# eSim Semester Long Internship Autumn 2025

On

## Analog and Digital IC Design in eSim


**Submitted by**

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# Acknowledgement

I would like to express my sincere gratitude to the FOSSEE team at IIT Bombay for providing me with this valuable opportunity to work as part of the eSim project. Being selected for this fellowship was a moment of pride, and the experience has truly been enriching, both technically and personally.

My heartfelt thanks to Prof. Prabhu Ramachandran for initiating and leading this impactful platform that empowers students like me to explore the world of open-source electronics.

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When I started, I lacked hands-on experience with simulation tools and was unsure of my ability to complete a project independently. However, through this fellowship, I have not only built technical skills but also developed a sense of discipline, time management, and self-confidence.

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This opportunity has significantly contributed to my growth, and I am proud to have been part of the FOSSEE eSim team. I look forward to applying the knowledge gained here in future endeavors and contributing meaningfully to the open-source community.

Thank you, once again, to everyone who made this experience so memorable and impactful.

# Contents

# 1 Introduction

FOSSEE (Free/Libre and Open Source Software for Education) project promotes the use of FLOSS tools to improve the quality of education in our country. It aims to reduce dependency on proprietary software in educational institutions. It encourages the use of FLOSS tools through various activities to ensure commercial software is replaced by equivalent FLOSS tools. It also develops new FLOSS tools and upgrades existing tools to meet requirements in academia and research [9].

The FOSSEE project is part of the National Mission on Education through Information and Communication Technology (ICT), Ministry of Human Resource Development (MHRD), Government of India.

## 1.1 eSim

eSim is a CAD tool that helps electronic system designers to design, test, and analyze their circuits. The important feature of this tool is that it is open source, allowing users to modify the source as per their needs. The software provides a generic, modular, and extensible platform for experimenting with electronic circuits. eSim is built using various free/libre and open-source software components including:

### 1.1.1 Kicad

Integrated software where all functions of circuit drawing, control, layout, library management, and access to the PCB design software are carried out.

### 1.1.2 Ngspice

Ngspice is a general-purpose circuit simulation program for nonlinear dc, nonlinear transient, and linear ac analysis.

### 1.1.3 KiCad to Ngspice converter

Analysis parameters, source details are provided through this module. It allows us to add and edit the device models and subcircuits included in the circuit schematic.

### 1.1.4 Subcircuit Builder

This module allows the user to create a subcircuit for a component. Once the subcircuit for a component is created, the user can use it in other circuits.

### 1.1.5 NGHDL

A module for mixed signal circuit simulation is also integrated with eSim. It makes use of VHDL code.

### 1.1.6 NgVeri

NgVeri, a module for mixed signal circuit simulation, is also integrated with eSim. It makes use of Verilog/System Verilog/Transaction-Level Verilog code.

### 1.1.7 Makerchip

Makerchip is a cloud-based browser application developed by Redwood EDA to do digital circuit design. One can simulate Verilog/SystemVerilog/Transaction-Level Verilog code in Makerchip.

# 2 Abstract


## 2.1 Objective

The objective of this internship was to design and develop various integrated circuits using the Subcircuit Builder Method in eSim. This involved modeling the ICs with eSim library files and subsequently simulating them with different circuits. The goal was to expand the eSim Subcircuit Library for future use, enhancing its utility and application in educational and practical scenarios.

## 2.2 Approach

- Identify and research an integrated circuit (IC) that is not currently available in the eSim library.
- Obtain and study the datasheet of the selected IC thoroughly.
- Carefully examine the schematic provided in the datasheet.
- Accurately recreate the schematic in eSim using the Subcircuit Builder Method.
- Model the IC in eSim, ensuring all parameters and configurations match those in the datasheet.
- Simulate the integrated circuit within eSim, testing it with various circuits to verify its functionality.
- Document the process and results to contribute to the future use and expansion of the eSim Subcircuit Library.

# 3 Integrated Circuit Design

## 3.1 LM566

### 3.1.1 Description

The LM566 device is a voltage-controlled oscillator (VCO) designed to generate precise square-wave and triangular-wave output signals [1]. The output frequency is controlled by an external control voltage, allowing easy and linear frequency variation. The LM566 uses an internal voltage reference and current source along with external resistor and capacitor components to set the oscillation frequency. This IC is widely used in timing circuits, modulation systems, and signal-generation applications.

**Features of LM566**

- **Voltage-Controlled Oscillator:** This chip is primarily designed to generate frequencies that vary linearly with an applied control voltage, making it ideal for modulation and timing applications.
- **Wide Operating Voltage Range:** It typically operates from 10 V to 24 V, suitable for many analog and mixed-signal circuit designs.
- **Good Stability & Linearity:** The LM566 provides stable frequency operation with good temperature compensation and linear control characteristics.
- **Simple and Compact Design:** Requires very few external components, making it easy to use in compact and cost-effective circuit designs.

