Semester Long Internship Spring 2026

On

Designing Integrated Circuit in eSim

Submitted by

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Acknowledgment

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This internship has been an enriching learning experience, allowing me to work closely with open-source EDA tools, develop IC subcircuits in eSim, and gain exposure to real-world circuit modelling and simulation workflows. The knowledge acquired during this period will undoubtedly support my future academic and professional pursuits.

I would also like to thank the entire FOSSEE team for their coordination, assistance, and timely interactions at various stages of this work. Their collective efforts ensured smooth workflow, resource accessibility, and effective project execution.

Contents

Chapter 1

Introduction

1.1 FOSSEE

FOSSEE (Free/Libre and Open Source Software for Education) is an initiative of the Indian Institute of Technology Bombay aimed at promoting the use of open-source software in education and research. It encourages students, educators, and professionals to adopt open-source alternatives and contribute to their development. Through workshops, documentation, internships, and collaborative projects, FOSSEE supports the growth of open-source engineering and scientific computing tools.

1.2 eSim

eSim is an open-source Electronic Design Automation (EDA) tool developed under the FOSSEE project at IIT Bombay. It combines various open-source software packages into a unified platform for circuit design, simulation, and PCB development. eSim provides features for schematic creation, circuit simulation, PCB layout generation, and subcircuit development.

The software is particularly useful for students, educators, and researchers as it offers an affordable and accessible alternative to proprietary EDA tools. The Subcircuit feature of eSim allows users to create reusable circuit modules, making complex circuit design more efficient and organized.

1.3 Ngspice

Ngspice is an open-source mixed-signal circuit simulator based on the SPICE simulation engine. It supports simulation of analog, digital, and mixed-signal circuits. Users can perform DC, AC, transient, and noise analysis to study circuit behavior and verify functionality.

Ngspice provides extensive device libraries including transistors, diodes, resistors, capacitors, inductors, and digital logic elements. It plays a vital role in eSim by enabling accurate circuit simulation and waveform analysis.

1.4 KiCad

KiCad is an open-source Electronic Design Automation software suite used for schematic capture and PCB design. It provides tools for creating professional-quality circuit schematics and multilayer PCB layouts. KiCad supports component libraries, design rule checking, and Gerber file generation for PCB manufacturing.

Within eSim, KiCad is integrated to provide schematic design and PCB layout capabilities.

1.5 GHDL

GHDL is an open-source VHDL simulator used for digital hardware design and verification. It enables users to analyze, compile, and simulate VHDL code for digital systems. GHDL helps designers understand the behavior of combinational and sequential logic circuits before hardware implementation.

The simulator is widely used in digital electronics education, FPGA development, and hardware modeling applications.

Chapter 2

Features of eSim

The primary objective behind the development of eSim is to provide a comprehensive open-source Electronic Design Automation solution for electronics and electrical engineers. The software supports schematic design, PCB development, circuit simulation, and subcircuit creation within a single environment.

1. **Schematic Creation**

   eSim provides a user-friendly graphical interface for creating electronic circuit schematics. Components can be selected from extensive libraries and connected through wires and buses. Editing tools allow users to move, rotate, label, and organize circuit components efficiently.

2. **Circuit Simulation**

   eSim integrates Ngspice for analog, digital, and mixed-signal circuit simulation. Users can perform transient, DC, AC, and noise analysis to study circuit performance. Waveform viewers help visualize simulation results and verify circuit operation.

3. **PCB Design**

   eSim incorporates KiCad for PCB layout generation. Components can be placed accurately on the board and interconnected using routed traces. Design Rule Checking (DRC) ensures manufacturable PCB designs while Gerber files can be generated for fabrication.

4. **Subcircuit Feature**

   The Subcircuit feature enables modular circuit development by allowing users to create reusable circuit blocks. Designers can build complex systems by integrating multiple subcircuits, reducing design effort and improving project organization.

5. **Open Source Integration**

eSim integrates several open-source tools including KiCad, Ngspice, and GHDL into a unified environment. Being open-source, the software is freely available to students, educators, and researchers, eliminating licensing costs while encouraging collaborative development.

Chapter 3

Problem Statement

The objective of this internship project is to design and develop various digital Integrated Circuit (IC) models using the Subcircuit feature available in eSim. These ICs are implemented using device model files already present in the eSim library and are intended for future integration into the eSim subcircuit library.

The project focuses on developing reusable digital logic components and validating their functionality through simulation and waveform analysis.

3.1 Approach

The implementation process followed a systematic methodology based on official datasheets provided by manufacturers such as Texas Instruments, Nexperia, and ON Semiconductor.

1. **Datasheet Analysis**

   Datasheets of various digital ICs were studied in detail to understand their functionality, truth tables, pin configurations, and electrical characteristics.

2. **Subcircuit Development**

   Each selected IC was implemented using available device models within eSim. Symbol creation, pin mapping, and internal circuit modeling were performed according to datasheet specifications.

3. **Test Circuit Design**

   Dedicated test circuits were developed to verify the operation of each IC under different input conditions. These circuits were designed based on the functional requirements described in the datasheets.

4. **Simulation and Verification**

   The developed circuits were simulated using Ngspice within eSim. Output waveforms were analyzed and compared with expected results from datasheets. Any discrepancies were corrected through iterative design modifications until the circuit behaved correctly.

Chapter 4

Integrated Circuit Design

4.1 74HC137 – 3-to-8 Line Decoder, Demultiplexer with Address Latches; Inverting

The 74HC137 is a high-speed CMOS 3-to-8 line decoder and demultiplexer IC with address latch functionality and active LOW outputs.

