicate the type and location of issues in circuit designs, enabling users to debug and resolve problems more efficiently.

Chapter 5

References

FOSSEE eSim spoken tutorials
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TDA2003 – 10W Car Radio Audio Amplifier
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SN5444A – Gray to Decimal
URL: https://www.ti.com/product/SN74LS92

SN5443A – Excess to Decimal
URL: https://www.ti.com/product/SN74LS92

MC14016B – Quad Analog Switch/Multiplexer
URL: https://www.onsemi.com/pdf/datasheet/mc14016b-d.pdf

SN5423 – Dual 4-Input nor Gates with Strobe
URL: https://www.ti.com/product/SN5423