### 3.1.2 Pin Diagram

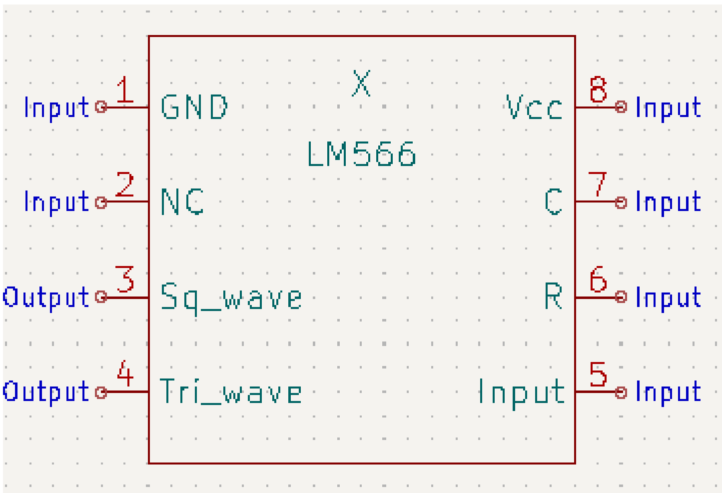


Figure 1: Pin Diagram of LM566

### 3.1.3 Subcircuit Diagram

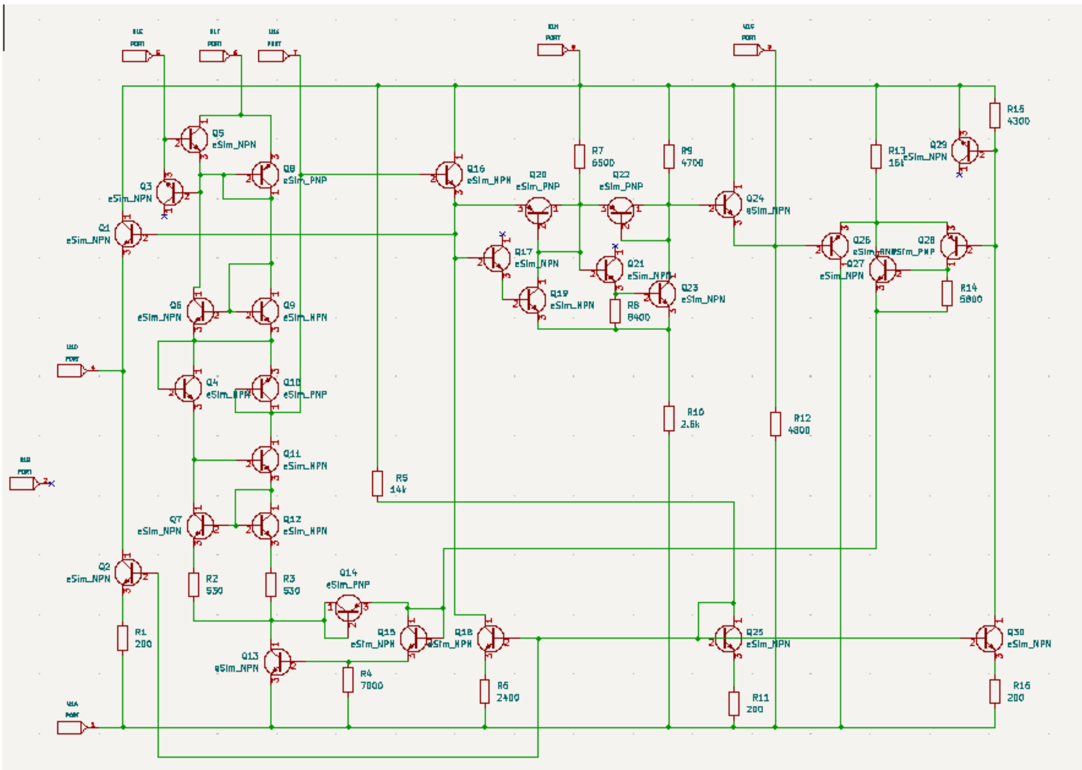

Figure 2: Subcircuit Diagram of LM566

### 3.1.4 Test Circuit

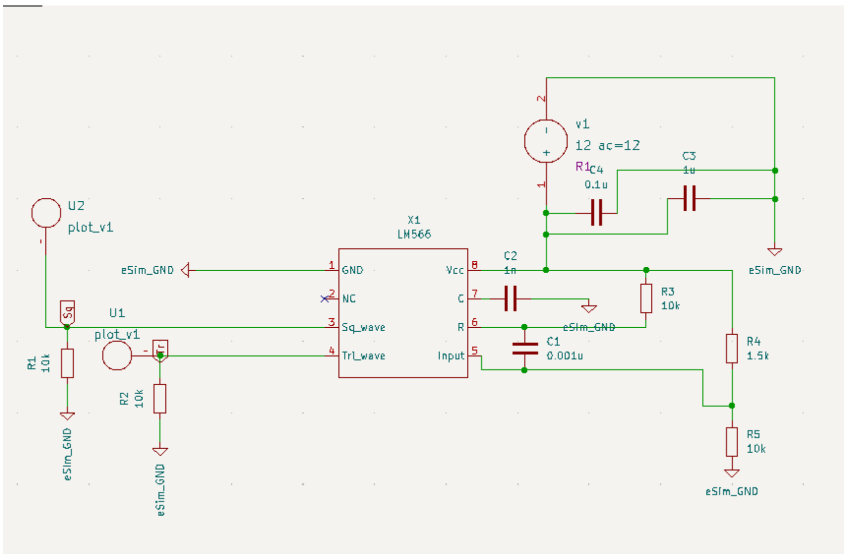


Figure 3: Test Circuit of LM566

### 3.1.5 NgSpice Plot

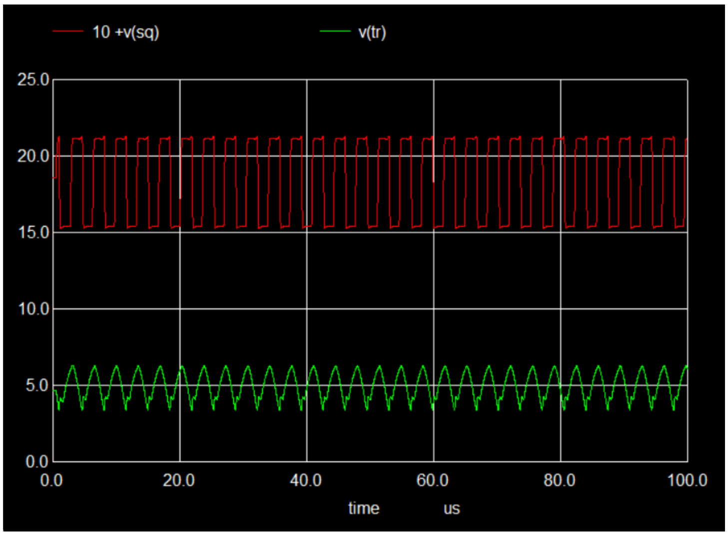


Figure 4: NgSpice Plot of LM566

## 3.2 LM715

### 3.2.1 Description

The LM715 device is a high-speed video amplifier designed for wideband signal amplification and fast transient response applications [2]. It is optimized for handling high-frequency analog signals with minimal distortion, making it suitable for video, pulse, and communication circuits. The LM715 provides stable gain and wide bandwidth operation using standard dual power supplies and requires minimal external components for proper functioning.

#### Features of LM715

- **High-Speed Video Amplifier:** This chip is primarily designed for amplifying high-frequency and video signals where fast response and signal integrity are critical.
- **Wide Bandwidth Operation:** Supports wide bandwidth performance, making it suitable for video processing, pulse amplification, and RF-related applications.
- **Fast Slew Rate & Low Distortion:** Ensures accurate reproduction of rapidly changing signals with minimal waveform distortion.
- **Simple Analog Design:** Requires few external components and is easy to integrate into analog and mixed-signal circuit designs.