4.1.1 Symbol

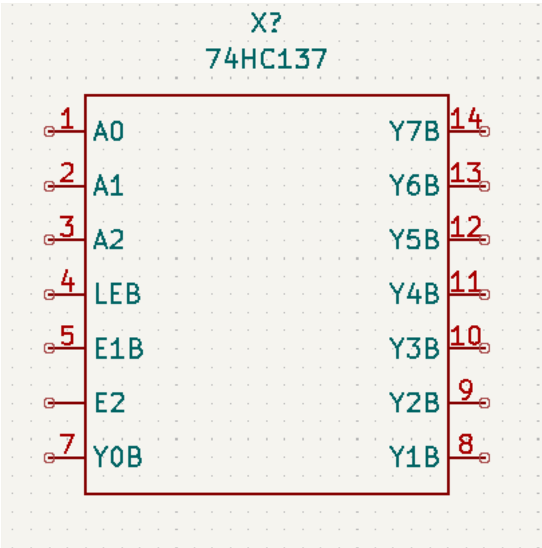

Figure 4.1: 74HC137 Symbol

4.1.2 Schematic

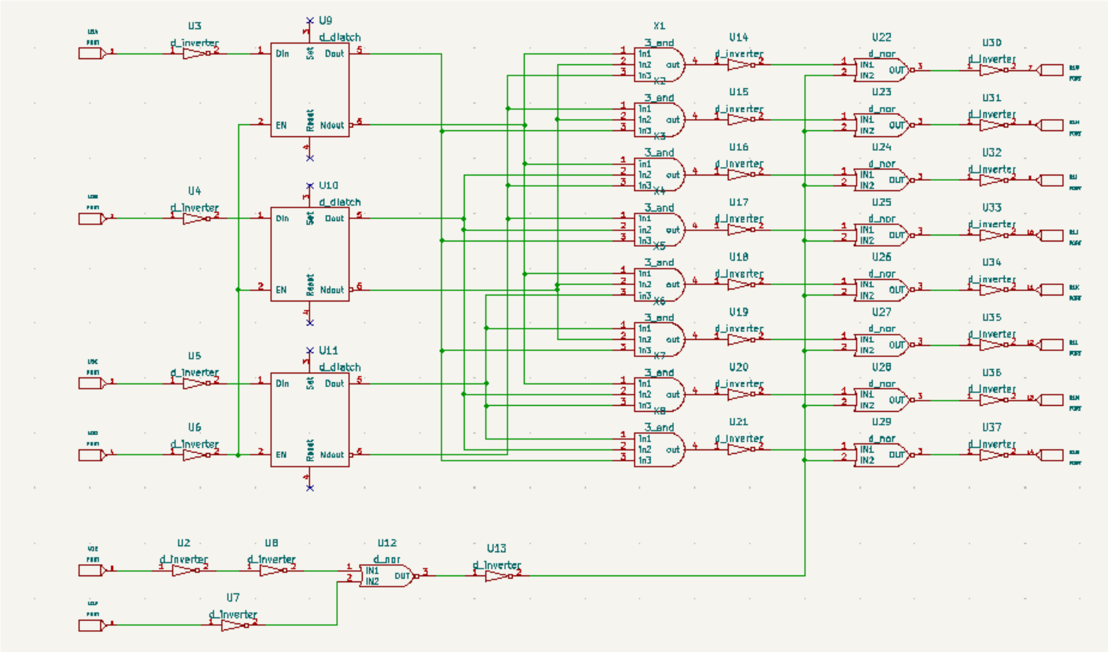

Figure 4.2: 74HC137 Schematic

4.1.3 Test Circuit

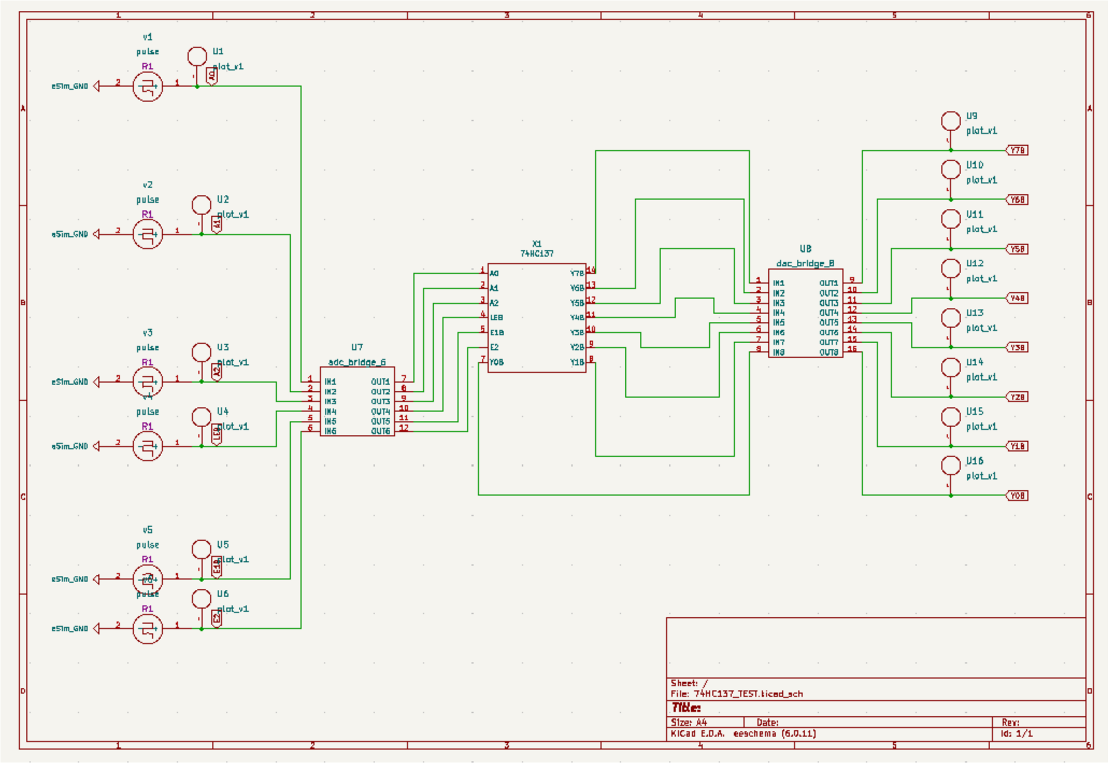

Figure 4.3: 74HC137 Test Circuit

4.1.4 Output Waveform

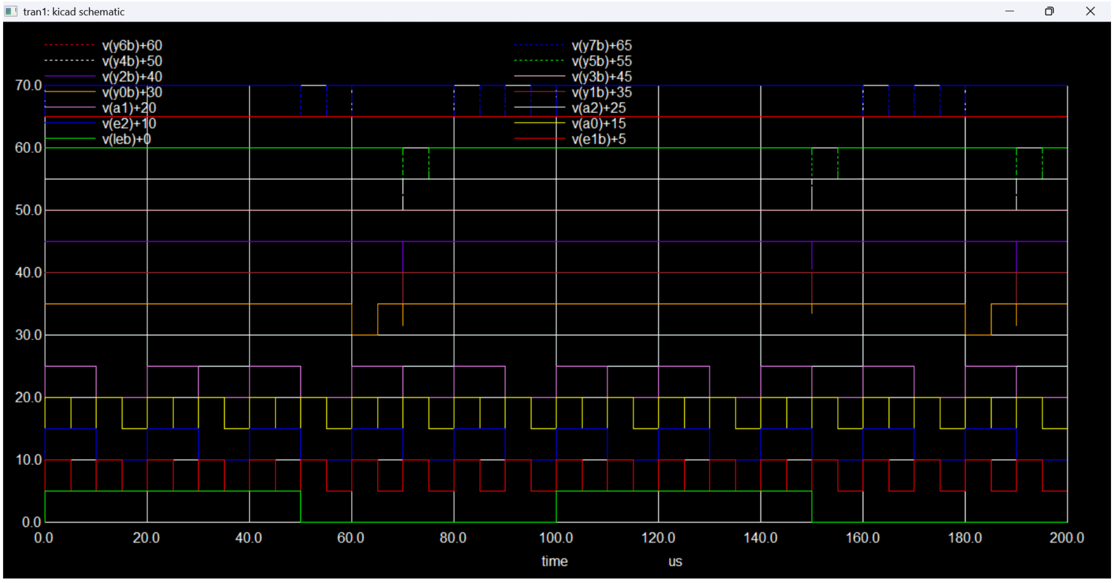

Figure 4.4: 74HC137 Output Waveform

4.2 74HC14 – Schmitt-Trigger Inverter

The 74HC14 is a Schmitt-trigger inverter IC used for waveform shaping, noise filtering, and signal conditioning applications.

4.2.1 Symbol

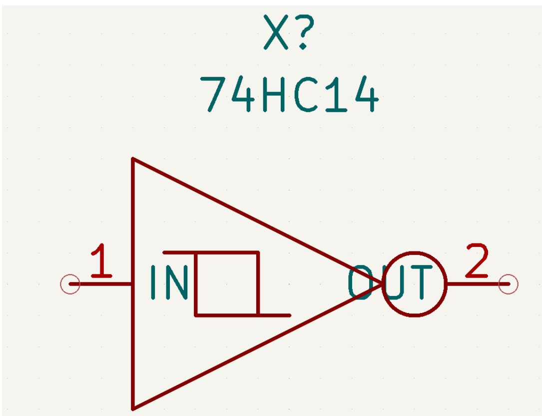

Figure 4.5: 74HC14 Symbol

4.2.2 Schematic

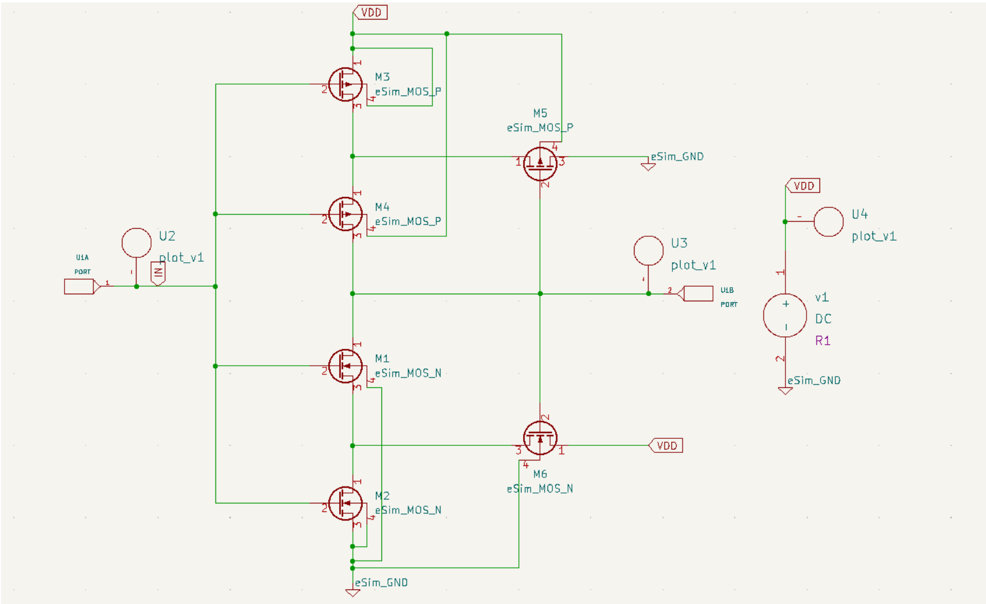

Figure 4.6: 74HC14 Schematic

4.2.3 Test Circuit

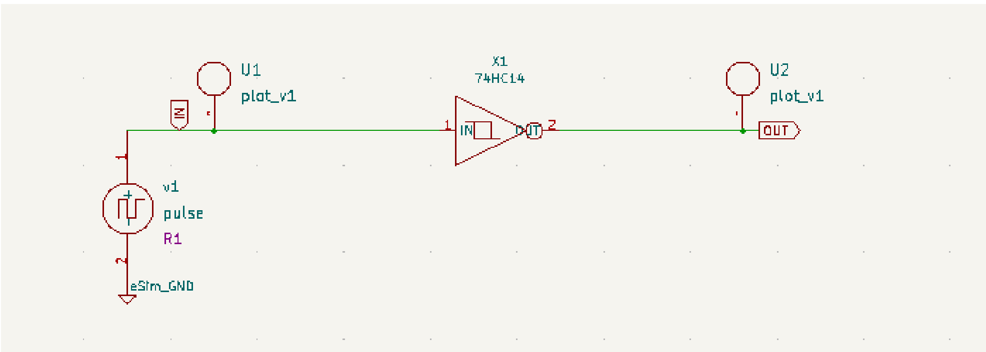

Figure 4.7: 74HC14 Test Circuit

4.2.4 Output Waveform

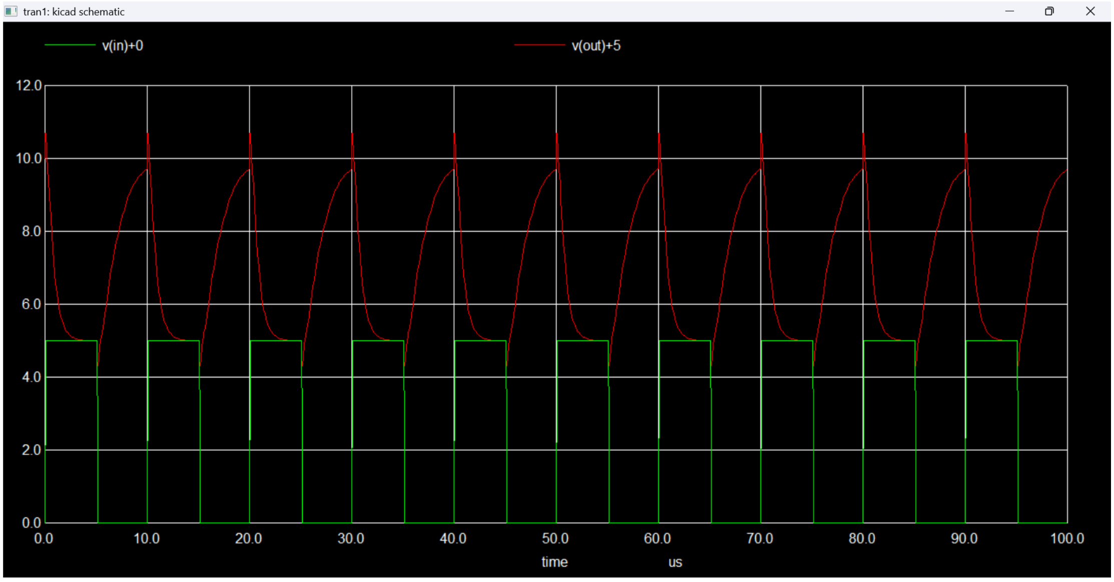

Figure 4.8: 74HC14 Output Waveform

4.3 74HC242 – Octal Buffers and Line Drivers; 3-State

The 74HC242 is an octal buffer and line driver IC with 3-state outputs used for bus-oriented digital systems.