### 3.2.2 Pin Diagram

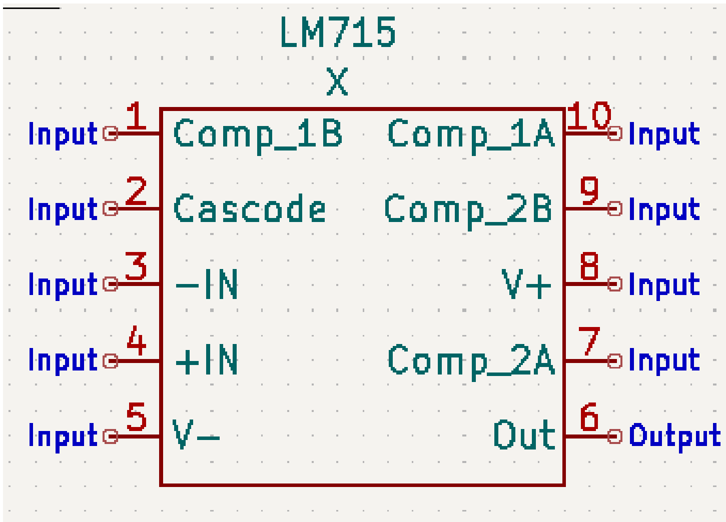


Figure 5: Pin Diagram of LM715

### 3.2.3 Subcircuit Diagram

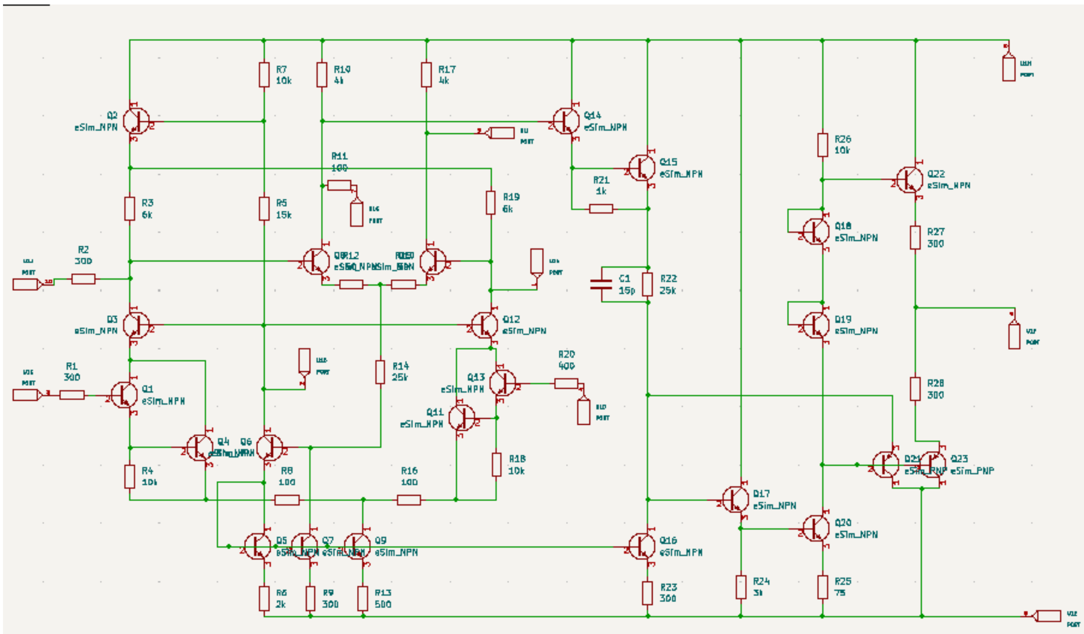

Figure 6: Subcircuit Diagram of LM715

### 3.2.4 Test Circuit

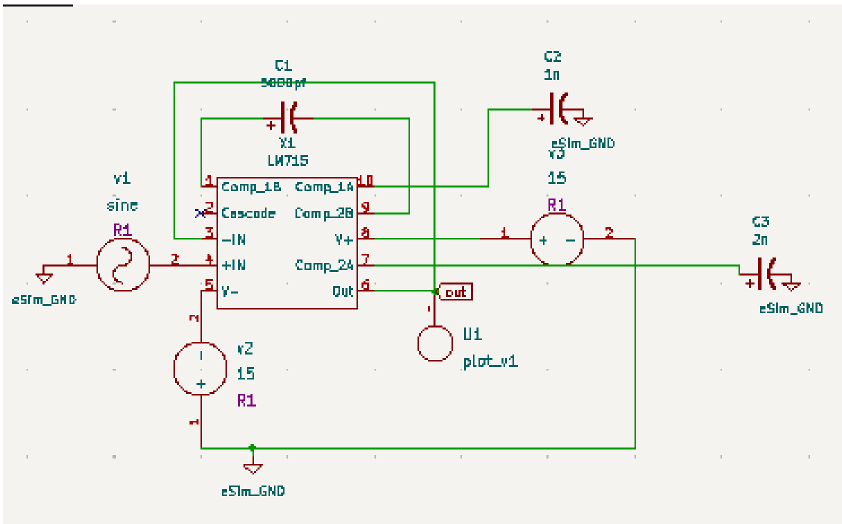


Figure 7: Test Circuit of LM715

#### 3.2.5 NgSpice Plot

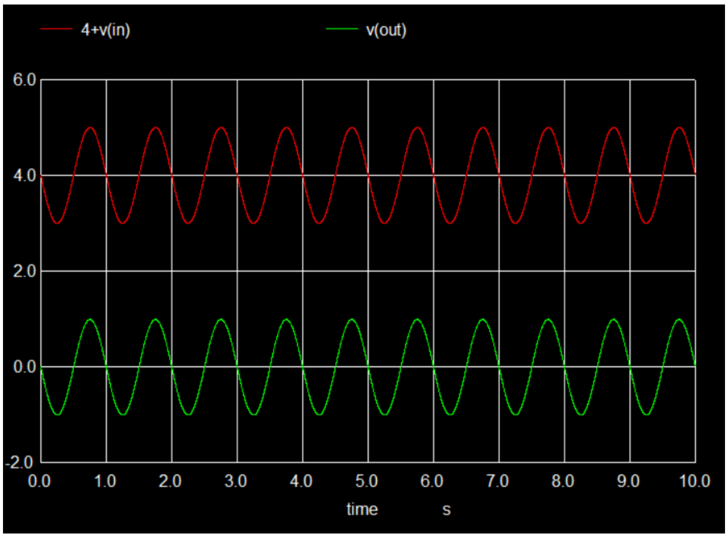


Figure 8: NgSpice Plot of LM715

## 3.3 LF412

### 3.3.1 Description

The LF412 device is a dual JFET-input operational amplifier designed for applications requiring low input bias current and low noise performance [3]. It consists of two independent, high-performance op-amps in a single package, making it suitable for precision analog signal processing. The LF412 operates over a wide supply-voltage range and provides stable operation with minimal external components.

**Features of LF412**

- **Dual JFET-Input Op-Amp:** This chip contains two JFET-input operational amplifiers, ideal for high-input-impedance and low-bias-current applications.
- **Wide Operating Voltage Range:** Operates with dual supplies typically from ±5 V to ±18 V, suitable for various analog circuit designs.
- **Low Noise & Low Input Bias Current:** Ensures accurate amplification of low-level signals without loading the input source.
- **Compact and Efficient Design:** Combines two op-amps in one package, reducing component count and saving board space.

### 3.3.2 Pin Diagram

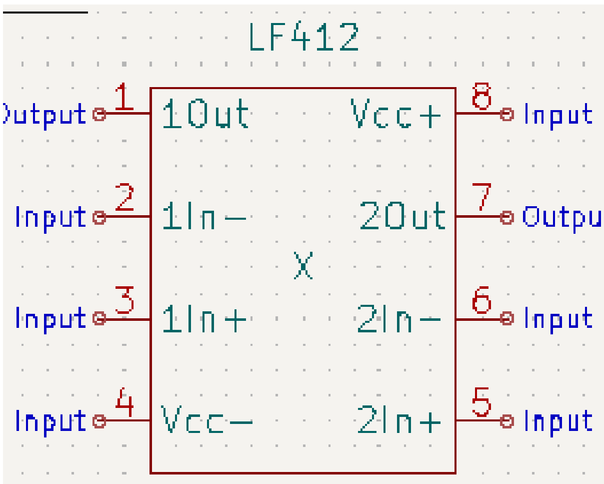


Figure 9: Pin Diagram of LF412

### 3.3.3 Subcircuit Diagram

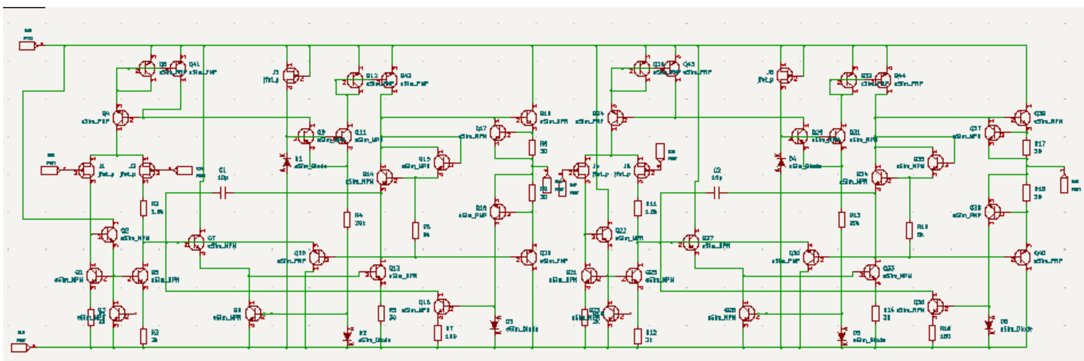

Figure 10: Subcircuit Diagram of LF412

### 3.3.4 Test Circuit

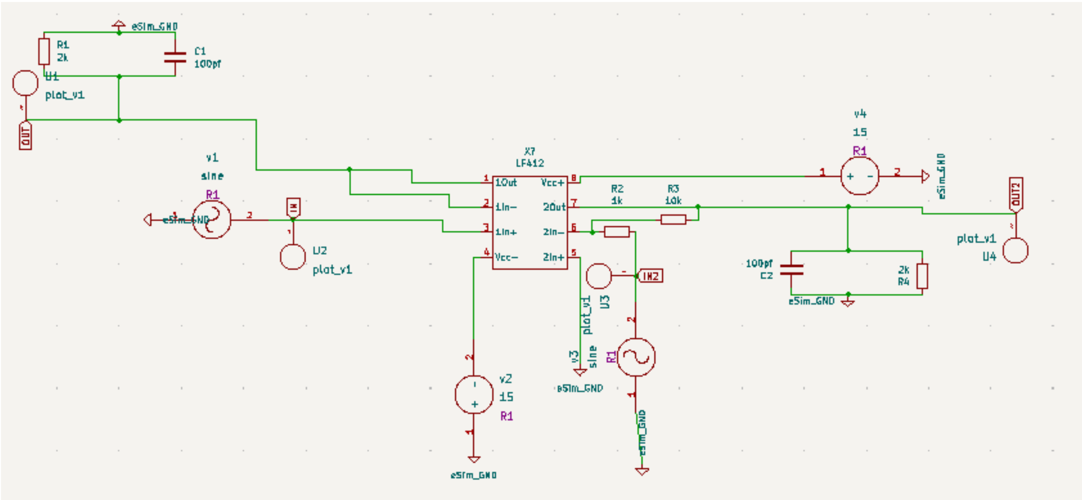

Figure 11: Test Circuit of LF412

### 3.3.5 NgSpice Plot

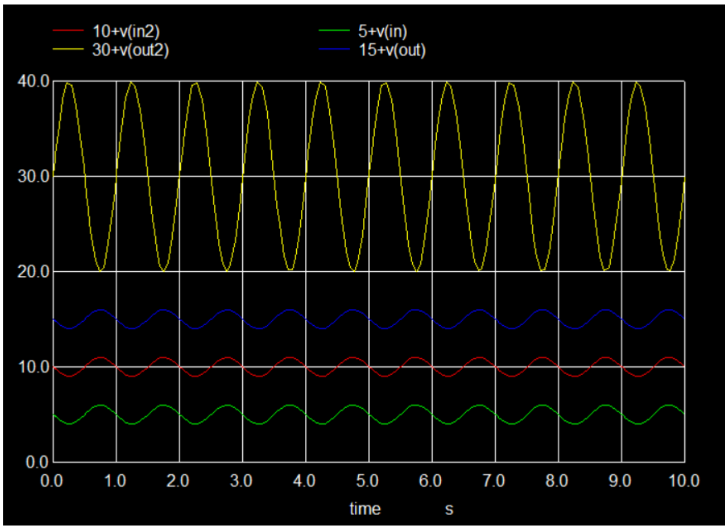


Figure 12: NgSpice Plot of LF412

## 3.4 LT1008

### 3.4.1 Description

The LT1008 device is a precision operational amplifier designed for applications requiring extremely low input offset voltage and high DC accuracy [4]. It uses advanced trimming techniques to achieve excellent long-term stability and low drift, making it suitable for high-precision instrumentation and measurement systems. The LT1008 operates over a wide supply-voltage range and delivers reliable performance with minimal external components.

#### Features of LT1008

- **Precision Operational Amplifier:** This chip is primarily designed for high-accuracy analog signal amplification where very low offset voltage is critical.
- **Wide Operating Voltage Range:** Operates with dual supplies typically from ±5 V to ±18 V, suitable for precision analog and mixed-signal designs.
- **Ultra-Low Offset & Low Drift:** Provides excellent DC precision and long-term stability over temperature variations.
- **Stable and Compact Design:** Requires minimal external components and is easy to integrate into compact, high-precision circuits.

### 3.4.2 Pin Diagram

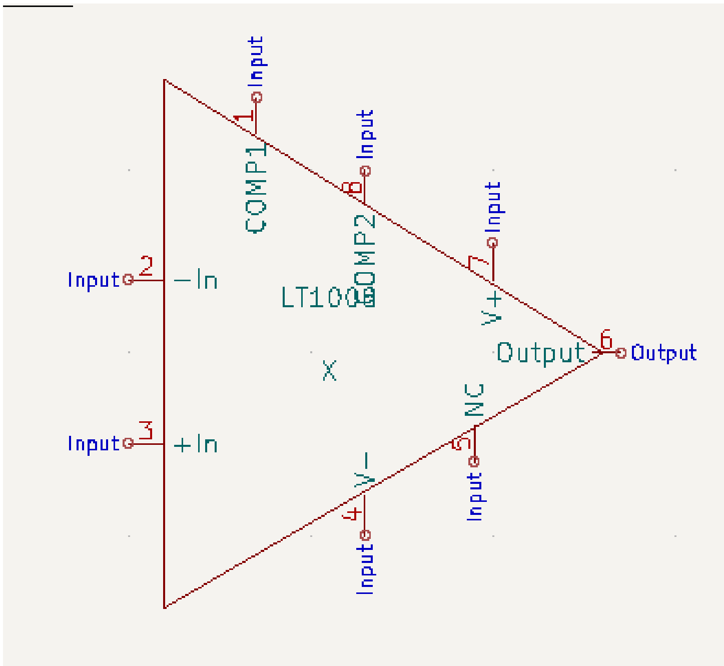


Figure 13: Pin Diagram of LT1008

### 3.4.3 Subcircuit Diagram

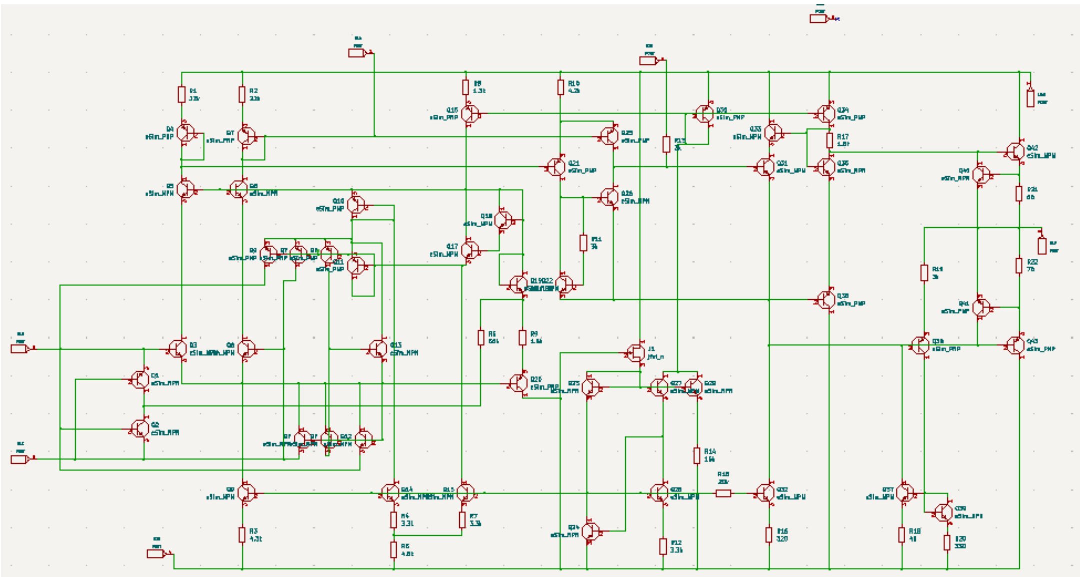

Figure 14: Subcircuit Diagram of LT1008

### 3.4.4 Test Circuit

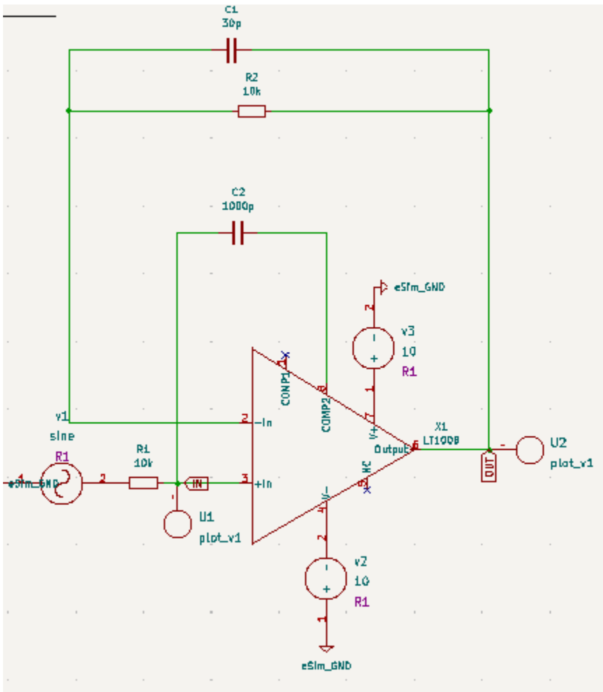


Figure 15: Test Circuit of LT1008

### 3.4.5 NgSpice Plot

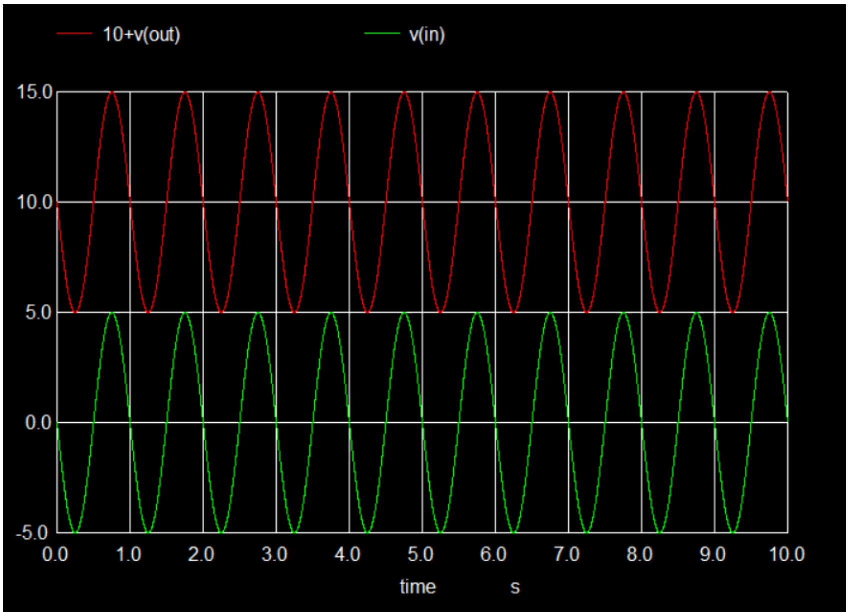


Figure 16: NgSpice Plot of LT1008

### 3.5 µA734

#### 3.5.1 Description

The µA734 device is a wideband operational amplifier designed for high-speed and video-frequency signal amplification [5]. It is optimized for applications requiring fast response, wide bandwidth, and stable gain performance. The µA734 operates using dual power supplies and is well suited for video amplifiers, pulse amplifiers, and high-frequency analog signal processing with minimal external components.

**Features of µA734**

- **Wideband Operational Amplifier:** This chip is primarily designed for amplifying high-frequency and video signals with fast transient response.
- **Dual Supply Operation:** Typically operates with ±5 V to ±15 V supplies, suitable for high-speed analog circuit designs.
- **High Slew Rate & Fast Response:** Ensures accurate amplification of rapidly changing signals with reduced distortion.
- **Simple and Reliable Design:** Requires few external components and is easy to integrate into high-speed analog applications.