4.3.1 Symbol

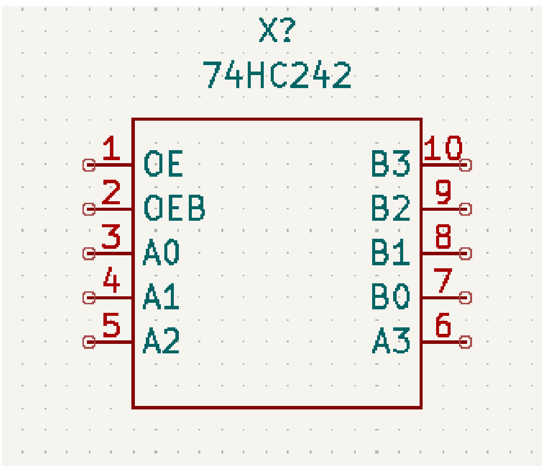

Figure 4.9: 74HC242 Symbol

4.3.2 Schematic

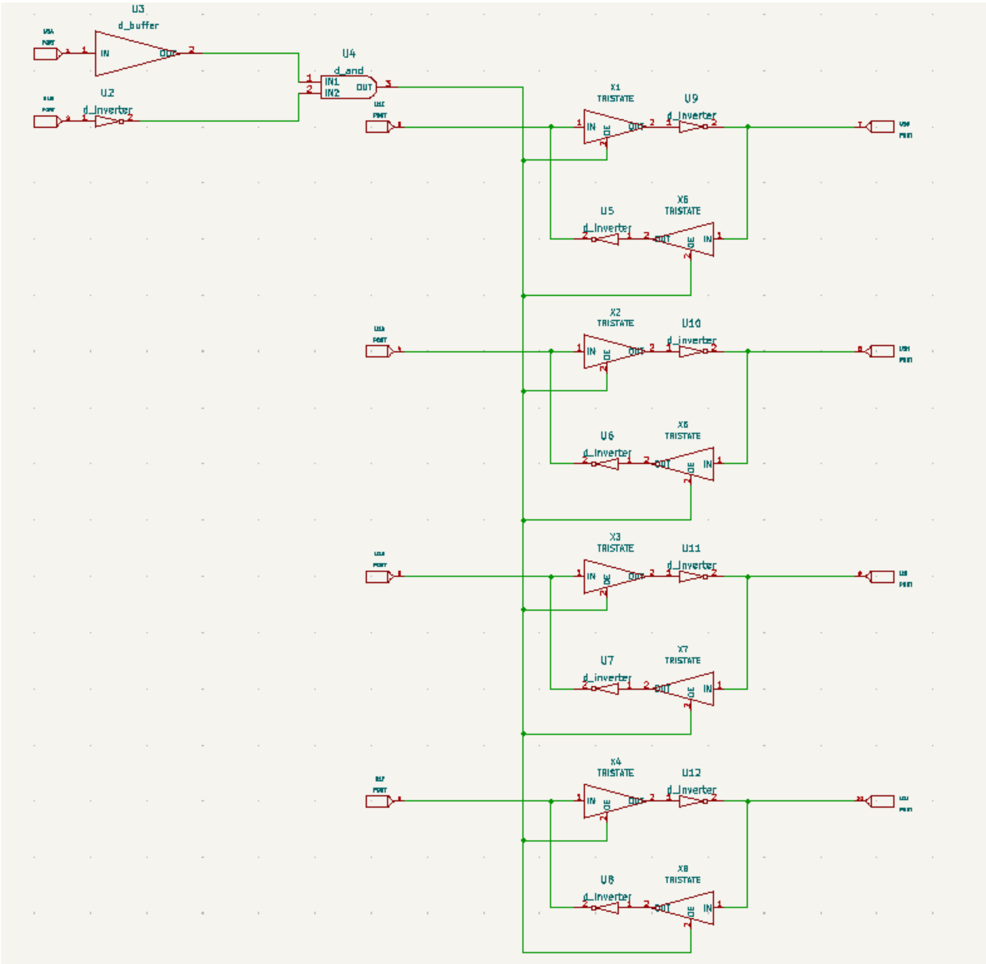

Figure 4.10: 74HC242 Schematic

4.3.3 Test Circuit

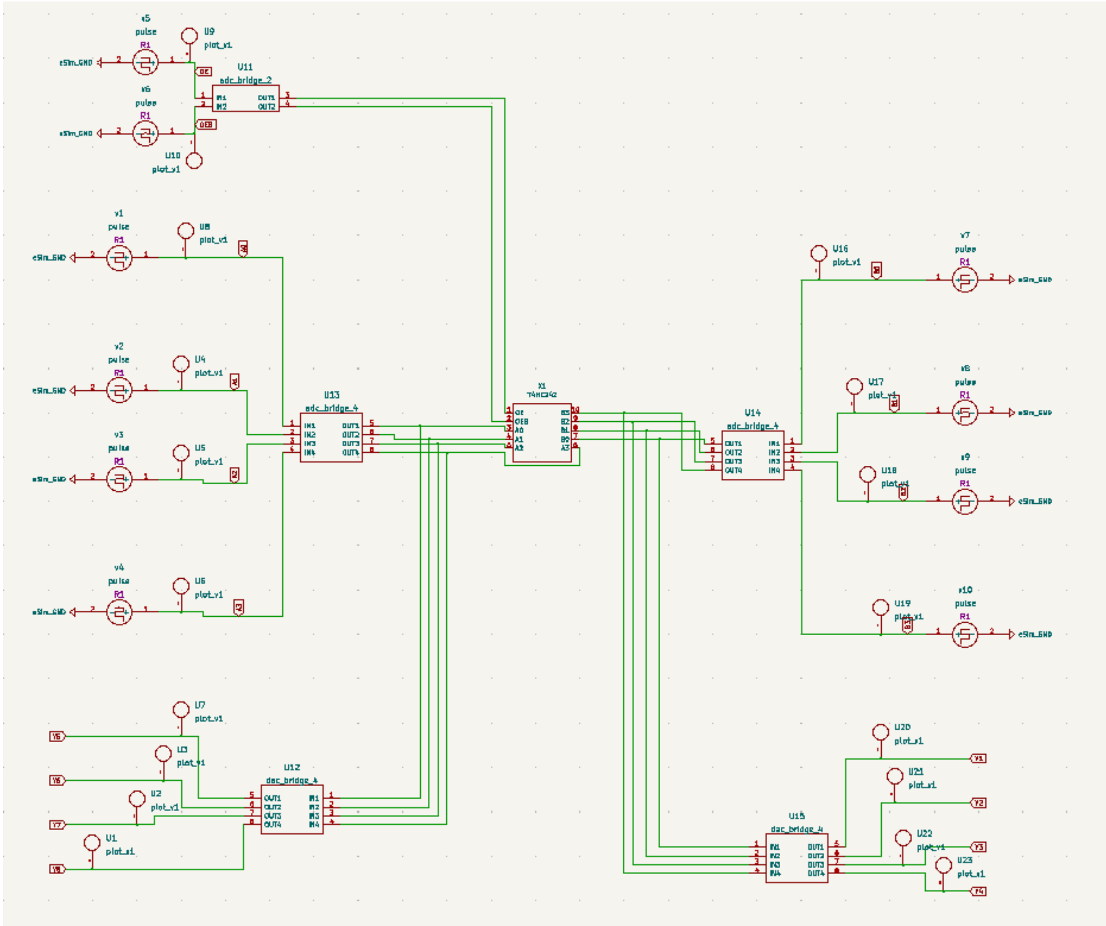

Figure 4.11: 74HC242 Test Circuit

4.3.4 Output Waveform

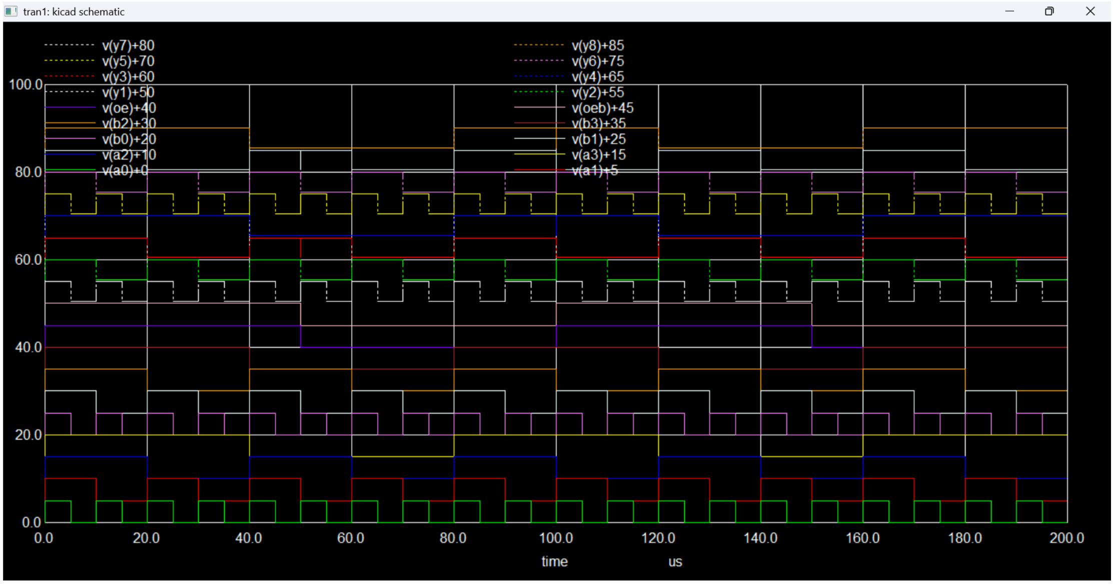

Figure 4.12: 74HC242 Output Waveform

4.4 74HC253 – Dual 4-Input Multiplexer; 3-State

The 74HC253 is a dual 4-input multiplexer IC with 3-state outputs used for digital data selection and routing applications.