#### 3.5.2 Pin Diagram

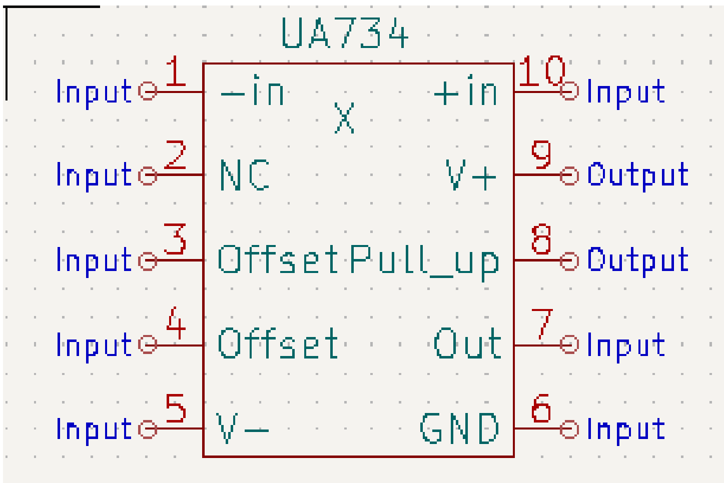


Figure 17: Pin Diagram of µA734

### 3.5.3 Subcircuit Diagram

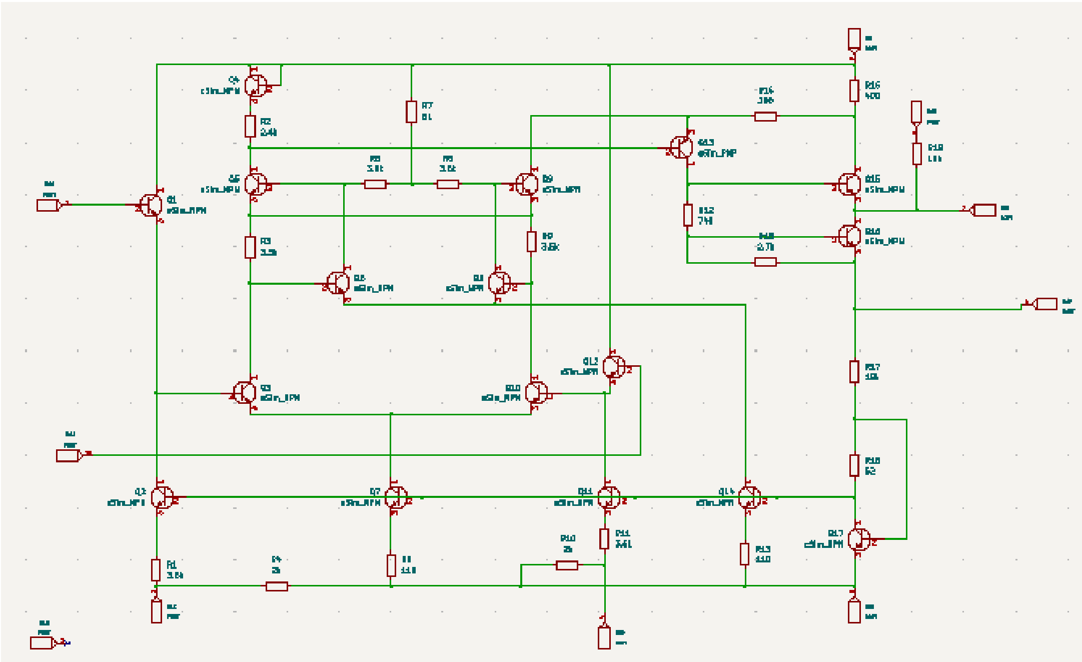

Figure 18: Subcircuit Diagram of µA734

### 3.5.4 Test Circuit

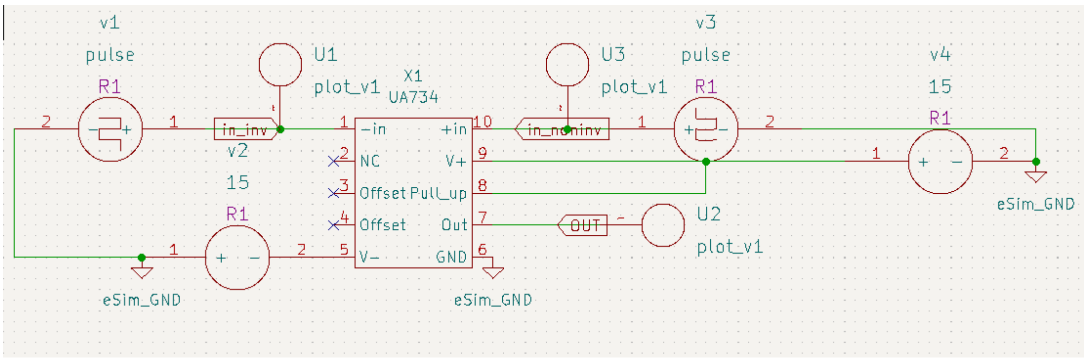


Figure 19: Test Circuit of µA734

### 3.5.5 NgSpice Plot

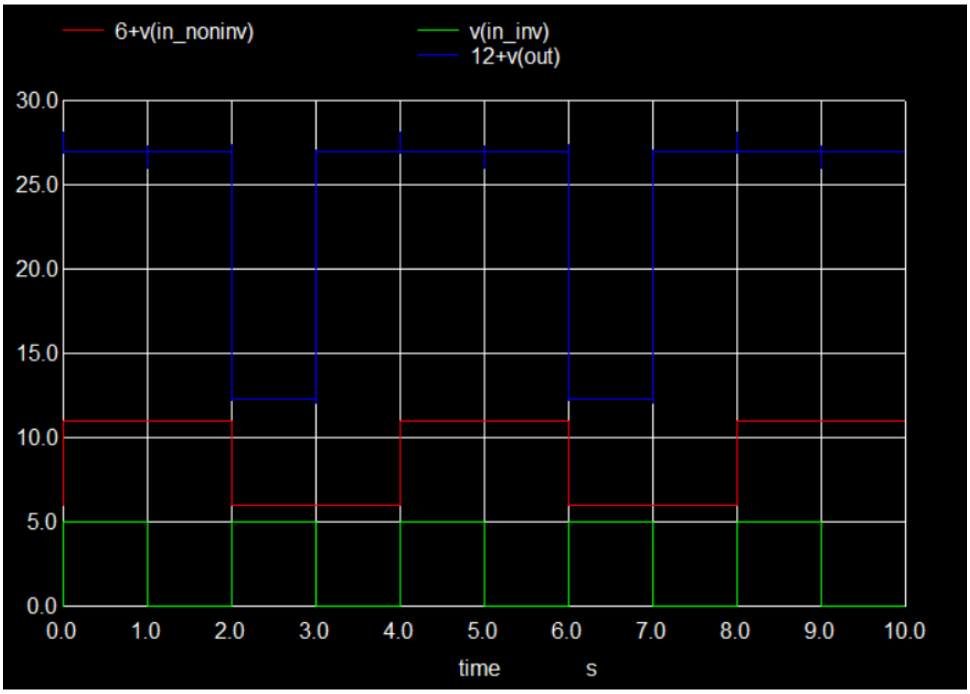


Figure 20: NgSpice Plot of µA734

## 3.6 74HC165

### 3.6.1 Description

The 74HC165 device is an 8-bit parallel-in, serial-out (PISO) shift register designed for high-speed data conversion from parallel to serial form [6]. It allows multiple digital input lines to be read using only a few microcontroller pins, making it ideal for input expansion. The device operates with CMOS technology, providing low power consumption and reliable performance over a wide supply-voltage range.

#### Features of 74HC165

- **Parallel-In Serial-Out Shift Register:** This chip is primarily designed to convert 8 parallel input signals into a serial data stream.
- **Wide Operating Voltage Range:** Operates typically from 2 V to 6 V, making it compatible with both 3.3 V and 5 V logic systems.
- **High-Speed & Low Power:** CMOS design ensures fast switching speeds with very low power consumption.
- **Simple and Compact Design:** Requires minimal external components and is well suited for compact digital input and interface circuits.