4.4.1 Symbol

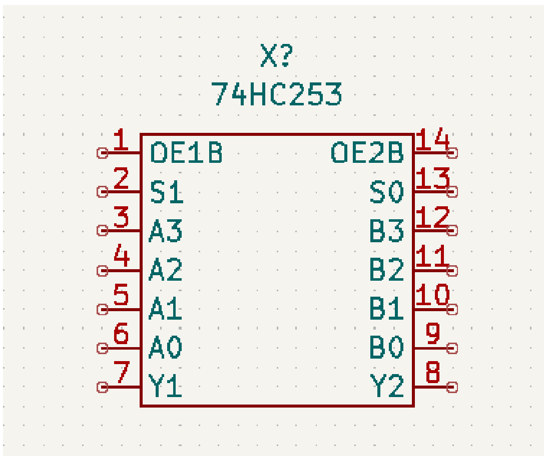

Figure 4.13: 74HC253 Symbol

4.4.2 Schematic

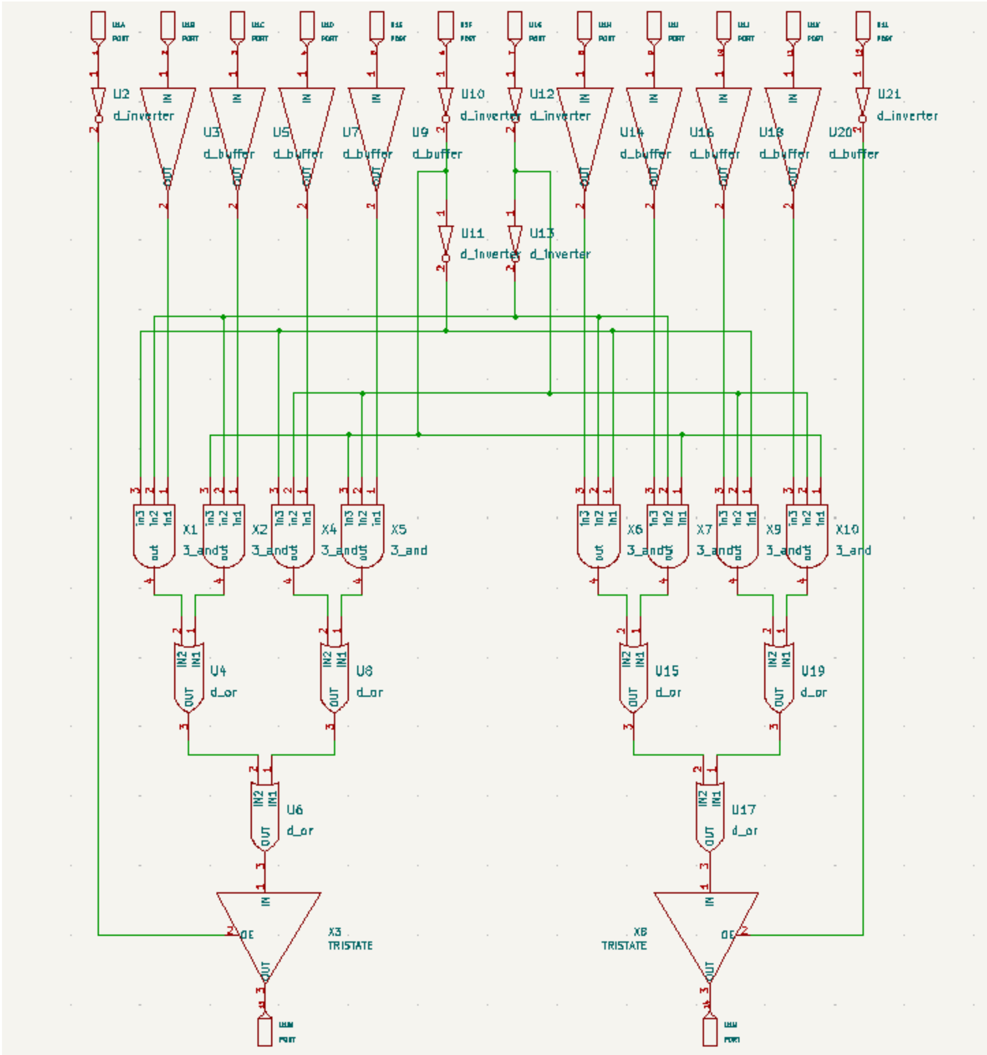

Figure 4.14: 74HC253 Schematic

4.4.3 Test Circuit

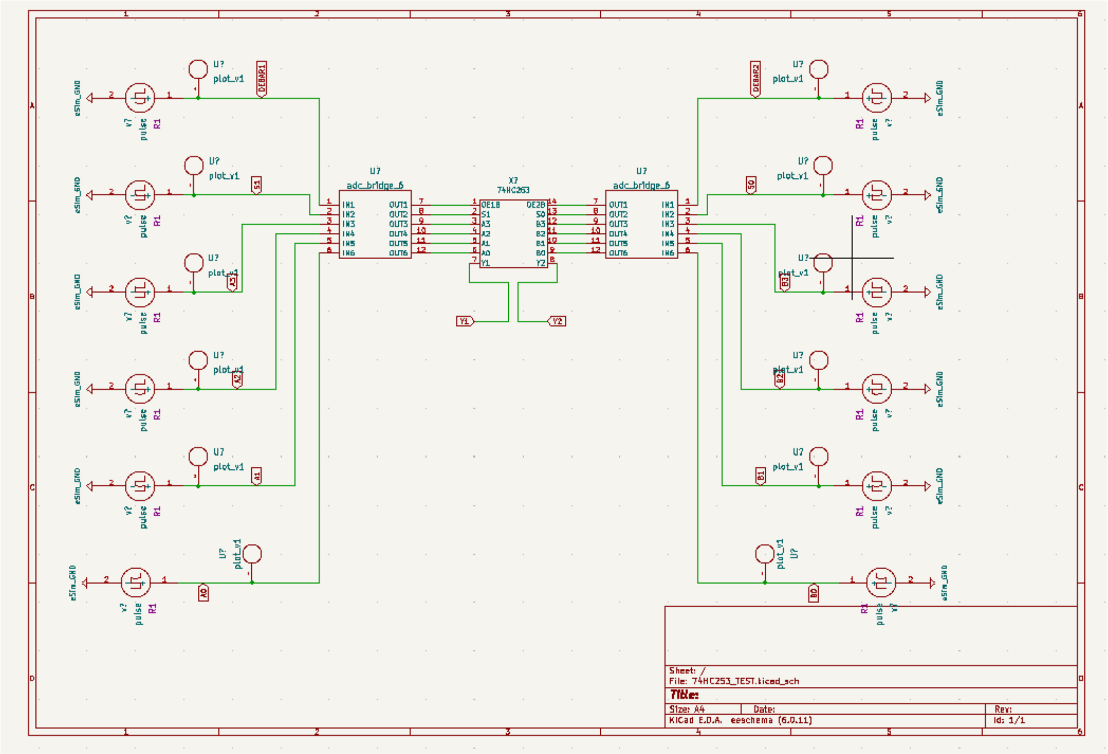

Figure 4.15: 74HC253 Test Circuit

4.4.4 Output Waveform

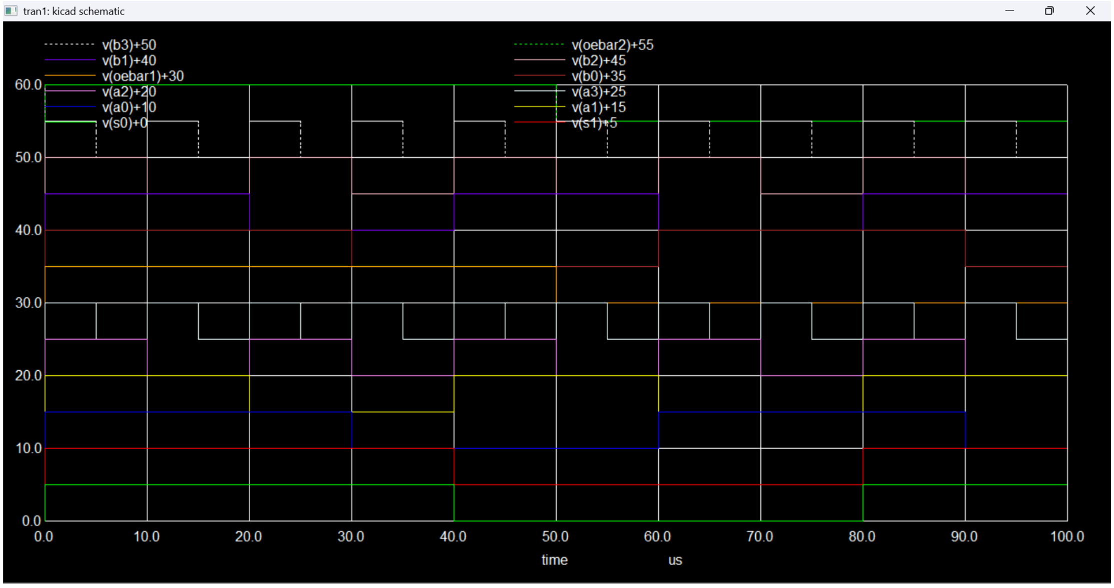

Figure 4.16: 74HC253 Output Waveform

4.5 74HC258 – Quad 2-Input Multiplexer with Inverted Outputs

The 74HC258 is a quad 2-input multiplexer IC featuring inverted outputs for digital signal selection applications.