### 3.6.2 Pin Diagram

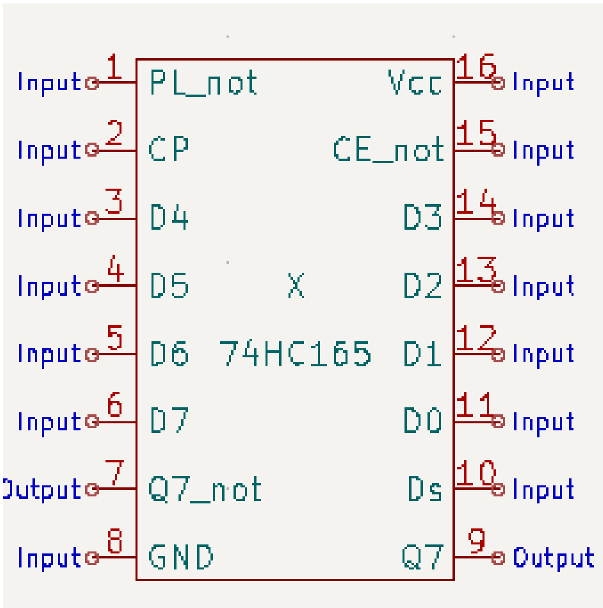


Figure 21: Pin Diagram of 74HC165

### 3.6.3 Subcircuit Diagram

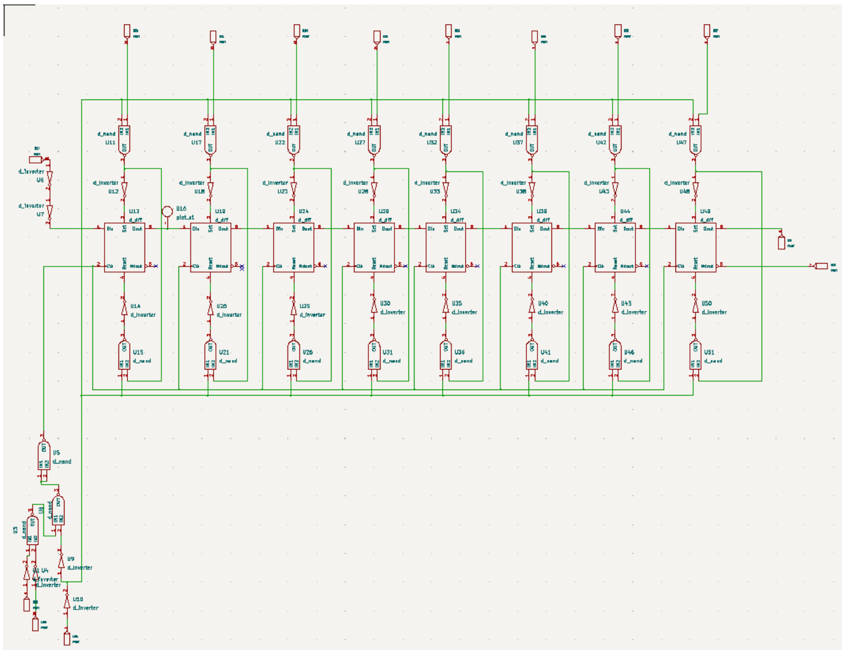

Figure 22: Subcircuit Diagram of 74HC165

### 3.6.4 Test Circuit

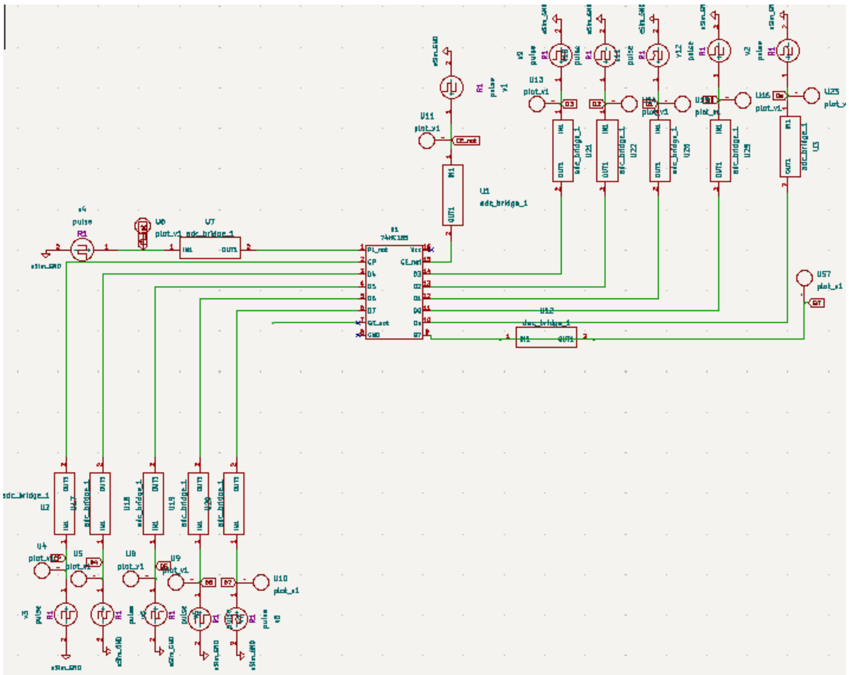

Figure 23: Test Circuit of 74HC165

### 3.6.5 NgSpice Plot

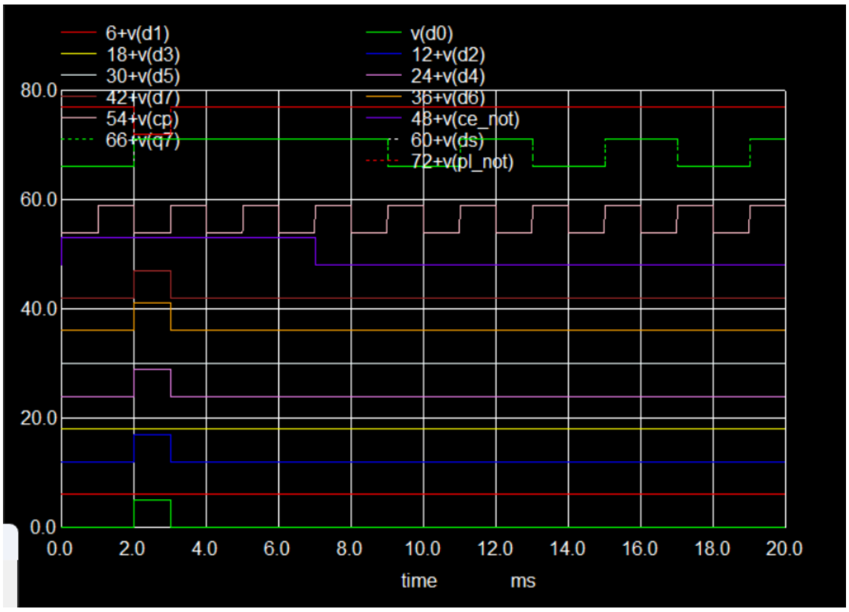


Figure 24: NgSpice Plot of 74HC165

## 3.7 SN74LS260

### 3.7.1 Description

The SN74LS260 device is a dual 5-input NOR gate built using Low-Power Schottky (LS) TTL technology [8]. It integrates two independent NOR logic gates in a single package, enabling efficient implementation of complex logic functions. The device is designed for reliable digital logic operations and is commonly used in control, decoding, and combinational logic circuits.

**Features of SN74LS260**

- **Dual 5-Input NOR Gates:** This chip provides two independent NOR gates, each capable of accepting five input signals.
- **TTL Logic Operation:** Operates from a standard 5 V supply, ensuring compatibility with other TTL devices.
- **Fast Switching Speed:** Low-Power Schottky technology offers improved speed compared to standard TTL logic.
- **Compact and Reliable Design:** Combines multiple logic functions in one package, reducing component count and board space.