4.5.1 Symbol

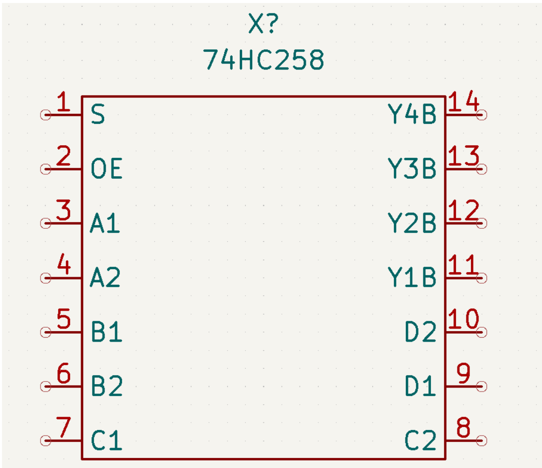

Figure 4.17: 74HC258 Symbol

4.5.2 Schematic

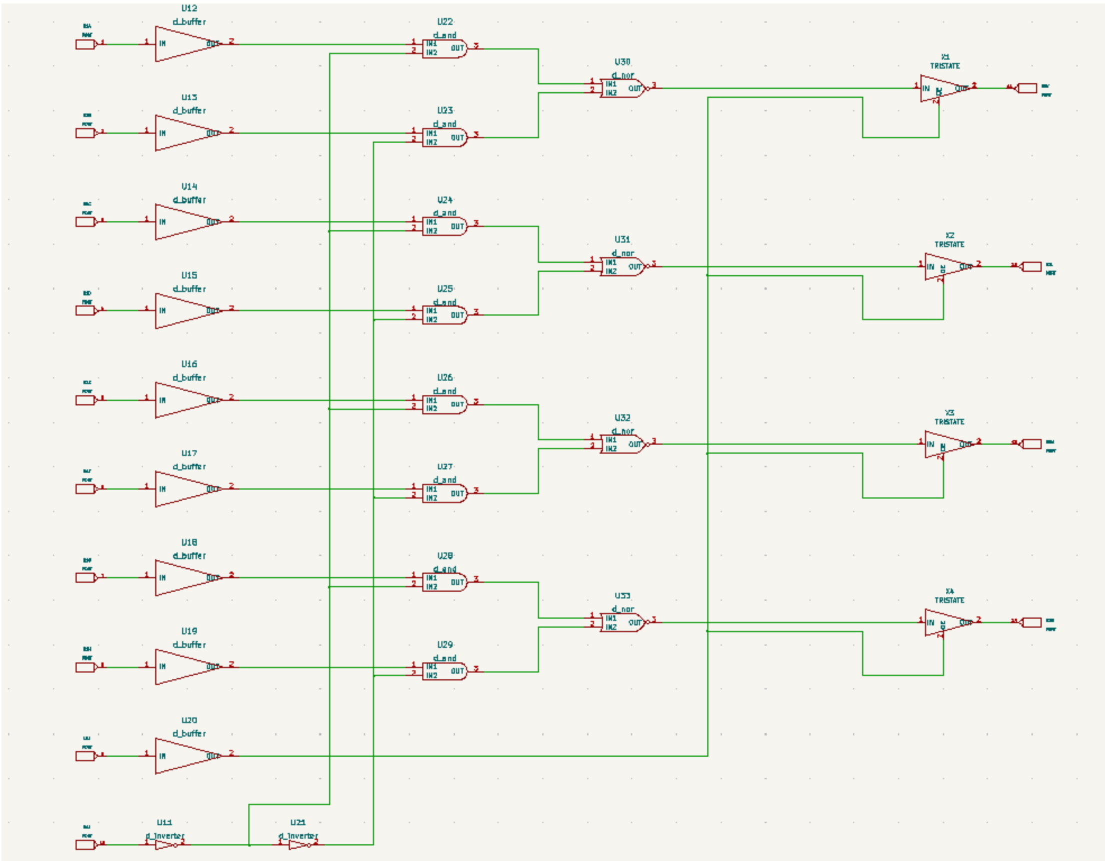

Figure 4.18: 74HC258 Schematic

4.5.3 Test Circuit

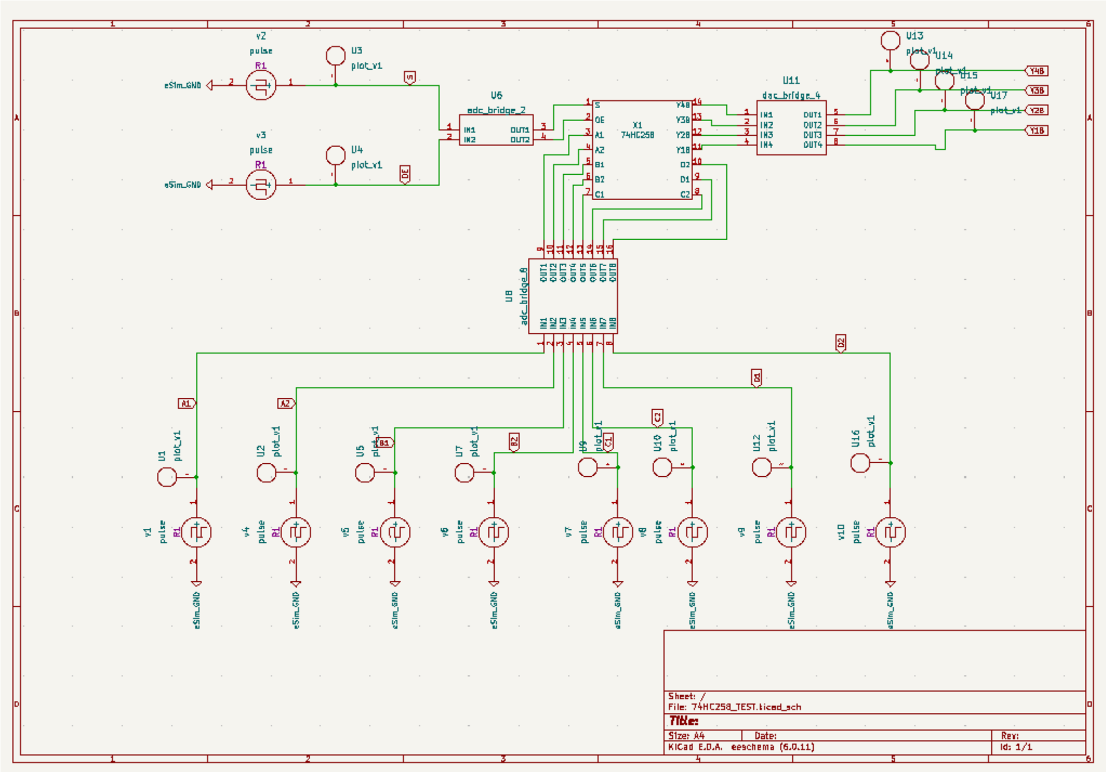

Figure 4.19: 74HC258 Test Circuit

4.5.4 Output Waveform

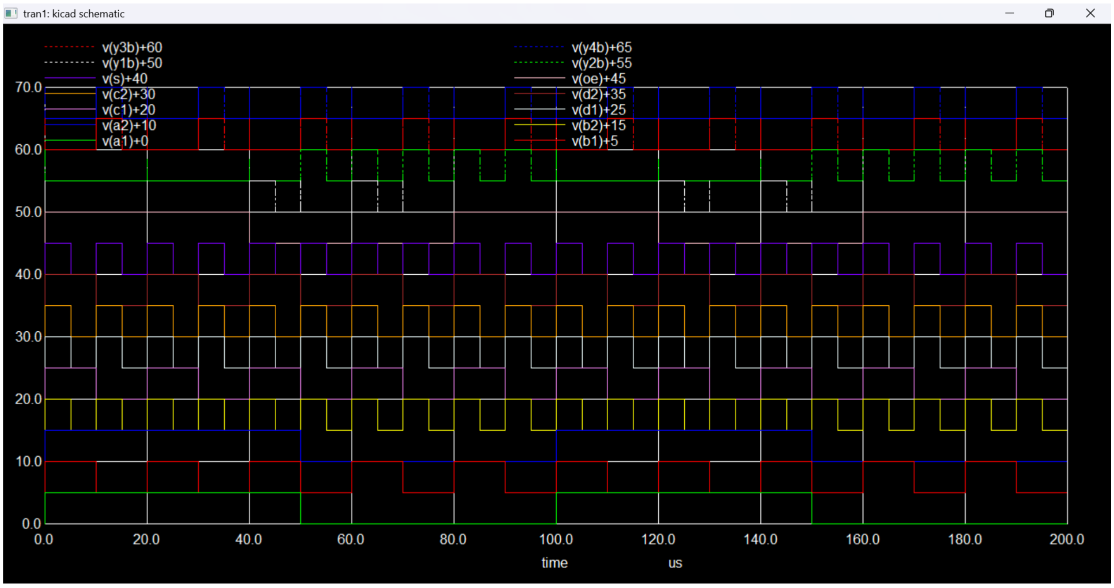

Figure 4.20: 74HC258 Output Waveform

4.6 74HC132 – Quad 2-Input NAND Schmitt Trigger

The 74HC132 is a quad 2-input NAND gate IC with Schmitt-trigger inputs designed for improved noise immunity in digital circuits.

4.6.1 Symbol

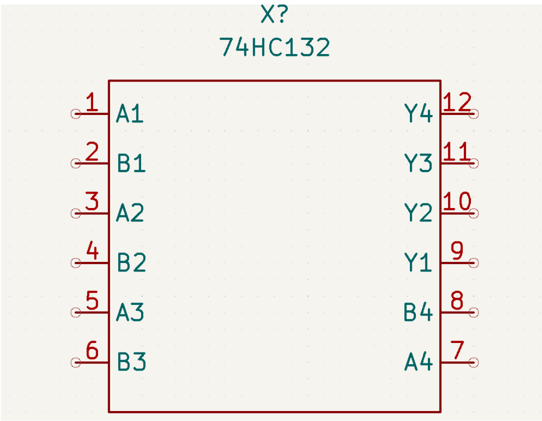

Figure 4.21: 74HC132 Symbol

4.6.2 Schematic

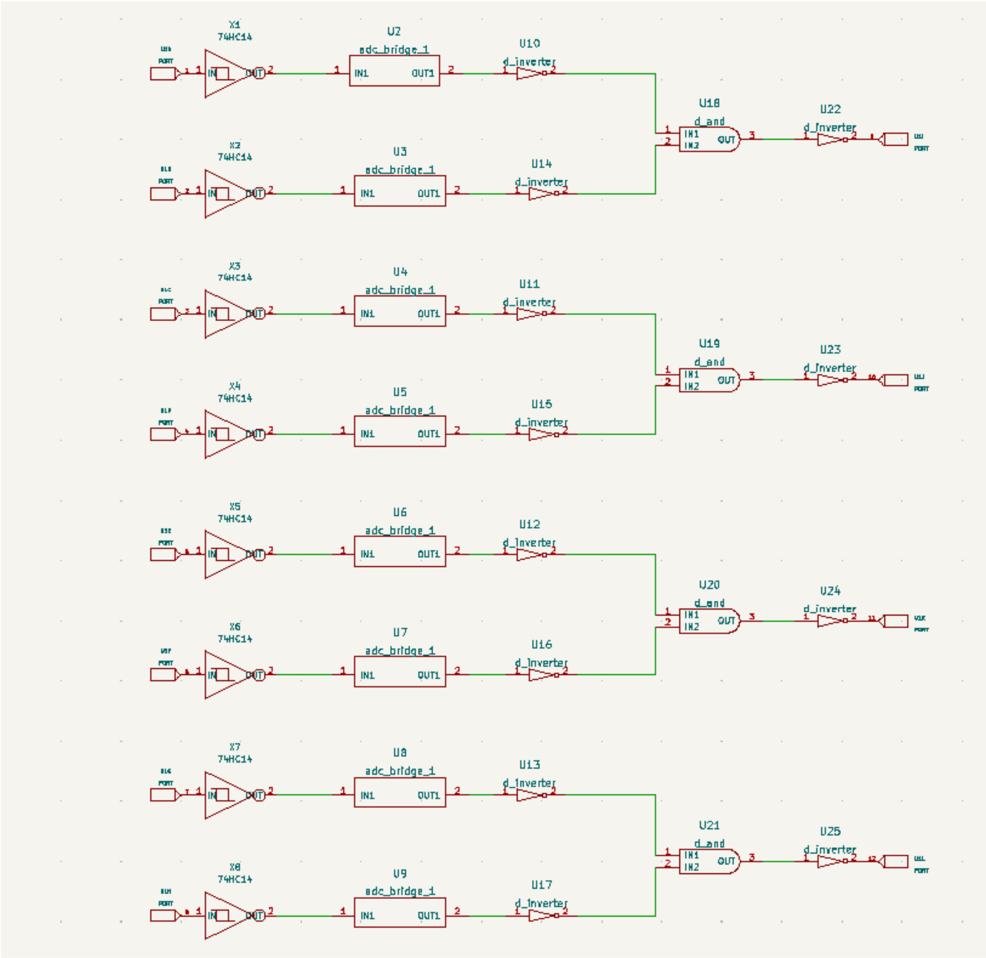

Figure 4.22: 74HC132 Schematic

4.6.3 Test Circuit

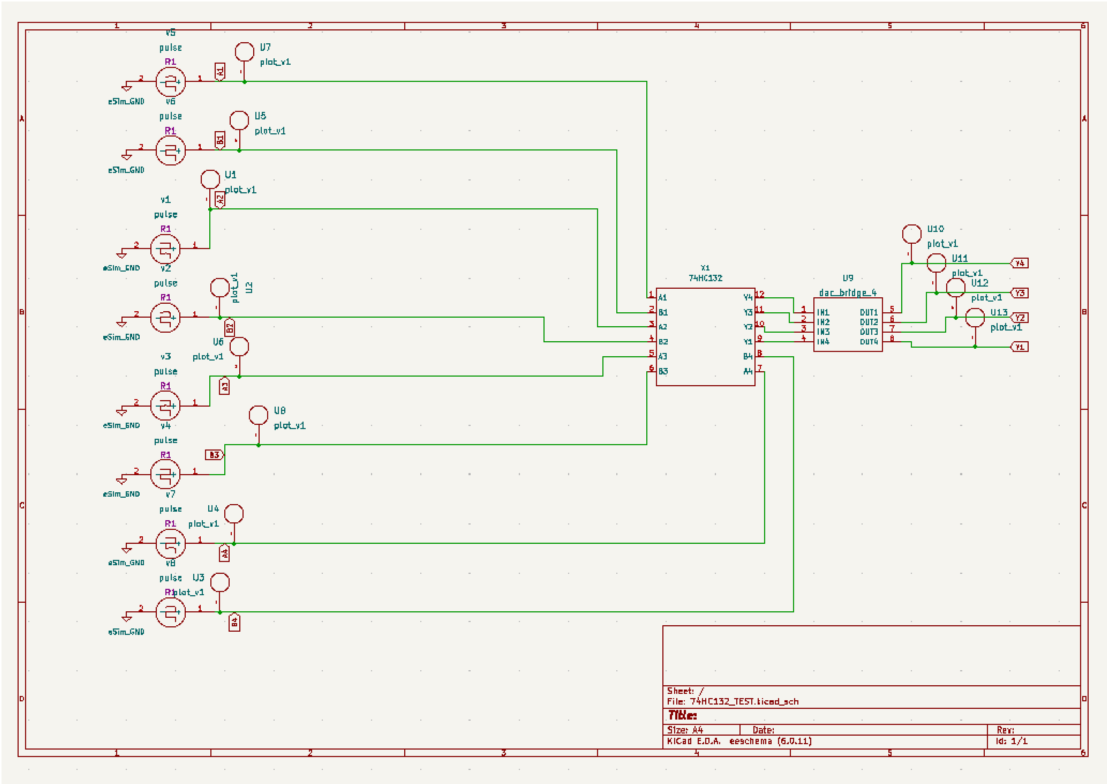

Figure 4.23: 74HC132 Test Circuit

4.6.4 Output Waveform

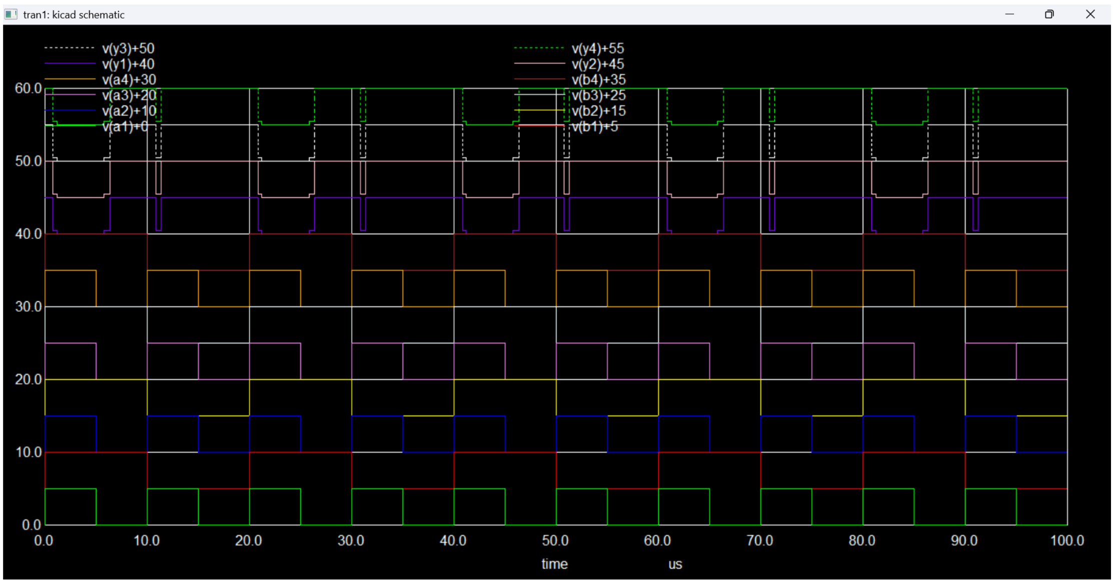

Figure 4.24: 74HC132 Output Waveform

4.7 CD4040B – 12-Stage Binary Ripple Counter

The CD4040B is a 12-stage binary ripple counter IC widely used for frequency division, timing, and counting applications.