### 3.7.2 Pin Diagram

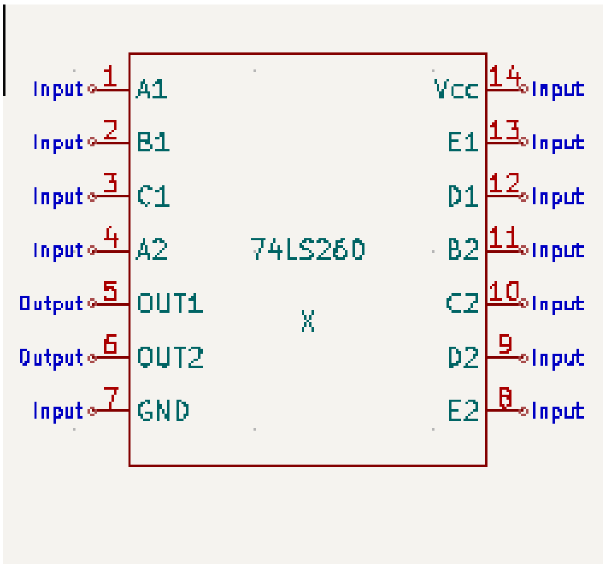


Figure 25: Pin Diagram of SN74LS260

### 3.7.3 Subcircuit Diagram

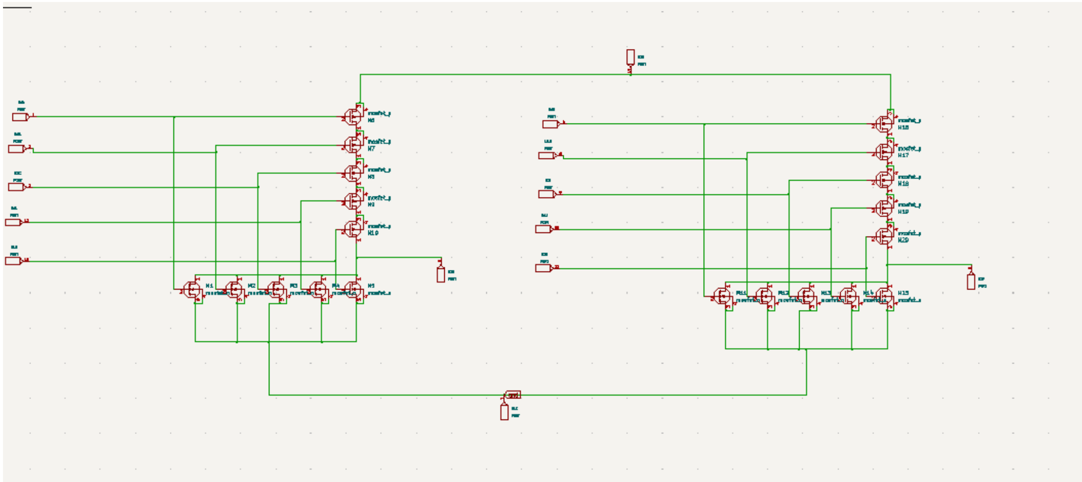

Figure 26: Subcircuit Diagram of SN74LS260

### 3.7.4 Test Circuit

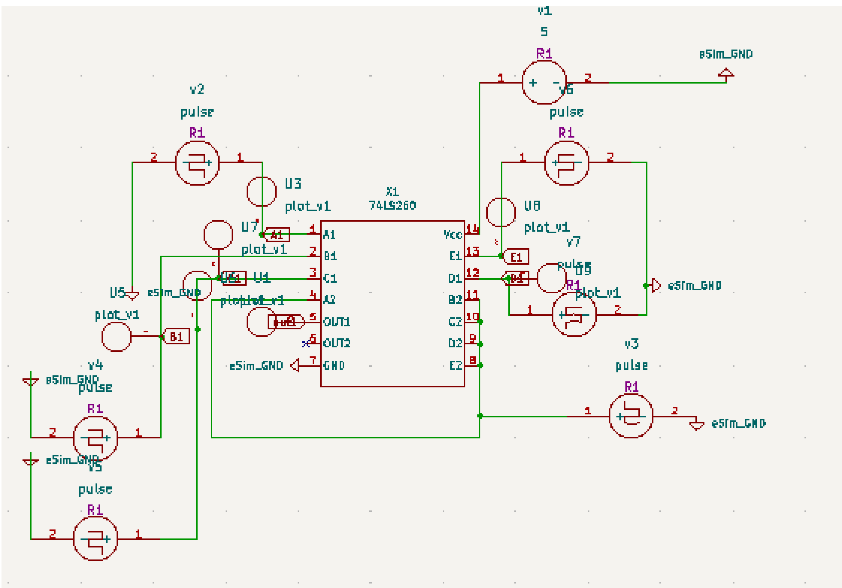


Figure 27: Test Circuit of SN74LS260

### 3.7.5 NgSpice Plot

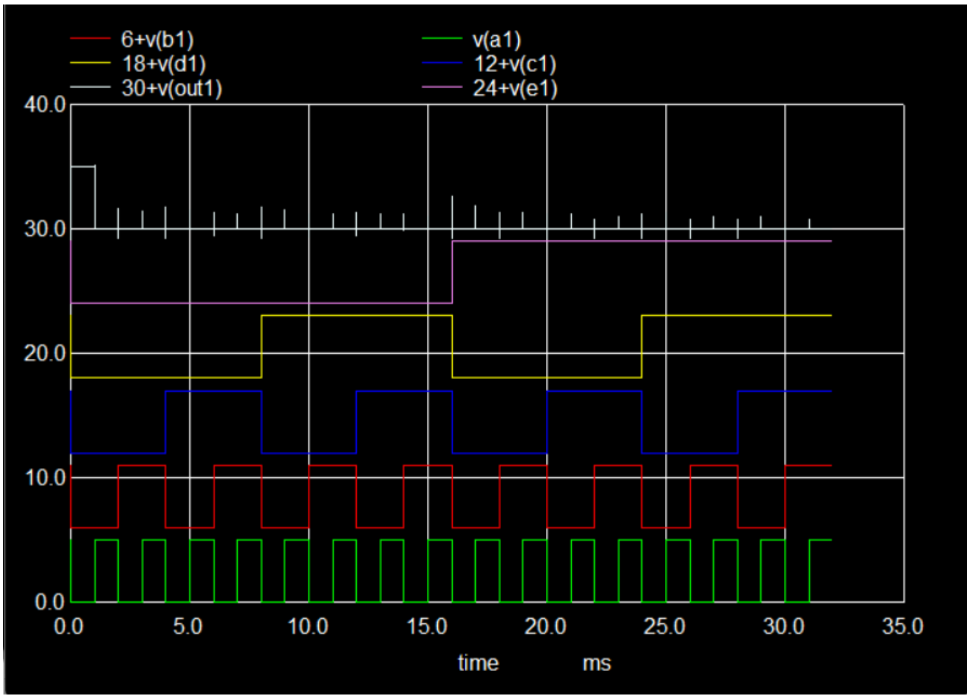


Figure 28: NgSpice Plot of SN74LS260

## 3.8 74LS22

### 3.8.1 Description

The 74LS22 device is a dual 4-input NAND gate with open-collector outputs, implemented using Low-Power Schottky (LS) TTL technology [7]. It is designed for digital logic applications where wired-AND connections or higher-voltage interfacing is required. The open-collector configuration allows multiple outputs to be tied together and used for logic expansion and control applications.

#### Features of 74LS22

- **Dual 4-Input NAND Gates:** This chip contains two independent NAND gates, each accepting four input signals.
- **Open-Collector Outputs:** Allows wired-AND logic and easy interfacing with different voltage levels using external pull-up resistors.
- **TTL Logic Operation:** Operates from a standard 5 V power supply, ensuring compatibility with LS-TTL systems.
- **Compact and Practical Design:** Integrates multiple logic functions in a single package, reducing circuit complexity and component count.