4.7.1 Symbol

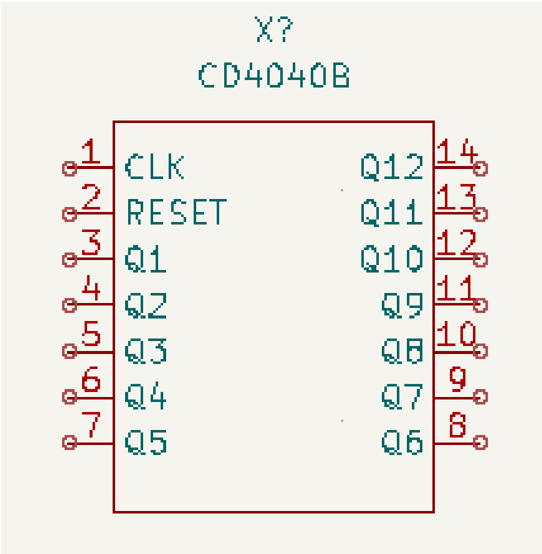

Figure 4.25: CD4040B Symbol

4.7.2 Schematic

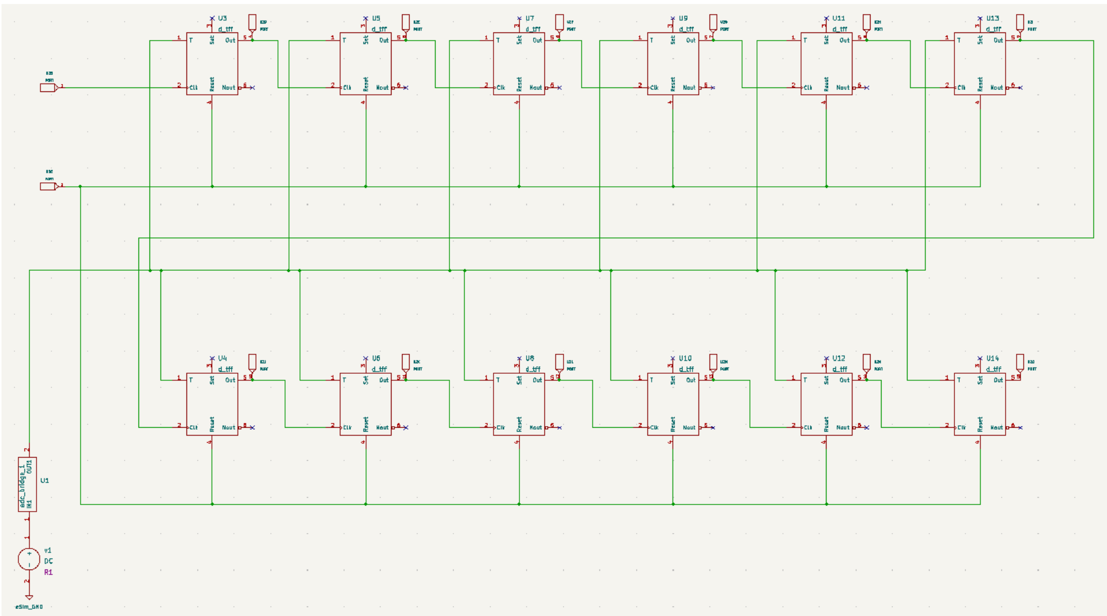

Figure 4.26: CD4040B Schematic

4.7.3 Test Circuit

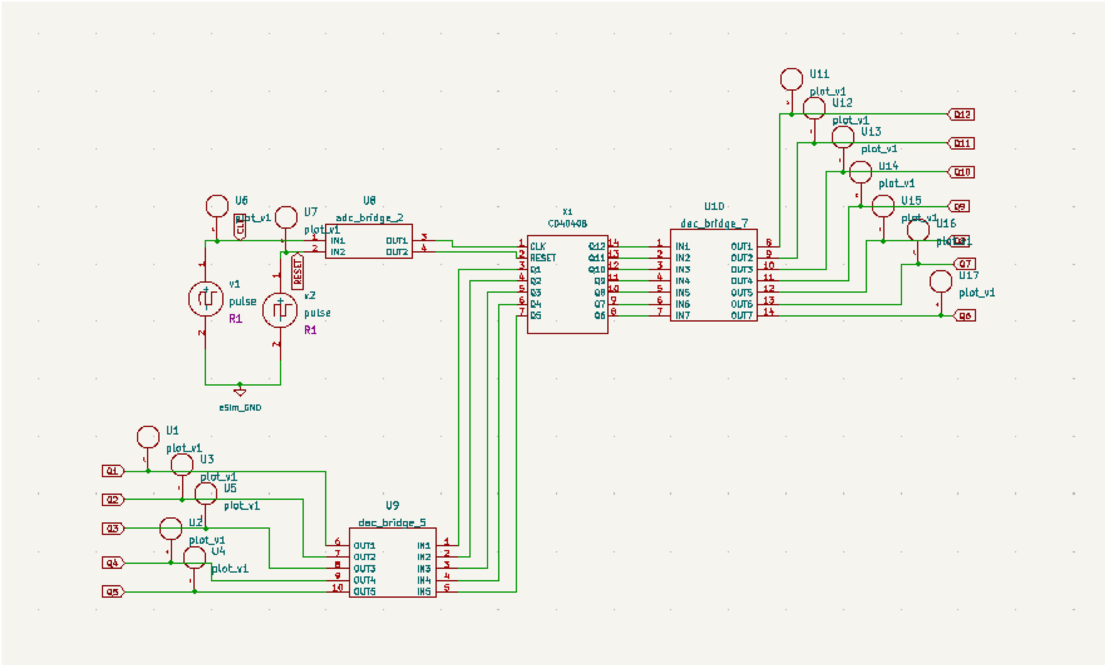

Figure 4.27: CD4040B Test Circuit

4.7.4 Output Waveform

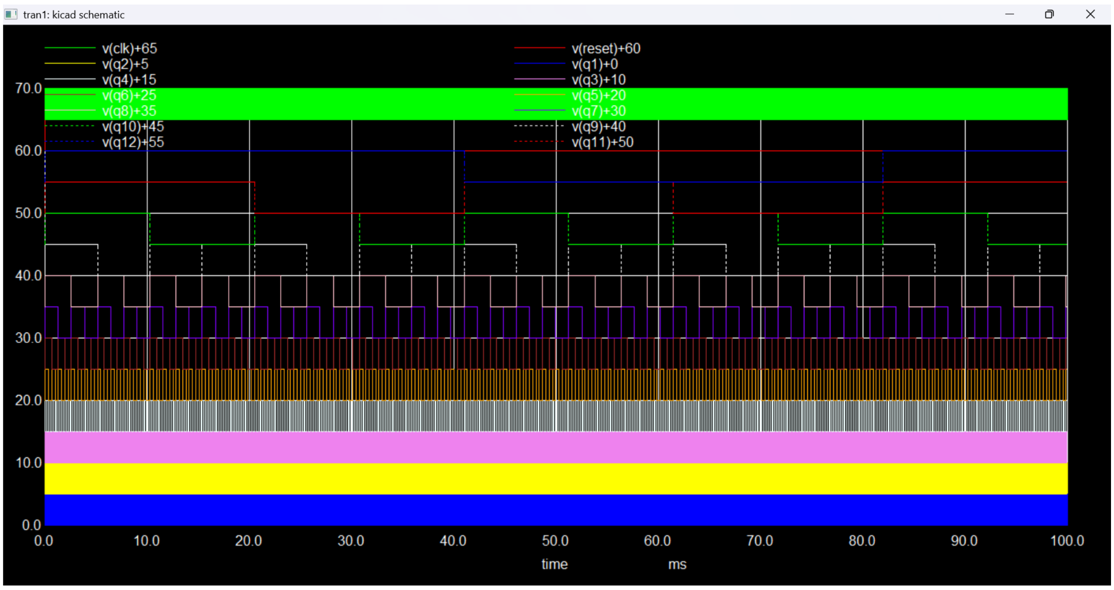

Figure 4.28: CD4040B Output Waveform

4.8 CDCV304 – 1:4 Clock Buffer with Enable

The CDCV304 is a 1:4 clock buffer IC with an active-LOW output enable, designed for high-speed clock distribution and fan-out applications.