### 3.8.2 Pin Diagram

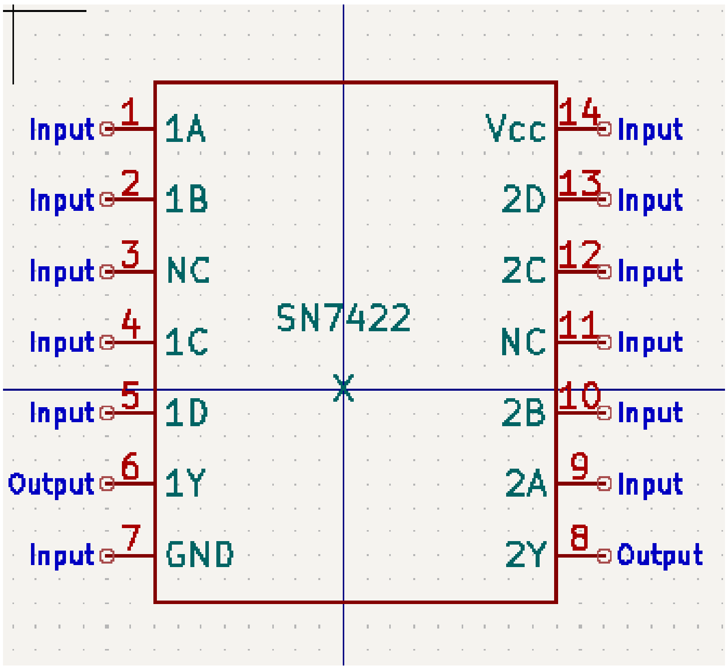


Figure 29: Pin Diagram of 74LS22

### 3.8.3 Subcircuit Diagram

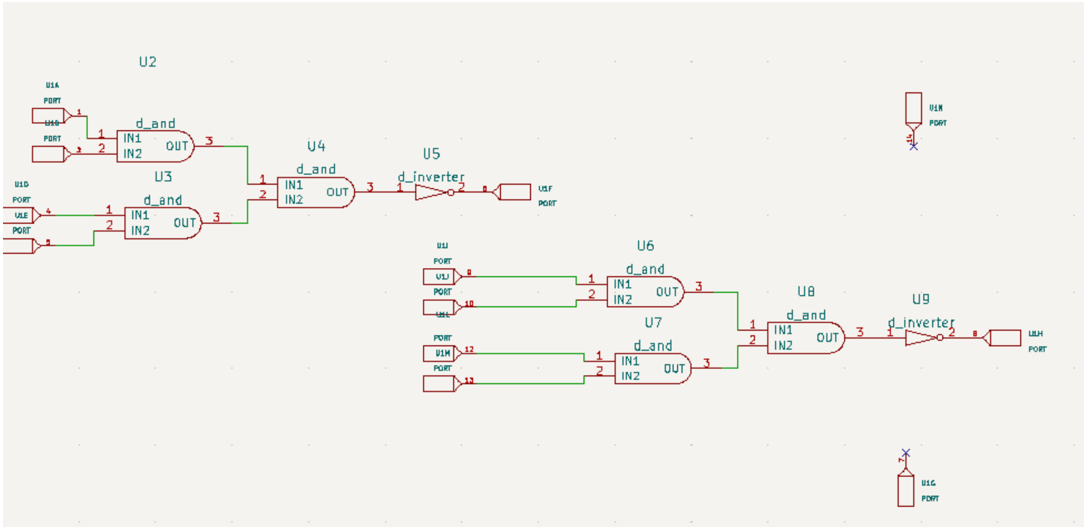


Figure 30: Subcircuit Diagram of 74LS22

### 3.8.4 Test Circuit

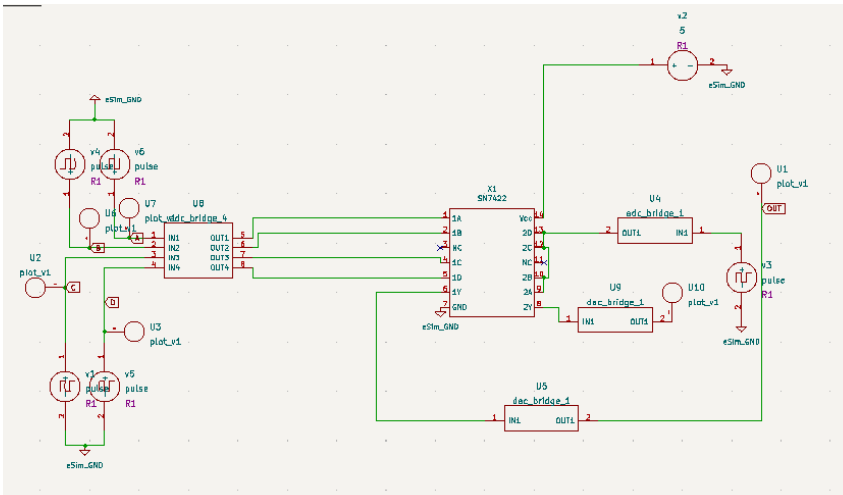

Figure 31: Test Circuit of 74LS22

### 3.8.5 NgSpice Plot

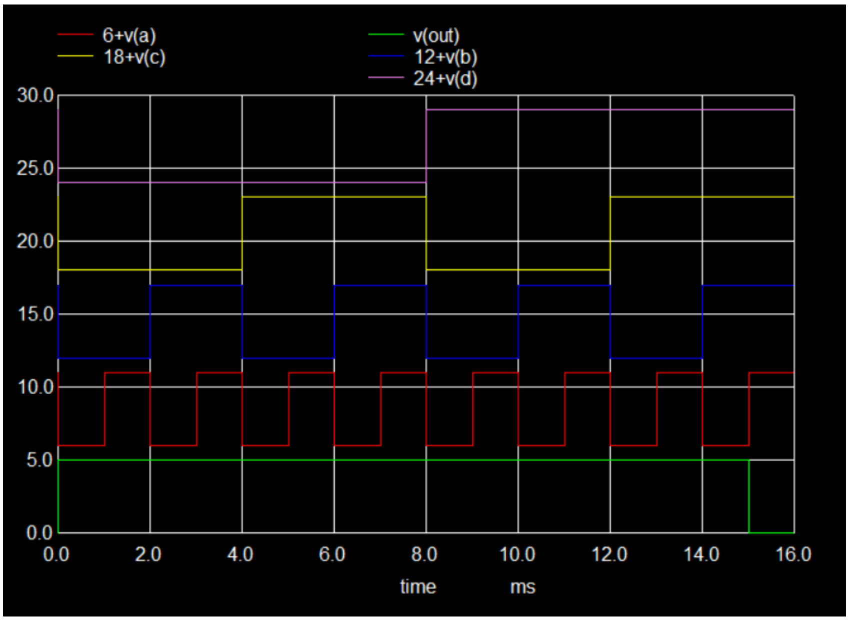


Figure 32: NgSpice Plot of 74LS22

### 3.9 Failed ICs

#### 3.9.1 LF198

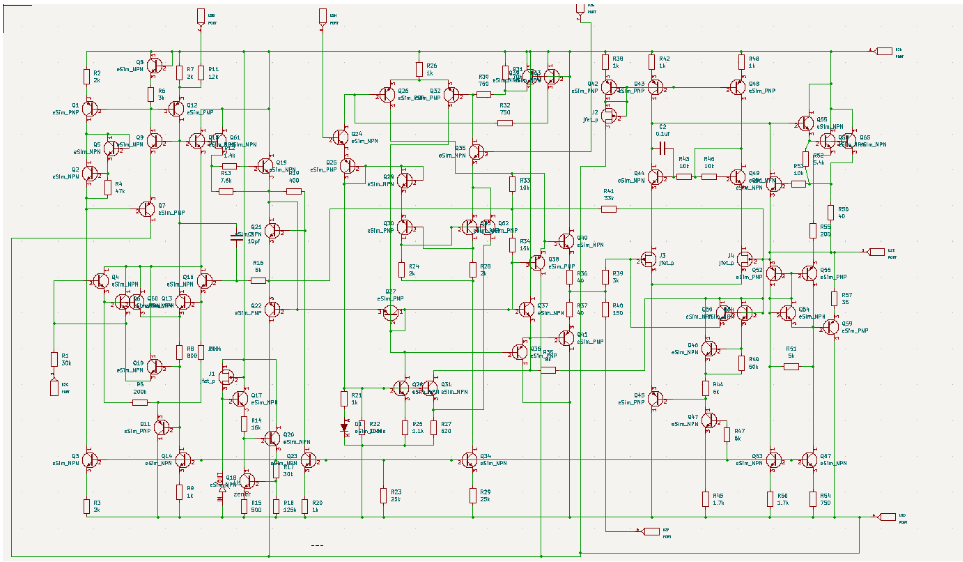

Figure 33: LF198 Circuit

#### 3.9.2 MC14013

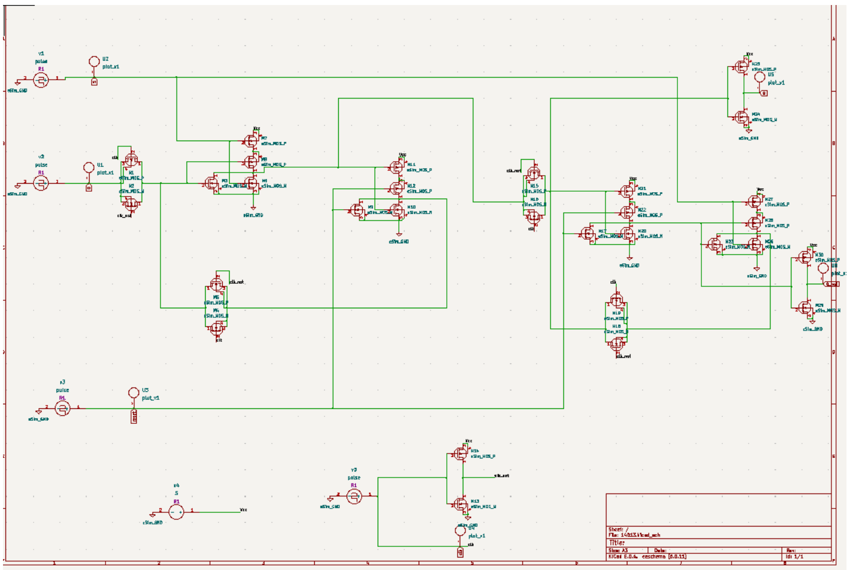

Figure 34: MC14013 Circuit

The simulation of the above two ICs did not produce the expected results due to possible design-related issues that might have occurred during circuit implementation. These issues may include missing power-supply and grounding arrangements, absence of required biasing, pull-up, or pull-down components, and incorrect input signal levels, timing, or control configurations. In addition, deviation from the recommended operating conditions specified in the IC datasheet, such as voltage limits, logic levels, or frequency constraints, might have contributed to the simulation failure. The selection of inappropriate component values or incomplete initialization of the IC may also have affected the overall behavior of the circuit during simulation.

Further improvements are open and can be achieved by carefully reviewing and refining the circuit design .

# 4 Conclusion and Future Scope

## Conclusion

The objectives of this internship were successfully accomplished through the design, implementation, and verification of multiple digital Integrated Circuit models in eSim. Each IC subcircuit was developed in accordance with its respective datasheet specifications and validated using suitable test circuits to ensure accurate functional behavior. The verified IC models can now be incorporated into the eSim subcircuit library and serve as reusable components for circuit simulation, experimentation, and academic applications. The work carried out contributes to the continuous development of open-source EDA tools and expands the availability of verified device models for the user community.

## Future Scope

There is considerable scope to extend this work in future efforts. Additional digital and analog ICs can be modeled and verified to further enhance the eSim device library. Introducing support for complex mixed-signal components and standardized testbench frameworks would streamline the verification process and improve model reliability. The integration of HDL-based components and co-simulation capabilities offers potential for more advanced system-level design workflows. With continued development, the availability of validated IC models will support rapid prototyping, research, and educational activities, further strengthening eSim as a valuable open-source EDA platform.

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