4.8.1 Symbol

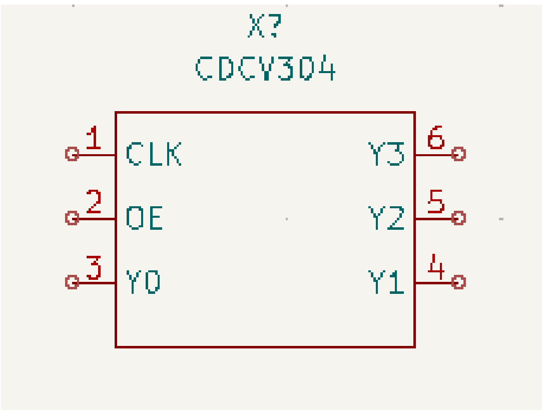

Figure 4.29: CDCV304 Symbol

4.8.2 Schematic

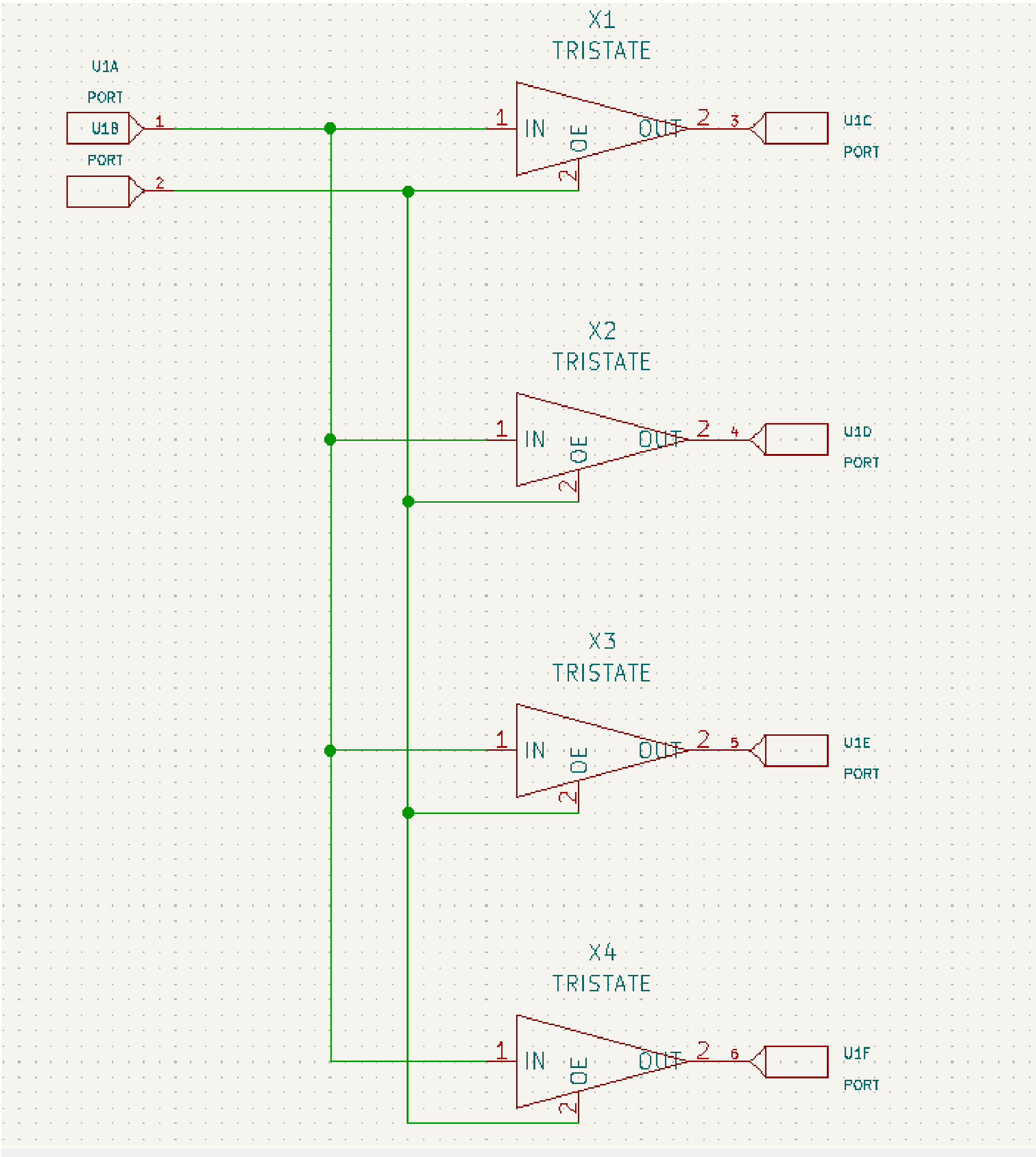

Figure 4.30: CDCV304 Schematic

4.8.3 Test Circuit

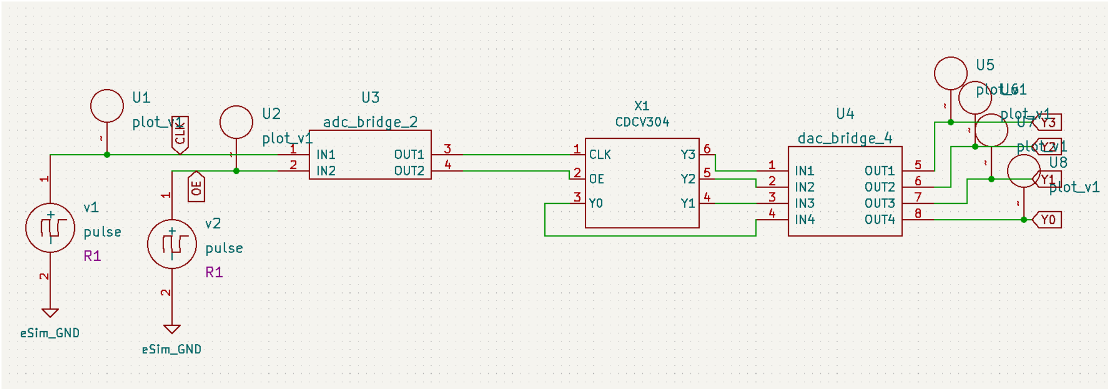

Figure 4.31: CDCV304 Test Circuit

4.8.4 Output Waveform

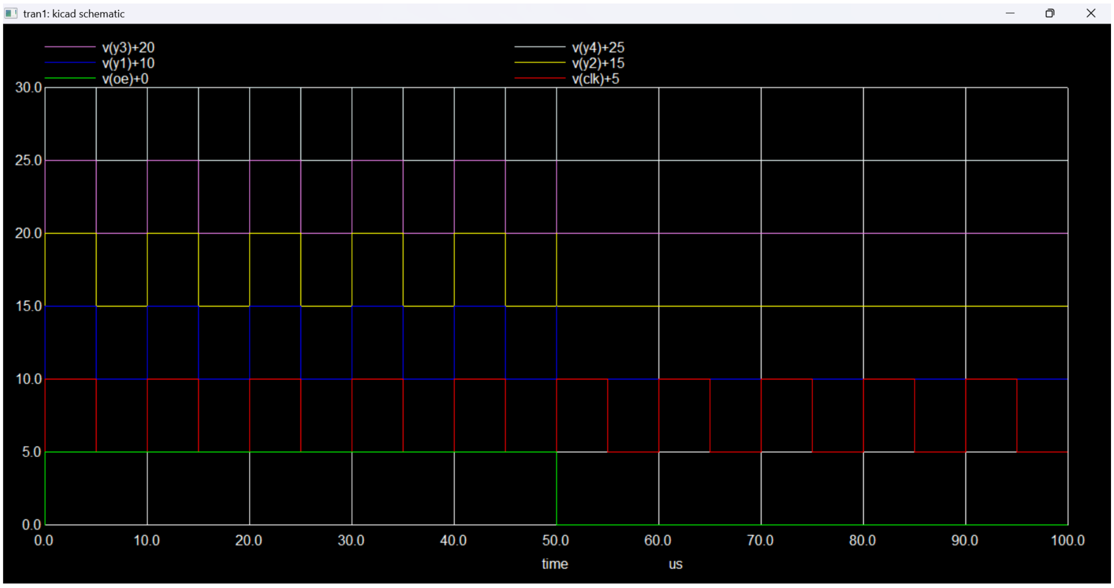

Figure 4.32: CDCV304 Output Waveform

4.9 HEF4894B – 8-Bit Serial-In, Parallel-Out Shift Register

The HEF4894B is an 8-bit serial-in, parallel-out shift register IC with output latches and a 3-state output enable, used for serial-to-parallel data conversion and bus interface applications.

4.9.1 Symbol

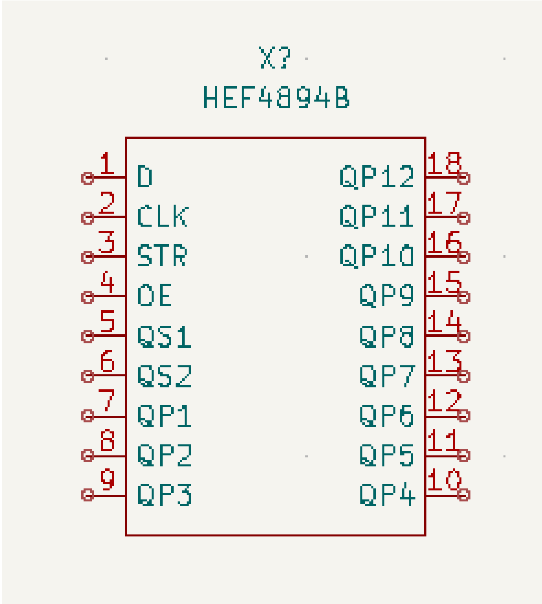

Figure 4.33: HEF4894B Symbol

4.9.2 Schematic

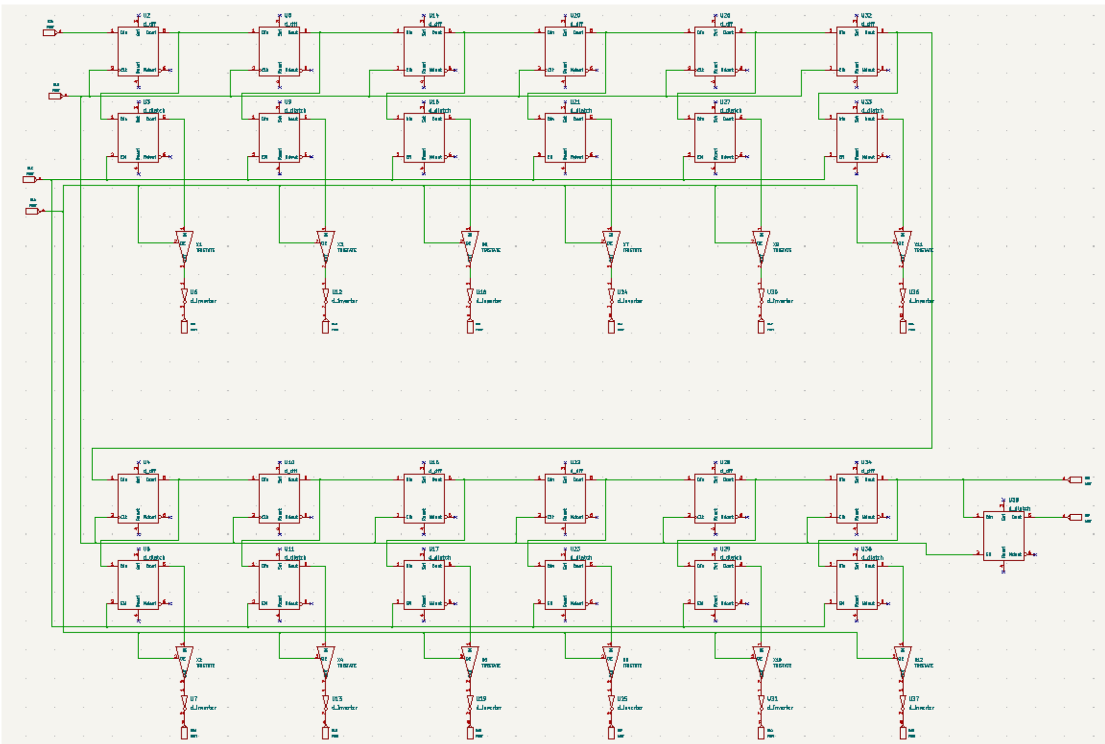

Figure 4.34: HEF4894B Schematic

4.9.3 Test Circuit

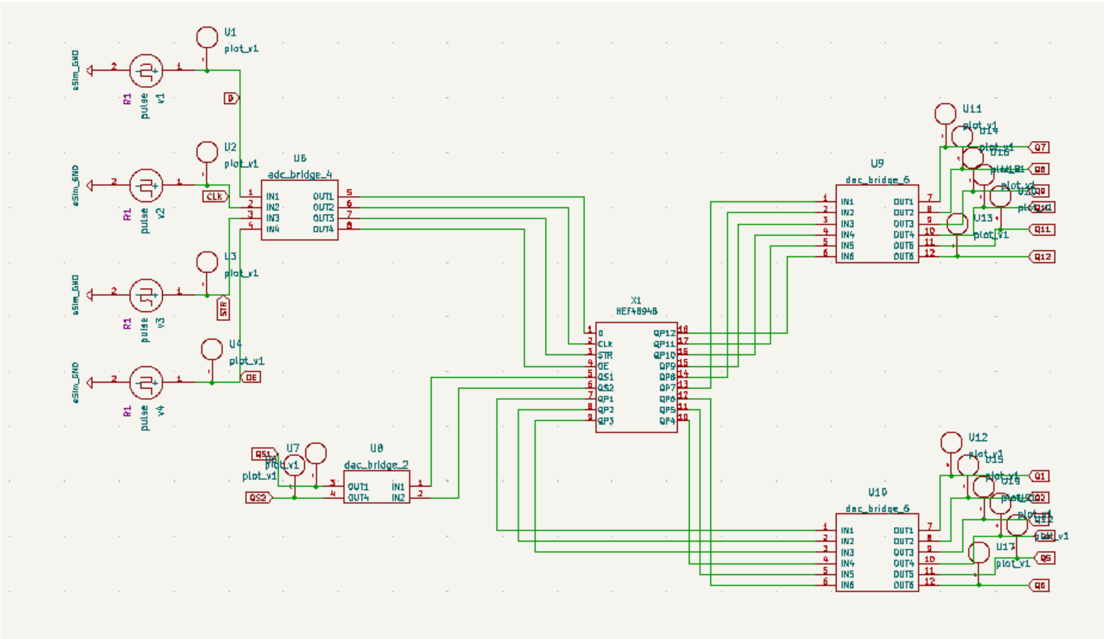

Figure 4.35: HEF4894B Test Circuit

4.9.4 Output Waveform

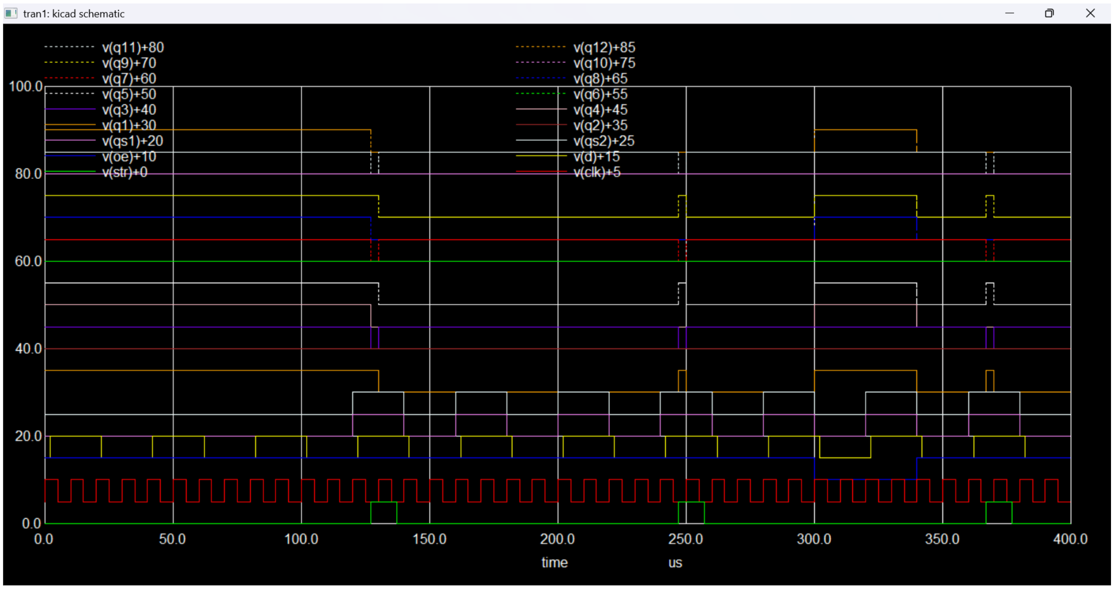

Figure 4.36: HEF4894B Output Waveform

4.10 NB3L553 – 1:4 Clock Fanout Buffer

The NB3L553 is a Clock Fanout Buffer IC designed for high-speed clock distribution and synchronisation applications.

4.10.1 Symbol

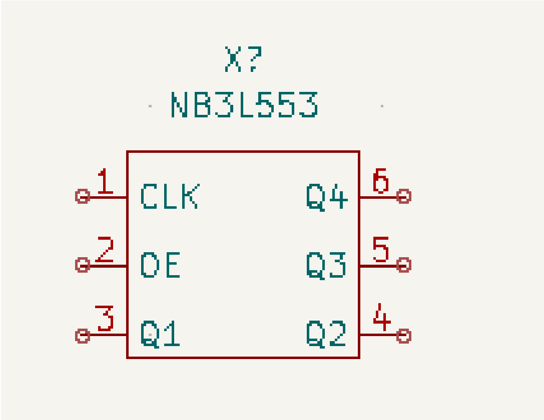

Figure 4.37: NB3L553 Symbol

4.10.2 Schematic

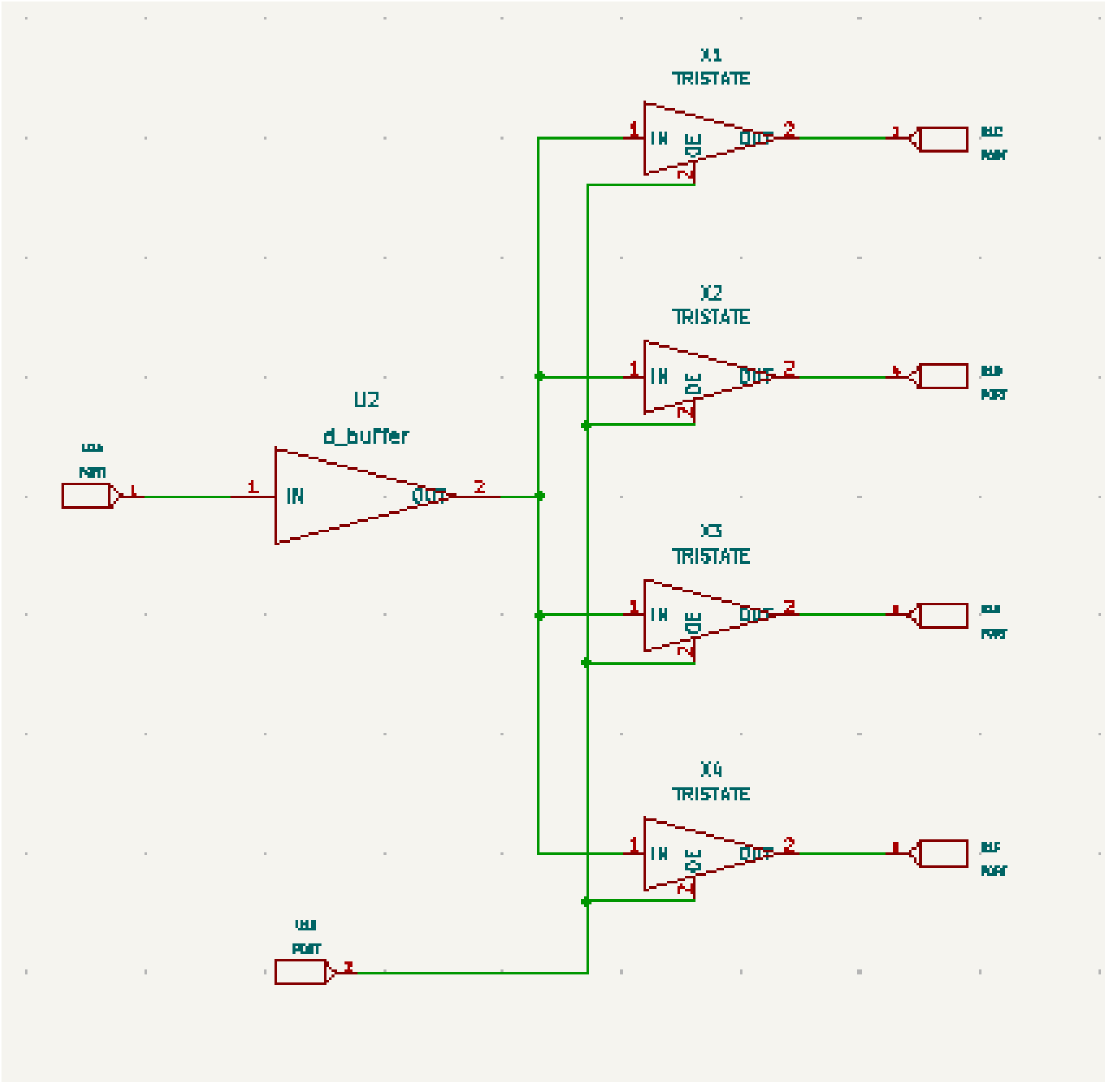

Figure 4.38: NB3L553 Schematic

4.10.3 Test Circuit

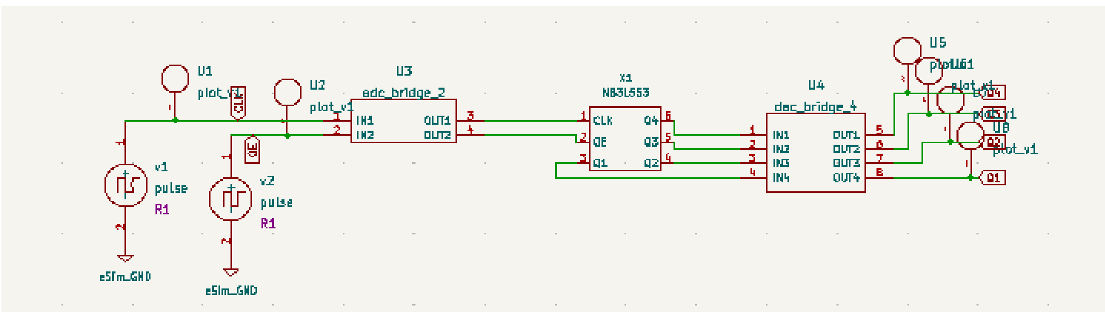

Figure 4.39: NB3L553 Test Circuit

4.10.4 Output Waveform

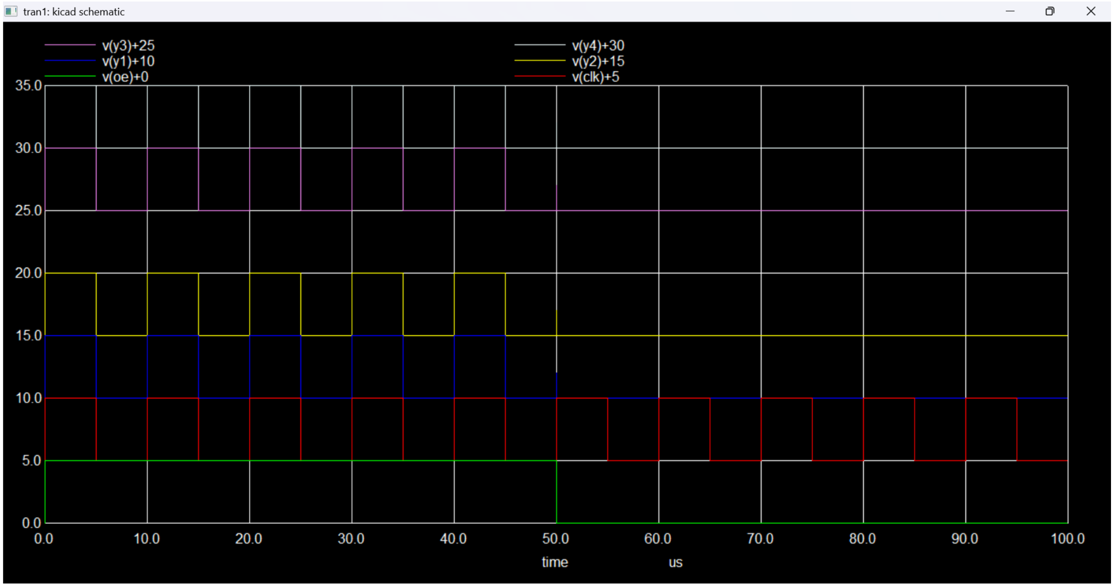

Figure 4.40: NB3L553 Output Waveform

Chapter 5

Conclusion and Future Scope

This internship provided practical knowledge of open-source EDA tools and digital IC design using eSim. A total of ten digital ICs were successfully designed, simulated, and verified using the subcircuit feature of eSim. The internship improved understanding of digital electronics, schematic design, waveform analysis, and circuit simulation using tools like eSim, KiCad, Ngspice, and GHDL. The developed subcircuits cover a diverse set of functions including decoding, multiplexing, buffering, counting, shifting, and clock distribution.

In future, more advanced digital ICs and reusable subcircuits can be developed and integrated into the eSim subcircuit library for educational and research purposes. Extension of this work to mixed-signal ICs, sequential circuits, and analog-digital interface components would further enrich the open-source EDA ecosystem.

Chapter 6

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